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# ROCZNIKI PAŃSTWOWEGO ZAKŁADU HIGIENY
[ANNALS OF THE NATIONAL INSTITUTE OF HYGIENE]

**Volume 71** **2020** **Number 4**


# Dietary Reference Values for the Polish population 2020

# Normy żywienia dla populacji Polski 2020

As part of the National Health Programme for 2016-2020, Dietary Reference Values (DRVs) for the Polish population have been updated. They take into account the latest developments in human nutrition science.
After the Institute of Food and Nutrition (IŻŻ) was incorporated on 1 February 2020 into the structures of the National Institute of Public Health – National Institute of Hygiene (NIZP-PZH), work on DRVs was continued.

The publisher of the updated DRVs is the NIZP-PZH.

W ramach Narodowego Programu Zdrowia na lata 2016-2020 zaktualizowane zostały normy żywienia dla populacji Polski. Uwzględniają one najnowsze zdobycze nauki o żywieniu człowieka.
Po włączeniu 1 lutego 2020 r. Instytutu Żywności i Żywienia (IŻŻ) do struktur Narodowego Instytutu Zdrowia Publicznego – Państwowego Zakładu Higieny (NIZP-PZH), prace nad normami były kontynuowane.

Wydawcą zaktualizowanych norm jest NIZP-PZH.

The electronic version of the monograph has been published on the websites:
National Institute of Public Health – National Institute of Hygiene/
Elektroniczna wersja monografii jest opublikowana na stronach:
Narodowego Instytutu Zdrowia Publicznego – Państwowego Zakładu Higieny

https://www.pzh.gov.pl/normy-zywienia-2020/

and the National Centre for Nutrition Education / oraz Narodowego Centrum Edukacji Żywieniowej

https://ncez.pl/abc-zywienia-/zasady-zdrowego-zywienia/normy-zywienia-2020

**The monograph from the above pages can be downloaded free of charge.**
**Monografię z ww. stron można pobrać bezpłatnie.**

The updated DRVs will be useful in conducting scientific research, in educating students of medical, natural sciences, agricultural and other schools with majors related to the science of human nutrition and in planning activities aimed at improving the health of Poles. They should also be helpful in the work of physicians, nutritionists and people planning individual and collective nutrition. It is also worthwhile for anyone who is interested in healthy nutrition to become acquainted with them. We encourage you to read it.

Uaktualnione normy będą przydatne przy prowadzeniu badań naukowych, w kształceniu studentów uniwersytetów medycznych, przyrodniczych, rolniczych i innych szkół z kierunkami związanymi z nauką o żywieniu człowieka oraz przy planowaniu działań mających na celu poprawę zdrowia Polaków. Powinny też być pomocne w pracy lekarzy, dietetyków oraz osób planujących żywienie indywidualne i zbiorowe. Warto też, żeby zapoznał się z nimi każdy, kto interesuje się zdrowym żywieniem. Zachęcamy Państwa do zapoznania się z monografią.

Ministerstwo Zdrowia
NPZ NARODOWY PROGRAM ZDROWIA
PZH NARODOWY INSTYTUT ZDROWIA PUBLICZNEGO od 1918 r.

"The task was realised from the funds of the National Health Programme for 2016-2020 and financed by the Minister of Health"
„Zadanie realizowane ze środków Narodowego Programu Zdrowia na lata 2016-2020, finansowane przez Ministra Zdrowia”

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REVIEW ARTICLE

# NATURAL GROUNDWATERS IN POLAND - OCCURRENCE, PROPERTIES AND CHEMICAL TYPES*

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## ABSTRACT
Chemical composition, organoleptic and physicochemical properties of natural groundwaters are varied and dependent on their geological environment. Determining the basic organoleptic properties – such as colour, taste, odour – as well as physical properties – such as electrical conductivity or redox potential – allow us to assess the stability of water chemical composition. Based on their origin, groundwaters can be divided into infiltration, as well as condensation, juvenile, metamorphic and relic groundwaters, which are currently of lesser value. Groundwaters sourced in Poland belong to various chemical types and play an important role in balneotherapy and the bottling industry. Of particular importance are thermal, bicarbonate, chloride or sulphate type waters. There is also a growing interest in humic waters found in the Wielkopolska region.

**Key words:** *infiltration waters, thermal waters, electrical conductivity of water, humic waters, chemical types of water*

## STRESZCZENIE
Skład chemiczny, właściwości organoleptyczne i fizykochemiczne naturalnych wód podziemnych są zróżnicowane i uwarunkowane środowiskiem geologicznym, z którego pochodzą te wody. Określenie podstawowych właściwości organoleptycznych, takich jak barwa, smak, zapach, a także fizycznych jak np. przewodność elektryczna czy potencjał redoks pozwalają ocenić stałość składu chemicznego wody. Wody podziemne ze względu na ich pochodzenie można podzielić na infiltracyjne, a także kondensacyjne, juwenilne, metamorficzne i reliktowe, mające obecnie mniejsze znaczenie. Wody podziemne wydobywane na terenie Polski należą do różnych typów chemicznych i odgrywają ważną rolę w balneoterapii i przemyśle rozlewniczym. Szczególne znaczenie mają wody termalne, wodorowęglanowe, chlorkowe czy siarczanowe. Rosnące zainteresowanie budzą również wody humusowe występujące na terenie Wielkopolski.

**Słowa kluczowe:** *wody infiltracyjne, wody termalne, przewodność elektryczna wód, wody humusowe, typy chemiczne wód*

## INTRODUCTION

Water is one of the most important substances that can be found in nature. It is necessary for hydration; thus, it is life-sustaining and constitutes a substantial and major constituent of a living cell in terms of weight [23,26]. Most physiological, chemical and physicochemical processes occurring in living organisms involve water. Waters present on the Earth can be divided into three basic groups, depending on their location (atmosphere, hydrosphere and lithosphere). These include atmospheric waters, surface waters and groundwaters [21,22].

Particular attention needs to be paid to groundwaters. According to the definition provided in the Water Law Act of 20 July 2017, groundwaters are understood as all the waters located under the Earth's surface within the saturation zone, including groundwaters that remain in direct contact with the ground and the substratum [17, 37]. In the previous definition set forth in the Water Law Act of 18 July 2001, groundwaters were waters occurring under the earth's surface in free cavities of the earth's crust's rocks, which create – depending on the water depth – near-surface or deeper usable aquifers [36].

A scientific field that is concerned with groundwaters is called hydrogeology (Greek: *hýdōr*

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* This article is also available in Polish version on the journal's website

– water, *ge* – ground, *logos* – science). It deals with studying their origin, physicochemical properties, distribution and movement within the earth's crust. The aim of hydrogeological studies is knowing the quality and quantity of groundwaters occurring in various geological formations, explaining the origin of those waters and determining the potential of their use for economic, industrial or health purposes [10].

Groundwaters are also studied by balneology, in order to determine their potential use in various forms of therapeutic treatments: drinking therapy, inhalation or bathing.

## ORIGIN AND DIVISION OF GROUNDWATERS

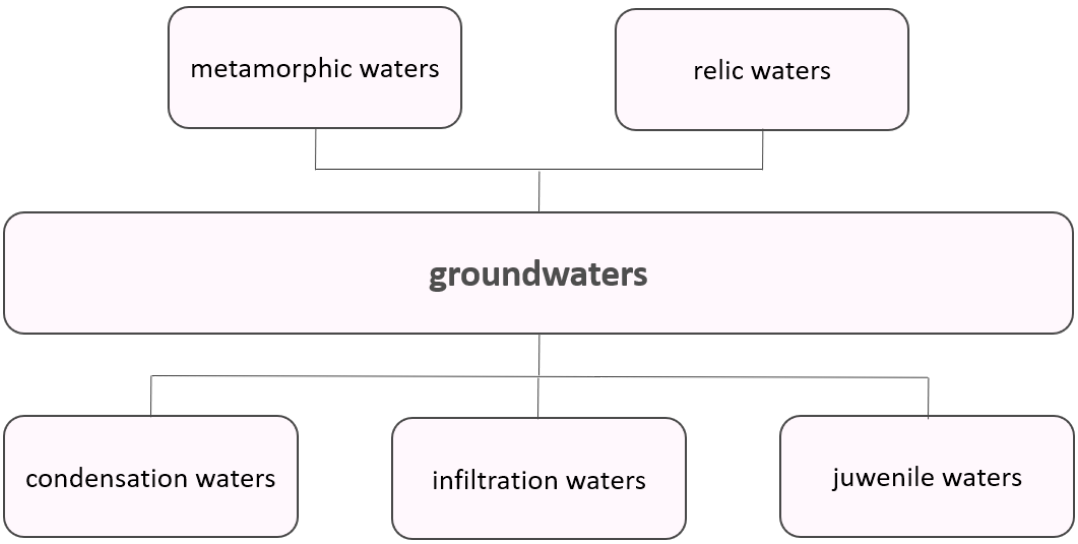
In terms of origin, groundwaters can be divided into infiltration, condensation, juvenile, metamorphic and relic waters (Scheme 1) [10,21,38].

Infiltration waters are groundwaters that owe their existence to penetration (infiltration) of atmospheric precipitation deep into the earth's crust. The amount of water penetrating the rocks mainly depends on the amount of precipitation and the size of chasms and pores in the rocks. The more cracks, pores and other cavities in rocks, the greater is the permeability of grounds and rocks, i.e. their ability to conduct water. The amount of precipitation waters penetrating the rocks depends on the lay of the land – the more diverse the land, the greater is the surface runoff and the less waters infiltrate the rocks. Negative factors influencing the volume of infiltration waters are evaporation and related temperature and humidity. The evaporation rate in the air is rising along with rising temperature. Humid air lowers or stops water evaporation and then it is conducive to infiltration [21]. Vegetation present on a given land as well as the geographical position of the area where the water occurs also have a significant impact on the amount of precipitation water. Dense vegetation inhibits surface runoff of the water and stores it in-between the roots, creating better conditions for infiltration. Infiltration waters flowing through the rocks become mineralised, although usually these are low-mineralised waters. Infiltration waters are used to supply people with drinking water. They are usually treated with aeration and filtration processes in order to give them acceptable organoleptic properties (lack of sedimentation, colour, smell). In certain regions of Poland, e.g. Opole, Busko or Nowy Korczyn, infiltration waters are very high in iron compounds, while in the region of Tarnobrzeg, they are characterised by unstable physicochemical composition. This might necessitate more advanced processing to make them suitable for consumption by people [16].

The infiltration waters can be contaminated by pollution from the ground environment, which should be controlled and removed before using this type of water to supply the population.

Condensation waters are groundwaters formed through condensation of water vapour present in the air filling the pores and cavities in the soil, grounds and rocks. Probably, there are more condensation waters in those areas where there are strong temperature fluctuations in the near-surface layers as well as on deserts, where at night the ground cools down faster than the air. In oceanic climates, the role of condensation in groundwater formation is probably small.

Juvenile (magmatic) waters are groundwaters formed at the last stage of magma solidification as it travels towards Earth's surface. In the light of contemporary opinions, only a small amount of groundwater is of magma origin [10]. Relic waters are




Scheme 1. Division of groundwaters in terms of their origin

defined as waters occurring in the zone of impeded exchange, with a very long residence time in the rock medium [1]. Metamorphic waters are formed during thermal rebuilding of perishable minerals [38].

## PHYSICAL, PHYSICOCHEMICAL AND ORGANOLEPTIC PROPERTIES OF GROUNDWATERS

Correct determination of groundwater physical, physicochemical and organoleptic properties allows a preliminary identification of the water type and its potential impurities. Water physical and physicochemical properties include temperature, pH, radon level and electrical conductivity. Organoleptic properties, on the other hand, are colour, turbidity, taste and odour. These properties depend on numerous factors, including geological environment of the water and its depth. Discussed below are selected physical, physicochemical and organoleptic parameters of groundwaters.

### Temperature of groundwaters

In the latitude of Poland, shallow waters are 5-12°C. From larger depths, waters are obtained the temperature of which can be even up to several dozen Celsjus degrees .

Groundwater temperature is influenced by such factors as geothermic level (depth expressed in metres where temperature rises by 1°C), the depth of occurrence of the water resources, mean annual air temperatures, period air temperature fluctuations within a given area, water flow rate and rock thermal conductivity. Groundwater temperature determines the course of hydrogeochemical processes [21,22].

Temperature-based groundwater division can use the hydrogeological or balneological criterion.

Hydrogeological division distinguishing cool waters ($t < t_{mean}$), ordinary waters ($t = t_{mean}$) and warm waters ($t > t_{mean}$) is based on the criterion of mean annual air temperature of this area where the given groundwaters are present [21].

Balneological division is based on the ratio of water temperature to human body temperature and the impact of different water temperatures on human body. Cool waters (t < 20°C) and thermal waters (t > 20°C) are distinguished. What is more, thermal waters are divided into:

- hypothermal, t = 20°C - 35°C
- homeothermal, t = 35°C - 40°C
- hyperthermal, t > 40°C [21]

Waters of natural origin – i.e. underground origin – with a noticeable higher temperature at their outflow point are referred to as a thermal spring or geothermal waters [12]. In the recent years, many new sources of this type of waters have been found in Poland. They are very diverse in terms of temperature and chemical composition [11,14]. Their mineralisation ranges from 0.15 g/dm$^3$ to 135 g/dm$^3$ and temperature from 20°C to 86°C. Dominating components of geothermal waters in Poland are usually chloride and sodium ions, but also sulphate carbonate, calcium and magnesium ions. Besides them, there are also various levels of components with specific biochemical properties, including ferrous, iodide and fluoride ions, radon, as well as sulphate compounds (II) [14,28]. Geothermal waters have been recognised as the first natural spa resources [9,12].

In Poland, thermal waters are commonly found in the three major regions: Polish Lowland, Sudetes and Carpathians. Based on observations conducted by *Chowaniec* et al., it can be concluded that the best conditions for sourcing thermal waters in the Carpathian Mountains are within the Podhale Basin due to: favourable geological structure, high temperature (up to 86°C at the outflow), low mineralisation (up to 3 g/dm$^3$), high efficiency (even more than 200 m$^3$/h from a single spring), renewability and easy land access [4].

Geothermal energy and be used directly for heating, leisure and balneology purposes, as well as agriculture, fishkeeping or thermophilous animal species. It is currently used in 78 countries of the world, although China, USA, Sweden, Turkey and Japan account for 55% of the total annual global use of geothermal heat [28]. Polish thermal waters are diverse in terms of temperature, therefore their use should especially be restricted to heating, preparation of hot utility water, as well as leisure and balneology. However, it is rather improbable that they will constitute an electrical energy source in the near future [20].

### Electrical conductivity of groundwaters

Water is a solution of electrolytes that conduct electricity. Electrical conductivity is one of the characteristic features of groundwaters and depends on the valence of all the free ions. Divalent ions can carry twice as much a charge than the same number of univalent ions. The determination of conductivity is of practical importance as it is one of the methods of detecting changes in the physicochemical state of water [27]. Therefore, it can be a simple indicator of stability or variability of water chemical composition in control testing of groundwaters [11]. Water electrolytic conductivity expressed in µS/cm roughly corresponds to water mineralisation expressed in mg/dm$^3$ [27]. It must be remembered, though, that the presence of surface-active substances in water, and

another compounds like oils, greases, tars, might falsify the results due to contaminating the electrode of the testing equipment.

## Oxidation-reduction potential of groundwaters

It is one of the factors that is largely determined by the chemical composition of groundwaters. It measures the ability to transfer (return or accept) electrons by ions, molecules, and solid phases participating in a reaction. It is an index parameter based on the presence of specific concentrations (activities) of all the components involved in the oxidation-reduction reactions in the solution [8]. Both water pH and oxidation-reduction potential (also known as redox potential, Eh) are values that change when the water comes in contact with the external environment. Hence, determining a water's redox potential should happen right after it flows to the surface or in as short a time after sampling as possible before iron hydroxide (III) forms. Redox potential depends on pH and temperature and is also influenced by the oxidation number of polyvalent elements, as well as the content of some organic compounds that, by oxidation, constitute a source of $CO_2$ [34]. The presence of $CO_2$ in groundwaters allows them to keep a low redox potential. In waters with a low redox potential, ions such as iron and manganese, remain at a low oxidation number, which makes them better absorbed by the body [5].

## Colour of groundwaters

Groundwaters are usually colourless. Groundwater colour can be caused by the content of certain organic or mineral compounds, or mechanical suspensions. The most frequent cause of natural water colour (yellow or brownish) is the scouring of humic substance and other products of plant material decomposition from the substrate. The greatest role in this process is attributed to humic and fulvic acids, which are high-molecular-weight substance with numerous function groups. Bluish-green colour of water might indicate the presence of acidic iron salts (such as sulphates), while rust colour might indicate the content of trivalent iron compounds [2,21,22].

Water colour is determined using platinum-cobalt or dichromate-cobalt standard solutions by comparing water samples with the standards. Colour determination should be performed immediately after a sample is taken.

## Turbidity of groundwaters

Turbidity is an optical property of water, which involves scattering and adsorbing some of visible spectrum by particles dispersed in water. The most common causes of water turbidity are the presence of sand, insoluble carbonates, iron hydroxide, organic substances or microorganisms. Clear groundwater might become significantly turbid after flowing out to the surface and being exposed to air. This is caused by the release of natural carbon dioxide and then precipitation of iron hydroxide or calcium carbonate. Turbidity determination should be performed immediately after sampling water from a spring [2, 10].

## Odour of groundwaters

Groundwaters are usually odourless. Waters having a less or more intensive odour are frequently those sourced from shallow layers that come in contact with swamps, marshes and moors, as well as waters contaminated with municipal or industrial sewage. There are five degrees of odour intensity – just like taste intensity. Water at three degrees is not suitable for consumptions, while at higher degrees it cannot be used even for household purposes.

Due to the origin, several types can be distinguished:

1. Odours of natural origin, which are divided into three groups:
   a) Plant odours caused by organic compounds, which are not subject to decomposition (smell of earth, peat, moss, tree bark, etc.),
   b) Decay odours caused by organic substances subject to decomposition (stale, decayed, etc.),
   c) Odours associated with the presence of natural inorganic water components (e.g. hydrogen sulphide)
2. Specific odours of unnatural origin caused by the contamination of groundwaters mainly by sewage, e.g.: chloric, phenolic [10].

## Taste of groundwaters

Groundwater taste frequently depends on their mineralisation. Highly mineralised waters (containing >1500 mg/dm$^3$ of dissolved substances) often has a distinctive taste, e.g. salty taste can be caused by the content of sodium chloride. Bitter taste, on the other hand, can come from sodium and/or magnesium sulphates, while alkaline taste can come from the dominant amount of sodium, calcium, and magnesium bicarbonate [13]. Excessive content of carbon dioxide gives water sour and stinging taste, which is why waters containing more than 250 mg $CO_2$/dm$^3$ are referred to as carbonic acid waters.

## CHEMICAL TYPES OF GROUNDWATERS

Chemical composition of waters largely depends on the composition of the earth's crust layers in which they form and through which they are flowing. Mineral components, such as calcium, magnesium, sodium, potassium, iron, manganese, ammonium ion, chlorides, bicarbonates, fluorides, iodides, sulphates, sulphides are accompanied by non-ionic components: orthoboric and metasilicate acids. Groundwaters also contain gases, such as carbon dioxide, hydrogen sulphide or radon. Waters naturally saturated with carbon dioxide in a larger concentration usually contain a certain amount of carbon dioxide bound in the form of bicarbonates. Waters containing carbon dioxide in concentrations higher than 250 mg $CO_2$/$dm^3$ are referred to as carbonic acid waters, while those containing more than 1000 mg/l – acidulous waters. Waters containing hydrogen sulphide are also characterised by the presence of hydrosulphides. Nitrogen and noble gases are present in waters come from considerable depths [19,21].

Apart from health-benefiting elements and compounds, groundwaters contain some trace amounts of heavy metals, including natural radioactive elements, which can have a negative impact on human body [18]. It is especially important when it comes to groundwaters used for bottled water manufacture. Natural, potentially toxic compounds that might occur in natural mineral waters include arsenic, barium, boron, lead, antimony, cadmium, mercury, chromium, copper, manganese, nickel, selenium, cyanides, fluoridesand radioactive compounds [6,15,24]. In waters made available for human consumption, including natural mineral and spring waters, maximum acceptable concentrations are determined for these components, the exceeding of which may constitute a health risk. Groundwaters in some regions of Poland, including the south-west region, are characterised by a considerable concentration of arsenic and radon from the toxicological point of view. However, appropriate procedures for preparing the water to be sold in unit packaging, including degassing and ozone aeration, allows reducing the content of these elements below the maximum acceptable limits. Some of the Polish groundwaters also contain barium and boron in concentrations higher than the maximum acceptable limits established by the Regulation of the Ministry of Health [30].

In the case of waters made available in unit packages (natural mineral and spring waters), it is permissible to remove or reduce the concentration of only some components, including arsenic, radon, fluoride, manganese, using methods proven and allowed in the applicable regulations cited above, provided that the method used does not change the concentration of other components, especially specific to a given water.

Natural components of groundwaters also include organic compounds, especially humus acids, i.e. humic, hymatomelanic and fulvic acids. A specific type of groundwaters are humic waters. Humic compounds they contain are formed in biochemical processes – condensation and polymerisation of decomposition products of plant- and animal-derived material. The aforementioned humic acids are macromolecular compounds with a poorly identified chemical structure, which can be divided depending on their solubility into:

- fulvic acids – soluble in water within the entire pH range
- humic acids – insoluble in water at pH < 2
- hymatomelanic acids – soluble in alcohol, insoluble in aqueous solutions with a pH < 2 [13].

Literature available so far shows that the structure of humic acids contains an aromatic core (indole, pyrimidine) and peripheral functional groups of aliphatic structure. Furthermore, fulvic, humic and hymatomelanic acids display significant differences in terms of molecular weight and molecular shape. Humic acids are compounds with a large molecular weight ranging from 50,000 Da to 100,000 Da and an extensive structure – a diameter of 60-100 Å. Fulvic acids, on the other hand, have a molecular weight ranging from 500 Da to 2000 Da and a diameter of 20-30 Å. Acid molecules with a larger weight show a higher affinity to bind metal ions. With a higher molecular weight and polymerisation degree, the colour intensity of humic waters also rises – from yellow (fulvic acid) to dark brown (humic and hymatomelanic acids) [15,32]. An example of intensely coloured waters in Poland are humic waters from the Miocene level within the Wielkopolska region [13].

Waters sourced from deep earth layers are generally characterised by stable chemical properties. Stable chemical composition does not mean absolutely the same concentration of particular water components, but their stable quantitative proportions [19,23]. Concentration fluctuations often depend on the size of the water intake from a given well.

Results of the determination of ions contained in tested water can be expressed in weight and equivalent concentrations. In hydrochemical practice, weight concentrations are expressed in mg/l, while equivalent concentrations in miligram equivalent in one litre of water (mval/l) [10]. One of the most frequently used qualification of mineralised and specific waters is Altowski-Szwiec qualification based on anionic-cationic composition and specific component concentration. According to the qualification, water type is determined based on concentration that is no less than 20% of milligram equivalents (mval%) of

aggregate content of main ions – hydrogen carbonate, sulphate, chloride, calcium, magnesium, and sodium ions.

In the characterization of medicinal waters, in addition to the components that are quantitatively dominant (> 20 mval%), the names of components with specific biochemical properties are listed - if their content is equal to or higher than the established limits - also in descending order of concentration.

When determining the chemical type of water, the name of the water begins with anions and then the cations with the highest content in the water are listed in terms of milligram equivalents. Below, three main chemical types of waters in Poland are discussed (based on their quantitatively dominating anionic component).

## Bicarbonate waters

Bicarbonate waters constitute a dominating type of shallow groundwaters of infiltration origin. They are used mainly for drinking water supply. Bicarbonate waters are characterised by renewability. The presence of bicarbonates is mainly caused by the dissolution of carbonate minerals and atmospheric carbon dioxide 11].

Due to the quantitative dominance of various cations, groundwaters in Poland belong to the following chemical types:

- bicarbonate-calcium-magnesium $HCO_3$-Ca-Mg
- bicarbonate-calcium-sodium $HCO_3$-Ca-Na
- bicarbonate-calcium-sodium-magnesium $HCO_3$-Ca-(Na)-(Mg)
- bicarbonate-sodium $HCO_3$-Na
- bicarbonate-sodium-calcium-magnesium $HCO_3$-Na-(Ca)-(Mg) [11].

For example, in the town of Krynica, there are numerous groundwater intakes characterised by diverse chemical type, with $HCO_3^-$ always dominating among anions and $Ca^{2+}$ i $Mg^{2+}$ dominating among cations [6]. Bicarbonate waters are also found in other areas of Poland, for example in Świeradów-Zdrój, Szczawnica, Polanica-Zdrój, Kudowa-Zdrój, Duszniki-Zdrój, Piwniczna and Muszyna [12].

Bicarbonate waters that are most frequently used for health and spa treatments are carbonic acid waters and acidulous waters. Carbon dioxide present in the waters intensifies the process of mineral component dissolution [9].

## Sulphate waters

This chemical type of waters is relatively rare within the territory of Poland. Dominating concentration of sulphates compared to other anions is usually associated with the presence of easily soluble minerals containing sulphur (e.g. gypsums and anhydrites) in the geological environment [11]. They also form in the weathering of sulphide minerals, oxidising gradually through sulphur to the sulphate form [27].

Sulphate waters containing hydrogen sulphide or sulphides in concentrations higher than 1 mg/dm$^3$ belong medicinal waters and are used in balneotherapy. Sulphates in combination with other components create various types: $SO_4$-Cl-Ca-Na,S, $SO_4$-($HCO_3$)-Ca-(Mg)-(Na),S, $SO_4$-Cl-Na-Ca-Mg,S [11].

Sulphate waters with a dominating content of sodium, i.e. $SO_4$-Na, are referred to as Glauber's water, calcium $SO_4$-Ca – gypsum waters, magnesium $SO_4$-Mg – bitter waters, iron $SO_4$-Fe – vitriol waters [27].

Sulphate and sulphide waters occur, among others in Busko Zdrój, Solec Zdrój, Lądek-Zdrój, Tarnów or Horyniec Zdrój [12].

## Chloride waters

Chloride waters constitute a dominating type of deep groundwaters in the territory of Poland. According to observations, their mineralisation level rises along with their rising depth [11].

Chloride-sodium waters Cl-Na – brines, form as a result of lixiviation of rock salt deposits or marine-origin sedimentary rocks. These waters also contain bromides and iodides. Apart from simple brines containing mainly chloride and sodium ions, there are also brines containing significant amounts of bicarbonate (Cl-$HCO_3$-Na), calcium (Cl-Na-Ca) and magnesium (Cl-Na-Mg) ions.

In geology, brine is defined as water containing > 35g/dm$^3$ of dissolved components, mainly sodium chloride, useful for industrial purposes. In balneology, brine is water containing more than 15 g/dm$^3$ of dissolved components with a predominance of sodium chloride. For medicinal baths it is recommended (depending on medical indications) concentration from 3 to 6 g/dm$^3$; for inhalation concentration in the range 0.9-1.5 g/dm$^3$.

An example of chloride waters are groundwaters of Rabka Zdrój. These are chloride-sodium waters with total mineralisation ranging from 17.1 to 27.8 g/dm$^3$, containing a specific component — iodides, at concentrations from 12 to 20 mg/dm$^3$ [29]. Chloride-sodium waters are also present, among others in Ciechocinek, Kołobrzeg, Międzyzdroje, Bochnia, Goczałkowice-Zdrój or Konstancin Jeziorna [12].

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**Conflict of interest**

*The authors declare no conflict of interest.*

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ORIGINAL ARTICLE

# ASSESSMENT OF EXPOSURE TO NICKEL INTAKE WITH SELECTED CEREAL GRAINS AND CEREAL-BASED PRODUCTS

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## ABSTRACT

**Background.** Cereal grains and their products are among the basic components of the diet all over the world. Their consumption varies depending on the dietary habits in each country. Apart from ingredients valuable from a health point of view, these products can also be a source of contaminants. The European Food Safety Authority (EFSA) included these foodstuffs in the group of main contributors to the dietary exposure to nickel by different groups of the population.

**Objective.** The aim of the studies was to determine the nickel content in cereal grains and selected cereal products commercially available in Poland and to assess the exposure of consumers to nickel intake with these foodstuffs.

**Material and methods.** A total of 56 samples of cereal grain and cereal products from trade were tested. Nickel content was determined after microwave mineralization of the samples by atomic absorption spectrometry with a graphite furnace atomization (GFAAS). The estimated exposure for the different groups of the population was assessed and compared with the Tolerable Daily Intake (TDI) value established by the European Food Safety Authority based on an updated risk assessment at 13 µg/kg body weight (b.w.) per day.

**Results.** The mean (MB) and 95th percentile (MB) nickel content in investigated samples of cereal grains and their products were 0.66 mg/kg and 1.93 mg/kg. The mean content of Ni in the analyzed samples of grains was 1.16 mg/kg. Obtained results in this group of products ranged from 0.10 mg/kg for rye to 4.80 mg/kg for millet. In the group of grain products, the mean (MB) concentration of nickel was 0.61 mg/kg (95th percentile (MB) 1.84 mg/kg). The highest nickel level was determined in the samples of bran, groats, and flakes compared to other grain-based products. The highest content of Ni in the group of cereal products was found in the samples of roasted buckwheat 1.81 mg/kg and oat flakes 2.53 mg/kg. Significantly lower nickel content was observed in barley groats as well as for pasta and flour.

The estimated average exposure of adults and children to nickel intake with grains and grain-based products ranged from 1.1% to 13.4% of TDI and it does not pose a health risk for consumers.

**Conclusions.** Based on the obtained results, it was found that the nickel content in the tested samples of cereals and their products does not pose a health risk, even though the contamination of individual samples was significant.

**Key words:** *nickel, cereals grains, cereal-based products, intake, exposure assessment, Tolerable Daily Intake, TDI*

## STRESZCZENIE

**Wprowadzenie.** Ziarna zbóż i produkty na ich bazie są zaliczane do podstawowych składników diety na całym świecie. Ich spożycie jest zróżnicowane w zależności od nawyków żywieniowych panujących w poszczególnych krajach. Poza cennymi ze zdrowotnego punktu widzenia składnikami produkty te mogą również stanowić źródło pobrania zanieczyszczeń. Europejski Urząd ds. Bezpieczeństwa Żywności zaliczył te środki spożywcze do grupy głównych składników mogących wnosić istotny udział do pobrania niklu z dietą przez różne grupy populacji.

**Cel badań.** Celem badań było oznaczenie zawartości niklu w wybranych ziarnach zbóż i produktów zbożowych dostępnych w obrocie handlowym w Polsce oraz ocena narażenia konsumentów na pobranie niklu z tymi grupami środków spożywczych.

**Materiał i metody.** Zbadano łącznie 56 próbek zbóż oraz produktów zbożowych pochodzących z obrotu handlowego. Zawartość niklu oznaczono po mineralizacji mikrofalowej próbek metodą absorpcyjnej spektrometrii atomowej z wykorzystaniem kuwety grafitowej (GFAAS). Oszacowane narażenie w odniesieniu do różnych grup populacji porównano z wartością tolerowanego dziennego pobrania – TDI (Tolerable Daily Intake) ustaloną przez Europejski Urząd ds. Bezpieczeństwa Żywności na podstawie uaktualnionej oceny ryzyka na poziomie 13 µg/kg m.c./dzień.

**Wyniki.** Średnia zawartość niklu (MB) w badanych próbkach ziaren zbóż i ich produktów wyniosła: 0,66 mg/kg (95-percentyl MB 1,93 mg/kg). Średnia zawartość Ni w analizowanych próbkach ziaren zbóż wyniosła 1,16 mg/kg. Uzyskane wyniki w tej grupie produktów wahały się od 0,10 mg/kg dla żyta do 4,80 mg/kg dla prosa. W grupie produktów zbożowych średnie (MB) stężenie niklu wyniosło 0,61 mg/kg (95 percentyl (MB), 1,84 mg/ kg). Najwyższą

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zawartość Ni stwierdzono w próbkach: otrąb, kasz i płatków w porównaniu z innymi produktami zbożowymi. W grupie przetworów zbożowych najwyższą zawartość Ni stwierdzono w próbce gryki prażonej 1,81 mg/kg i płatków owsianych 2,53 mg/kg. Znacząco niższą zawartość Ni otrzymano w kaszach jęczmiennych oraz w makaronie i mące.
Oszacowane średnie narażenie dorosłych i dzieci na pobranie Ni z ziarnami zbóż i produktami zbożowymi wyniosło od 1.1% do 13,4% TDI i nie stanowi ono zagrożenia dla zdrowia konsumentów.
**Wnioski.** Na podstawie uzyskanych wyników stwierdzono, że zawartość niklu w zbadanych próbkach zbóż i produktów zbożowych nie stanowi zagrożenia dla zdrowia, pomimo iż zanieczyszczenie pojedynczych próbek było istotne.

**Słowa kluczowe:** *nikiel, zboża, produkty zbożowe, pobranie, ocena narażenia, TDI, Tolerowane Dzienne Pobranie*

## INTRODUCTION

Cereals and cereal products are important components of the daily diet [5]. These products are the source of valuable minerals, vitamins mainly from group B, fiber, protein, and carbohydrates [4, 16, 34].

The average monthly consumption of cereal products and bread in Poland is high and amounts to 5.36 kg per person. We eat bread the most, on average 2.89 kg per person per month, compared to other cereal products such as flour 0.59 kg or pasta 0.40 kg [15]. These foodstuffs can be also a source of contaminants such as heavy metals (lead, cadmium, and nickel), pesticides, and herbicides [1, 3, 5, 31]. The presence of nickel is connected mainly with environmental contamination or can be connected with the migration of this metal during the production process from equipment used in the food industry or during food preparation [22, 23, 24, 29, 30, 33]. This element is also a natural component of the Earth's crust easily bioaccumulated [29].

The toxicity of nickel and its compounds has been confirmed in numerous scientific studies, including the International Agency for Research on Cancer (IARC), which has classified nickel compounds in Group I as carcinogenic to humans, and metallic nickel and nickel alloys in Group 2B as potentially carcinogenic to humans. Intake of Ni with a diet is associated rather with non-carcinogenic effects [22, 23, 24]. However, the mechanism of the toxic effect of nickel on the human body still requires understanding.

In 2015, European Food Safety Authority (EFSA) based on risk assessment and available data published scientific opinion on the risk to public health related to the presence of nickel in food and drinking water. EFSA indicated that grain and grain-based products are the main contributors to the dietary exposure to nickel for the general population, same as non-alcoholic beverages (except milk-based beverages), sugar and confectionery, legumes, nuts and oilseeds, and vegetables and vegetable products (including fungi), milk and dairy products [28, 29]. Based on the risk assessment a tolerable daily intake (TDI) of 2.8 µg/kg b.w. was established.

In its recent opinion from 2020 CONTAM Panel of EFSA established a tolerable daily intake (TDI) at 13 µg Ni/kg body weight (b.w.) per day which is 4.6 times higher than in the previous risk assessment [30].

The newly established TDI value was influenced, inter alia, by an updated version of the guidance on the use of the reference dose method (BMD) in the risk assessment [10]. According to newly collected occurrence data, EFSA confirmed that grains and grain-based products mainly contributing to the mean LB (lower bound) chronic dietary exposure to nickel across all age classes with contributions reaching up to 49% in infants and toddlers Ni/kg body weight (b.w.) per day [30].

Currently, studies on the determination of nickel contents in food are conducted in the Member States to a slightly greater extent than a few years ago. This is due to the recommendation developed in 2016 by the European Commission on monitoring the level of this contamination in various groups of foodstuffs to collect more representative data covering the entire territory of the European Union, which would allow taking appropriate measures in the area of risk management in the future [6].

Research on the absorption of nickel in the human body are still scarce, which makes it impossible to reliably assess the exposure to this element in the diet. The available information in this regard indicates a large spread in absorption (1%-30%), depending on many factors such as chemical form and thus, the solubility of the nickel compound, which additionally increases the uncertainty of such assessments [13, 22, 23, 24, 29, 30].

As a critical effect for the risk characterization of acute oral exposure a systematic contact dermatitis was identified by EFSA and the lowest observed adverse effect level of 4.3 µg Ni/kg bw was selected as the reference point. The margin of exposure (MOE) approach was also applied. MOE of 30 or higher was considered as being indicative of a low health concern.

Estimated mean chronic dietary exposure was below or at the level of the TDI. Whilst the 95th percentile chronic dietary exposure was below the TDI in adolescents and in all adult age groups, but generally exceeded the TDI in toddlers and in other children, as well as in infants in some surveys and raise a health concern in these young age groups. Calculated MOE values for mean acute dietary exposure to 95th

percentile exposures raise health concerns in nickel allergic individuals [30].

Currently applicable legislation of the European Union does not take into account the requirements for nickel contamination of foodstuffs, apart from the requirements for food additives [7]. For the time being, such requirements apply at national level to drinking water, natural mineral, spring and table waters [26, 27].

Accordingly, there is a need to protect the most vulnerable groups of the population by implementing appropriate risk management measures.

## MATERIALS AND METHODS

*Samples*

The samples were taken from the Polish market in the years 2019-2020. They consisted of 56 samples of grain and grain-based products. The profile of the grain products under analysis was: 11 samples of pasta; 13 samples of flours; 12 samples of groats; 10 samples of flakes and 5 samples of bran. In on the group of grains were: wheat, rye, barley, and millet.

Concentration of nickel was measured by using in-house fully validated and accredited method according to standard PN-EN ISO/IEC 17025:2018. The validation was performed based on the analysis of the certified reference material - SRM 1515 (Apple leaves NIST) with certified mass fraction for nickel 0.936 mg/kg ± 0.094 mg/kg.

The obtained validation paramteres of the method were as follows: LOD: 0.95 µg/L; LOQ: 1.25 µg/L; repeatability - RSDr 7%; correctness (relative error): 3.4%, recovery: 97%; range: from LOQ to 25.0µg/l, uncertainty 24%.

*Equipment*

VARIAN SpectrAA 880Z atomic absorption spectrometer equipped with graphite furnace and Zeeman background correction was used. For graphite furnace measurements, argon was used as an inert gas. Pyrolytic-coated graphite tubes (Agilent) without platform were used. The spectrometer settings were as follows: wavelength 232.0 nm, slit width 0.2 nm, lamp current 4.0 mA, argon (flow) 3.0 l/min

The atomic absorption signal was measured as a peak surface mode against an analytical curve. Milestone MLS 1200 (Italy) microwave closed system at the stage of sample preparation was used.

*Reagents*

Nitric acid (HNO3) 65% (Merck), hydrogen peroxide 30% (Merck), palladium matrix modifier for graphite furnace (Pd (NO3)2/HNO3 (Merck) hydrochloric acid 35%-38% (Chempur), L (+) - ascorbic acid (Poch), deionized water, argon. The element standard solution used for calibration was prepared by diluting a stock solution of 1g/L (GUM). All reagents used were on an appropriately high degree of purity.

*Elements of control and verification of the method*

The accuracy of the method was verified by the analysis of certified reference material SRM-1515 (Apple leaves NIST). As part of the external validation of results, the laboratory regularly participates in proficiency tests organized by reputable suppliers such as the UK Food Science Laboratory (FAPAS) and the EU reference laboratory for metals and nitrogenous compounds (EURL-MN), Denamrk.

*Samples digestion*

Approximately 0.5 g of sample was and transferred into clean teflon vessel then 5 mL of concentrated $HNO_3$ and 1 mL of hydrogen peroxide were added. The digestion was lead by using a microwave in the closed mineralization system. To prevent clumping the contents of the reaction vessel were thoroughly mixed. After finished of the spontaneous reaction, the reaction vessels were quickly closed. The mineralization was carried out following the guidelines of the mineralizer producer.

*Calibration curve*

Scope of calibration curve: from 0 µg/L to 25 µg/L. The standard curve was prepared from one calibration solution thanks to the automatic dilution of the reagents.

*Statistical evaluation of data*

Statistical assessment of results was performed according to the substitution method used by EFSA for the treatment of left-censored data – LC (below limits of quantification (LOQ was 0.06 mg/kg). For results reported to be below the LOQ, the value equal to the LOQ (upper bound – UB), zero (lower bound – LB), or half the LOQ (medium or middle bound – MB) were used [31].

## RESULTS AND DISCUSSION

Left-censored data (below limit of quantification), represented 27% of the analytical results for all investigated samples of grain and their products. The results are presented in Table 1. The mean (MB) and 95th percentile (MB) nickel concentration in investigated samples of grain and their products were 0.66 mg/kg and 1.93 mg/kg. The average concentration of the nickel in the analyzed samples of grains was 1.16 mg/kg (MB). Nickel contents for this group of products ranged from 0.10 mg/kg for rye to 4.80 mg/kg for millet. Similar results were obtained in the surveys conducted by other authors [16, 21].

Table 1. Nickel content in tested samples of cereal grains and grain-based products, mg/kg

| Cereal grains and grain-based products | Number of samples | Nickel content | | |
|---|---|---|---|---|
| | | Mean (MB) | P95 (MB) | SD (MB) |
| Cereal grains (millet, rye, wheat, barley) | 5 | 1.16 | 3.91 | 2.04 |
| Pasta | 11 | 0.26 | 1.04 | 0.52 |
| Flour | 13 | 0.35 | 1.35 | 0.58 |
| Groats | 12 | 0.63 | 1.72 | 0.67 |
| Flakes | 10 | 0.93 | 1.97 | 0.66 |
| Bran | 5 | 1.34 | 1.76 | 0.36 |
| All grain-based products | 51 | 0.61 | 1.84 | 0.66 |
| Cereal grains and grain-based products | 56 | 0.66 | 1.93 | 0.85 |

MB – middle bound, P95 – 95th percentile, SD – standard deviation

In the group of grain products, the mean (MB) concentration of nickel was 0.61 mg/kg (95th percentile (MB) 1.84 mg/kg). The highest nickel level was determined in the samples of bran, groats, and flakes compared to other grain-based products. In the case of bran mean, MB was 1.34 mg/kg, for flakes was 0.93 mg/kg whilst for groats 0.63 mg/kg. Another survey indicates a comparable concentration of Ni, for groats and flakes, mean was from 0.07 mg/kg to 2.68 mg/kg, and from 0.25 mg/kg to 1.16 mg/kg respectively.

The highest content of Ni in the group of cereal products was found in the samples of roasted buckwheat 1.81 mg/kg and oat flakes 2.53 mg/kg. The obtained results are comparable with the results from other EU countries, indicating higher nickel contamination of buckwheat and oat and products from these grains as compared to other products, mean were 2.0 mg/kg and 1.8 mg/kg [29]. A study conducted in the United States and Australia also confirmed higher nickel contamination of oats and its products, obtained results were in the range: 0.36 mg/kg - 2.10 mg/kg and 0.35 mg/kg - 0.41 mg/kg, respectively [11, 36].

The survey conducted in Sweden indicates lower contamination of cereal-based products than in our studies, the mean was 0.14 mg/kg [20].

Previous studies by other authors concerning cereal products indicate even higher nickel contamination of buckwheat groats, reaching up to 2.68 mg/kg and significantly lower values in the case of oatmeal – mean 1.16 mg/kg [18]. According to new EFSA occurrence data, the mean (LB-UB) concentration of nickel in grains and grain-based products was is in the range: 0.31 mg/kg - 0.33 mg/kg (95th percentile 1.25 mg/kg - 1.25 mg/kg) [30]. Average contamination of investigated samples of pasta and flour with nickel was lower than other investigated samples of grain-based products, mean MB was 0.26 mg/kg (95th percentile 1.04 mg/kg), and 0.35 mg/kg (95th percentile 1.35 mg/kg) respectively. In the case of wholemeal pasta, higher levels of nickel were observed than in the case of regular pasta made from wheat flour. The obtained results for both groups were in the range: from 0.20 mg/kg to 1.79 mg/kg and 0.03 mg/kg to 0.08 mg/kg for pasta made from wheat flour. The survey conducted in the UK indicates comparable contamination of pasta and wheat flour, mean was about 0.03 mg/kg and 0.04 mg/kg, accordingly [12]. Similar lower contents of Ni in pasta were observed in France, reported mean values were as follows: 0.02 mg/kg and 0.05 mg/kg [13, 19]. Other authors reported results for pasta in a wide range, from 0.05 mg/kg to 0.12 mg/kg [2].

A similar connection as for pasta was observed in the case of whole grain flour and wheat flour. For the first group concentration of Ni was much higher and ranged between 0.23 mg/kg and 2.12 mg/kg. In the case of wheat flour obtained results were below LOQ value whilst contamination of spelt flour was significantly higher than wheat flour and ranged from 0.14 mg/kg to 0.18 mg/kg.

The survey conducted in Spain concerning contamination of wheat flour indicates slightly higher values form 0.08 mg/kg to 0.09 mg/kg [34].

To assess the dietary exposure to nickel from commercially available grain and grain products mean and high contamination levels (P95), middle bound (MB), were taken into account. The data of the Central Statistical Office [15], and data of WHO, GEMS/ Food Consumption Cluster Diets [35] on consumption of cereals were used to assess consumption. The intake of nickel from these foodstuffs was assessed and compared to the Tolerable Daily Intake (TDI) at 13 µg/kg body weight per day, recently established by EFSA.

Taking into account the data of WHO, GEMS/ Food Consumption Cluster Diets on the consumption of cereal grains only (excluding rice) the assessed mean (MB) intake of nickel by adults from cereal grains would be 13.4% TDI; and do not raise a health concern.

Intake of nickel by adults and children based on average consumption of cereal products [14] (excluding bread, rice and bakery products) and taking into account the maximum absorption in the gastrointestinal tract would be 1.1 % of the TDI recently determined by EFSA for adults and 3.9% TDI for children. At the 95-percentile level of contamination, it would be 3.4% and 11.8% of this value. Studies conducted in Sweden indicated slightly higher exposure associated with the intake of Ni in cereal products by adults in comparison to our results. Mean MB intake of nickel with pasta by adults and children would be low, below 0.5% TDI and 1.3% TDI, respectively which also does not pose a health threat.

Assessed exposure was much lower than exposure to Ni intake with pasta calculated by Italian and French authors for both groups of the population [8, 19].

## CONCLUSIONS

The content of nickel in the tested samples of selected grain and grain products does not pose a health concern

The estimated exposure do not indicate excessive nickel intake with cereal grains and their products and is unlikely to be of toxicological concern.

The obtained results may contribute to legislative work allowing for proper risk management in this area.

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**Conflict of interest**

*The authors declare no conflict of interest.*

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ORIGINAL ARTICLE

# RADIATION MONITORING OF AGRICULTURAL SOILS OF THE VOLYN REGION IN UKRAINE

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## ABSTRACT

**Background.** The development of effective environmental management programs requires an appropriate assessment of the current state of the environment and contributes to anticipating future changes in the state of the environment. Obtaining such information is one of the main objectives of monitoring the environment, which is subject to anthropogenic stress, including radiological contamination. The distribution of radionuclides and their ability to migrate in ecological chains and concentration in individual parts requires special control in contaminated areas.

**Objective.** The purpose of the study was to analyze the content of radionuclides ($^{137}$Cs and $^{90}$Sr) in soils near the settlements of the zone of radioactive contamination of the Volyn region and their spatial differentiation. Priority is given to agricultural lands, soils, crop products, which necessitates the organization of targeted monitoring of the agro industrial complex

**Material and methods.** Radioactivity from $^{137}$Cs and $^{90}$Sr in the soil originating in the Volyn region was studied from 1996 to 2018. Radiation control was carried out on the area of 59852 ha (arable land - 38897 ha, meadows and pastures – 20955 ha).

**Results.** A significant part of the study area has elevated levels of radioactive contamination. The density of radionuclide contamination of agricultural soils in the settlements of the region has been determined. Density of pollution of all surveyed agricultural lands $^{137}$Cs ranges from 0.01 to 2.826 Ci/km$^2$, and $^{90}$Sr from 0.01 to 0.048 Ci/km$^2$.

**Conclusions.** The radiological situation in the Volyn region (Ukraine) remains stable. There are slight fluctuations of $^{137}$Cs and $^{90}$Sr, which is due to changes in weather conditions, which leads to an increase or decrease in groundwater and as a consequence - the migration of radionuclides. The most polluted were the soils of administrative districts of Manevychi and Liubeshiv.

**Key words:** radionuclides, $^{90}$SR, $^{137}$CS, radioactive contamination, soils, monitoring, settlement

## INTRODUCTION

Rational use of agricultural lands in the conditions of technogenic impact on the environment, in particular optimization of nature use in the zone of radioactive contamination is an important task of modern times [13]. One of the most important objects of radiation pollution monitoring is the sphere of agricultural production, especially crop and livestock products. The main source of radionuclides in human food is soil. Radionuclides are absorbed by plants and entered the crop products, and during its use they are absorbed in the human body.

Taking into consideration the behavior of radionuclides in the natural environment and decision-making on measures to reduce radioecological indicators of risks caused by the Chernobyl disaster remain relevant. The Volyn region, in particular the Kamin-Kashyrsky, Lyubeshivskyi and Manevychi administrative districts, also suffered from radioactive contamination. Much of the territory of these areas has elevated levels of radioactive contamination. To solve the problems related to the optimization of agro-landscapes in the conditions of radioactive contamination requires a comprehensive analysis of the ecostates of the study area.

The analysis of stock materials on the contaminated territories of the Volyn region showed the absence of scientific generalizations on radioactive contamination formed on the basis of unified approaches. The available information needs to be overviewed and systematized. It is necessary for the development of these conclusions, proposals for the rational use of agricultural land has been

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exposed to radioactive contamination. The content of radionuclides, ecostate of landscapes of the region, the degree of safety of local water and resources use were studied periodically. Many years of research, considerable attention has been paid to the use of water, biotic and land resources. However, there is an urgent need to clarify the state, dynamics, spatial distribution of radiation pollution, which largely determines the environmental safety of residents.

This problem of contamination of toxic substances is devoted a significant amount of studies. Special attention is paid to works by *Samoilenko* who proposed a comprehensive zoning of radioactive contaminated areas and the possible ecological consequences of the resource [16], *Tavrov* [17] who identified the most environmentally hazardous local complexes and forms of the use of water, biological and land resources of geosystems reservoirs of the Polessia and North Forest. *Ilyina* et al. [8, 9, 10, 11] have studied natural ponds as the environment complexes and accumulation of sediments and established geochemical indicators of the conditions investigated anthropogenic transformation processes and the sources and types of toxic substances in the conditions of Ukrainian Polissia. *Korotun* [12] analysed the monitoring of radiation pollution in the territory of Rivne region, *Romanchuk* [15] carried out the evaluation of the radioecological formation of radiation doses to rural residents of Polissia of Ukraine, *Hromyk* et al. [4, 5, 6, 7] have carried out eco-geographical substantiation of optimisation of agricultural landscapes in the zone of radioactive contamination of the Volyn region, *Dutov* [1] has considered agroecological aspects of minimize population exposure and *Grygus* et al. [3] found out the medical and geographical aspects of radioactive contamination. However, important special and temporal aspects of the propagation and accumulation of pollutants especially near settlements require detailed studies. It is part of a wide system of measures on liquidation of consequences of Chernobyl accident.

The purpose of the study was to analyse the content of radionuclides in soils near the settlements of the zone of radioactive contamination of the Volyn region and their spatial differentiation.

## STUDY AREA

Radiation control was carried out on an area of 59852 ha (arable land - 38897 ha, meadows and pastures - 20955 ha) in seven administrative districts of the Volyn region (Ukraine), including in the area of radioactive contamination (Manevychi, Lyubeshiv and Kamin-Kashyrskyi administrative districts).

## MATERIALS AND METHODS

To assess the effects of pollution, data on surface contamination of soils with radionuclides $^{137}Cs$ and $^{90}Sr$ (Ci/km$^2$) were used. All measurements were carried out in the Laboratory of Ecological Land Safety and Product Quality of the Volyn Branch of the State Institution 'Soil Protection Institute of Ukraine' (Lutsk). Determination of $^{137}Cs$ in soil was performed by the gamma-spectrum method on the AI-1024-95-17 unit, as well as on the PSA 68-01, RUB-01P6 radiometers, SEG-02, SEG-05 gamma spectrometers. The results of internal control over the accuracy of gamma spectrometric work to determine $^{137}Cs$ showed that the main relative error of measurements does not exceed 7%, of the allowable 25%. $^{90}Sr$ was determined by a radiochemical method with measurement on a modernized DP-100 No A 16-878 installation with PSO 3-4 M 09 [14].

The main types of soils are sod-podzolic, podzolic, chernozem, sod and swamp. The area of radioactive contamination of the region is characterized by a high rate of transfer of radionuclides from the soil to plants, which complicates the radiation situation and can adversely affect the health of residents [16].

## RESULTS AND DISCUSSION

As a result of the Chernobyl catastrophe, radionuclides that went outside the station were released into the atmosphere, where they accumulated. High migration capacity in the food chain (soil → plant → animal → livestock products) led to their entry into the human body. Internal radiation was added to the external irradiation. The presence of long-lasting radionuclides in the food chain causes internal exposure of humans and animals for many decades after contamination. Radionuclides get into the environment in different ways, but the soil, due to its absorbency, is the main accumulator of radioactive isotopes.

The ability to migrate and concentrate in certain parts of the food chain necessitated the organization of targeted monitoring of the agro-industrial complex. The monitoring system includes: observation and assessment of the level of radioactive contamination of nature components and biota elements in order to prevent possible negative consequences for human health; identification of patterns of spatial and temporal migration of radionuclides in biotic chains and making a forecast on this basis of future levels of radioactive contamination.

The purpose of radiation pollution monitoring is to accumulate the information needed to make decisions on the management and regulation of radioactive contamination of the natural environment

and to develop measures to reduce the absorption of doses by the population. Taking into account specific tasks and purposes, monitoring programs are developed, which establish the choice of objects of observation, type, frequency and frequency of changes, sampling, their further laboratory analysis, methods of statistical processing of results, principles of collection, accumulation and processing of information.

The only source of objective information about the radiation situation is direct observations and measurements. Monitoring of radiation pollution includes: periodic measurements of dose rates of β and γ parts in the field; periodic sampling at specially selected observation sites and control points, determination of the concentration of radionuclides in these samples, radiation contamination and physicochemical forms of radionuclides; calculation of dose loads on biota on the basis of primary data of radiation pollution monitoring; assessment of current conditions and forecasting of possible changes in the radiation situation.

Several authors [8, 16, 17] have studied the radioactivity of soils and other elements of the environment in Ukraine after the Chernobyl disaster, drawing attention to the identification of the most heavily contaminated sites and to the ecological consequences.

According to the results of monitoring (1994–1995) of $^{137}$Cs and $^{90}$Sr soil contamination in settlements, it was established that the maximum content of $^{137}$Cs and $^{90}$Sr is available in the Lyubeshiv administrative district of the village Berezna Volya ($^{137}$Cs-2.83 Ci/km$^2$, $^{90}$Sr-0.04 Ci/km$^2$) and village Lakhvychi ($^{137}$Cs-0.65 Ci/km$^2$, $^{90}$Sr - 0.04 Ci/km$^2$) (Table 1, Figure 1).

According to the level of soil contamination of the territory, settlements with villsges Lychyny, Stavyshche, Kachin (Kamin-Kashyrskiy district), Berezna Volia (Lyubeshiv district), Haluziya, Prylisne (Manevychi district) we attributed to the zone of enhanced radiation control (Table 2).


Figure 1. Distribution of radionuclide $^{137}$Cs content in soils (according to observation points, 1994-1995), Ci/km$^2$

Table 1. Results on complex monitoring of radiation pollution of soils in the settlements of Kamin-Kashirskyi, Lyubeshivskyi and Manevychi areas of the Volyn region, Ukraine (1994–1995)

| No | Settlement | $^{137}$Cs Ci/km$^2$ | $^{90}$Sr Ci/km$^2$ |
|---|---|---|---|
| **Kamin-Kashira district** | | | |
| 1994 | | | |
| 1 | Lychyny | 1.398 | 0.028 |
| 2 | Buzaky | 0.794 | 0.026 |
| 3 | Cherche | 0.968 | 0.022 |
| 4 | Stavyshche | 1.404 | 0.014 |
| 5 | Nuyne | 0.614 | 0.024 |
| 1995 | | | |
| 1 | Karasin | 0.656 | 0.048 |
| 2 | Viderta | 1.114 | 0.038 |
| 3 | Kachin | 1.410 | 0.042 |
| 4 | Olshani | 0.244 | 0.022 |
| **Lyubeshiv district** | | | |
| 1994 | | | |
| 1 | Mala Hlusha | 0.344 | 0.032 |
| 2 | Mukoshyn | 0.384 | 0.026 |
| 3 | Lakhvychi | 0.652 | 0.040 |
| 4 | Berezna Volya | 2.826 | 0.040 |
| 1995 | | | |
| 1 | Lobna | 0.868 | 0.028 |
| 2 | Lyubotyn | 0.44 | 0.042 |
| 3 | Vetly | 0.464 | 0.024 |
| 4 | Pozhoh | 0.612 | 0.034 |
| **Manevychi district** | | | |
| 1994 | | | |
| 1 | Haluziya | 1.236 | 0.038 |
| 2 | Kulykovychi | 0.466 | 0.012 |
| 3 | Chornyzh | 0.810 | 0.024 |
| 1995 | | | |
| 1 | Haluziya | 1.368 | 0.032 |
| 2 | Komarove | 0.486 | 0.024 |
| 3 | Prylisne | 1.182 | 0.030 |

1 Ci/km$^2$ = 37 kBq/m$^2$

The results of radioecological monitoring of soils conducted in 1996–1998 in Kamin-Kashirsky, Lyubeshivsky and Manevychi districts are summarized in Table 3. Analysis of the results of the study of $^{137}$Cs content in soils showed that the maximum content of radionuclides was recorded in 1997 in the village. Borovno (0.27 Ci/km$^2$) Kamin-Kashirskiy district, village Volya Lyubeshivska (0.34 Ci/km$^2$) of Lyubeshiv district and village Yablunka (0.46 Ci/km$^2$) of Manevychi districts. The main $^{90}$Sr batteries were soils in 1997 Rakiv Lis (0.02 Ci/km$^2$) and village Borovno (0.02 Ci/km$^2$) of Kamin-Kashirsky district. The maximum content of radionuclides in the soils of Lyubeshiv district is concentrated in the village Volia Lyubeshivska (0.03 Ci/km$^2$) in 1996. The soils of the village Lyshnivka (0.03 Ci/km$^2$) in 1996 and the village Komarovo (0.03 Ci/km$^2$) in 1998, Manevychi district.

Table 2. Scale for assessing the level of radioactive soil contamination $^{137}$Cs

| Contamination of the territory, Ci/km$^2$ | Soil contamination | Possibility of human habitation |
|---|---|---|
| 0 –1 | Clean soil | Ordinary residence |
| 1–5 | Zone of enhanced radiation control | Accommodation is allowed |
| 5–15 | Contaminated soil | Zone guaranteed voluntary resettlement |

Table 3. Results on the complex monitoring of radiation pollution of soils in the settlements of Kamin-Kashirskyi, Lyubeshivskyi and Manevychi areas of the Volyn region, Ukraine (1996–1998)

| No | Settlement | Year of research | $^{137}$Cs Ci/km$^2$ | $^{90}$Sr Ci/km$^2$ |
|---|---|---|---|---|
| **Kamin-Kashirskiy district** | | | | |
| 1 | Rakiv Lis | 1996 | 0.12 | 0.01 |
| | | 1997 | 0.15 | 0.02 |
| | | 1998 | 0.06 | 0.02 |
| 2 | Borovno | 1996 | 0.25 | 0.01 |
| | | 1997 | 0.27 | 0.02 |
| | | 1998 | 0.18 | 0.01 |
| **Lyubeshiv district** | | | | |
| 1 | Velyka Hlusha | 1996 | 0.236 | 0.02 |
| | | 1997 | 0.25 | 0.01 |
| | | 1998 | 0.40 | 0.01 |
| 2 | Volya Lyubeshivska | 1996 | 0.20 | 0.03 |
| | | 1997 | 0.34 | 0.01 |
| | | 1998 | 0.23 | 0.01 |
| **Manevychi district** | | | | |
| 1 | Lyshnivka | 1996 | 0.34 | 0.03 |
| | | 1997 | 0.41 | 0.02 |
| | | 1998 | 0.27 | 0.02 |
| 2 | Yablunka | 1996 | 0.30 | 0.02 |
| | | 1997 | 0.46 | 0.01 |
| | | 1998 | 0.36 | 0.01 |
| 3 | Komarovo | 1996 | 0.14 | 0.01 |
| | | 1997 | 0.26 | 0.01 |
| | | 1998 | 0.17 | 0,03 |

1 Ci/km$^2$ = 37 kBq/m$^2$

In 2011–2018, radiological control was carried out in seven administrative districts (Lyuboml, Shatsk, Starovyzhiv, Ratniv, Kivertsiv, Manevychi and Lutsk). The content of radionuclides was controlled on the area of 59852 ha (arable land - 38897 ha, meadows and pastures - 20955 ha). The density of contamination of the surveyed agricultural soils at $^{137}$Cs was up to 1 Ci/km$^2$, and at $^{90}$Sr up to 0.02 Ci/ km$^2$.

The highest indicators of density of $^{137}$Cs contamination of soils are in the areas included in the zone of radioactive contamination, village Yablunka - 0.15 Ci/km$^2$, village Kostyukhnivka - 0.24 Ci/km$^2$, village Lyshnivka - 0.31 Ci/km$^2$, village Prilisne - 0.27 Ci/km$^2$, village Sytnytsia - 0.09 Ci/km$^2$, village Komarovo - 0.08 Ci/km$^2$ Manevychi district; with. village Seat - 0.18 Ci/km$^2$, village Velyka Hlusha - 0.11 Ci/km$^2$, village Volya Lyubeshivska - 0.12 Ci/km$^2$ Lyubeshiv district (Table 4, Figure 2). According to toxicological indicators the soils of the experimental plots do not exceed the maximum allowable concentrations.


Figure 2. Dynamics of changes of $^{137}$Cs content in soils in the surveyed areas of Volyn region, Ukraine (2011-2018)

Table 4. Contamination of $^{137}Cs$ in soils on the surveyed areas of the Volyn region, Ukraine (2011-2018)

| No | Districts | Settlement | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $^{137}Cs$, Ci/km$^2$ | | | | | | | |
| 1 | Volodymyr-Volynskyi | Ovadne | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 |
| 2 | Gorokhivsky | Zhuravnyky | 0.03 | 0.04 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| 3 | Gorokhivsky | Uhryniv | 0.03 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 4 | Lutsk (Rokyni Res. Farm) | Rokyni | 0.06 | 0.06 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 |
| 5 | Ivanychivsky | Hryady | 0.03 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 |
| 6 | Kamin-Kashirsky | Olenine | 0.12 | 0.15 | 0.09 | 0.12 | 0.09 | 0.07 | 0.05 | 0.07 |
| 7 | Kamin-Kashirsky | Rakiv Lis | 0.07 | 0.07 | 0.08 | 0.08 | 0.06 | 0.05 | 0.04 | 0.05 |
| 8 | Kivertsivsky | Hremyache | 0.12 | 0.11 | 0.08 | 0.04 | 0.02 | 0.02 | 0.02 | 0.03 |
| 9 | Kivertsivsky | Omelne | 0.11 | 0.12 | 0.09 | 0.04 | 0.03 | 0.03 | 0.04 | 0.03 |
| 10 | Kovelsky | Kozlynychi | 0.17 | 0.18 | 0.15 | 0.12 | 0.08 | 0.07 | 0.06 | 0.05 |
| 11 | Kovelsky | Stari Koshary | 0.05 | 0.05 | 0.03 | 0.01 | 0.03 | 0.03 | 0.02 | 0.02 |
| 12 | Kovelsky | Ukhovetsk | 0.08 | 0.09 | 0.10 | 0.11 | 0.07 | 0.07 | 0.08 | 0.09 |
| 13 | Lokachinsky | Hubyn | 0.03 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| 14 | Lokachinsky | Pryvitne | 0.02 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.01 | 0.01 |
| 15 | Lutsk | Vesele | 0.03 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 |
| 16 | Lutsk | Pidhaytsi | 0.04 | 0.04 | 0.02 | 0.02 | 0.03 | 0.02 | 0.01 | 0.01 |
| 17 | Lutsk | Krupa | 0.04 | 0.05 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| 18 | Lyubeshivsky | Velyka Hlusha | 0.18 | 0.18 | 0.19 | 0.18 | 0.14 | 0.14 | 0.12 | 0.11 |
| 19 | Lyubeshivsky | Volya Lyubeshivska | 0.24 | 0.24 | 0.21 | 0.19 | 0.17 | 0.15 | 0.13 | 0.12 |
| 20 | Lyubeshivsky | Sedlyshche | 0.22 | 0.23 | 0.18 | 0.18 | 0.16 | 0.16 | 0.17 | 0.18 |
| 21 | Lubomlsky | Kusnyshche | 0.05 | 0.06 | 0.03 | 0.02 | 0.03 | 0.02 | 0.02 | 0.01 |
| 22 | Manevychi | Komarovo | 0.13 | 0.16 | 0.11 | 0.09 | 0.06 | 0.04 | 0.05 | 0.08 |
| 23 | Manevychi | Kostyukhnivka | 0.14 | 0.39 | 0.35 | 0.28 | 0.27 | 0.24 | 0.22 | 0.24 |
| 24 | Manevychi | Lyshnivka | 0.39 | 0.43 | 0.36 | 0.37 | 0.36 | 0.35 | 0.32 | 0.31 |
| 25 | Manevychi | Prylisne | 0.51 | 0.52 | 0.48 | 0.36 | 0.32 | 0.29 | 0.22 | 0.27 |
| 26 | Manevychi | Sytnytsya | 0.27 | 0.02 | 0.12 | 0.13 | 0.11 | 0.10 | 0.11 | 0.09 |
| 27 | Manevychi | Tsminy | 0.25 | 0.30 | 0.20 | 0.18 | 0.11 | 0.01 | 0.03 | 0.03 |
| 28 | Manevychi | Yablun′ka | 0.23 | 0.24 | 0.19 | 0.15 | 0.12 | 0.13 | 0.11 | 0.15 |
| 29 | Ratnivsky | Hirnyky | 0.04 | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 30 | Rozhyschensky | Pozharky | 0.10 | 0.11 | 0.06 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 |
| 31 | Rozhyschensky | Perespa | 0.10 | 0.13 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.01 |
| 32 | Starovyzhivsky | Krymne | 0.12 | 0.08 | 0.06 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 |
| 33 | Starovyzhivsky | Synove | 0.10 | 0.11 | 0.07 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 |
| 34 | Turian | Kupychiv | 0.03 | 0.04 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 |
| 35 | Kivertsivsky | Tsuman forestry | 0.16 | 0.19 | 0.12 | 0.11 | 0.08 | 0.08 | 0.07 | 0.09 |
| 36 | Shatsky | Pulmo | 0.07 | 0.07 | 0.05 | 0.02 | 0.03 | 0.02 | 0.01 | 0.01 |

## CONCLUSIONS

The radiological situation in the Volyn region of Ukraine remains stable. There are slight fluctuations of $^{137}Cs$ and $^{90}Sr$, which is due to changes in weather conditions, which leads to an increase or decrease in groundwater and as a consequence - the migration of radionuclides.

In order to preserve the natural resource potential of the radioactive contamination zone of the region, it is necessary to carry out a set of agrotechnical and agrochemical measures aimed at reducing radioactive contamination. The main measures include the method of tillage, crop placement and liming of acid soils. Application of organic, mineral fertilizers and sorbents with obligatory liming of acid soils is one of the main ways that can most effectively affect the blocking of radionuclides by the soil absorption complex.

Elucidation of the features of spatial differentiation of radionuclides, establishment of levels of contamination with radioactive elements $^{137}Cs$, $^{90}Sr$ soils of the studied area requires further study of

their migration and accumulation. The problem of radionuclide contamination has serious socio-economic consequences. The territory needs a long process of socio-economic rehabilitation, which involves the restoration of lost natural resource potential and safe living conditions and the introduction of advanced technologies for the production of environmentally friendly agricultural products.

**Conflict of interest**
*None declared.*

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ORIGINAL ARTICLE

# INTERVENTION FOR IMPROVEMENT THE DIET AND PHYSICAL ACTIVITY OF CHILDREN AND ADOLESCENTS IN POLAND

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## ABSTRACT

**Background.** The effects of a two-year educational Programme "Keep Balance" addressed to children and adolescents have been evaluated. Its purpose has been to implement the rules of proper nutrition and increasing the level of physical activity on the population level.

**Objective.** The main objective of the evaluation was an indication if, after two years of programme activities, outcome indicators have been achieved.

**Material and methods.** Approximately 400,000 pupils/students from 1600 educational units from the territory of the whole country have been included in the education programme. The efficiency evaluation has been carried out in a sample of n = 1506 pupils/students in the interventional group and n = 1589 in the control group. Education has been addressed to the entire school environment, pupils, students, parents, teachers, headmasters, and the local community. The survey methodology, body weight and height measurements, the BMI index, and EUROFIT physical fitness tests have been used to assess the effects of the education programme in the scope of knowledge and nutritional behaviour regarding physical activity. There were assumed outcome indicators. The certification of schools/kindergartens with "The Certificate of a School/Kindergarten Friendly to Nutrition and Physical Activity" has been used to evaluate the activation of school environments.

**Results.** There was an improvement achieved over the assumed target points in the level of knowledge of pupils/students in the scope of nutrition and the role of physical activity, in the changes of nutritional habits, and in the results of physical fitness tests. There were achieved 20% increase in knowledge in the scope of nutrition and 5% increase in physical activity. There have been changes in the frequency in the consumption of the first breakfast before going to school (by 25% among the younger ones and by 17% among the older ones), an increase in the consumption of bottled water by 49% and reduction of sweet drinks by 19%. The percentage of the pupils/students consuming the recommended 5 meals increased by 33%. Physical fitness indicators were achieved over assumed 5% increase in the individual exercise tests. The Certificate was obtained after meeting the criteria and documenting the durability of the changes by 65% of 1600 educational units included in the Programme. A decrease in the frequency of overweight and obesity occurrence in the whole intervention sample by 1% was obtained; it was greater (but statistically insignificant) among younger students by 3.3% in comparison to the older ones where there was an increase of 1%.

**Conclusions.** Summing up all achieved results the educational programme "Keep Balance" implemented on the population level aimed at children and adolescents has turned out to be effective and deserves to be continued after minor adjustments. Many positive changes have been identified as well as those that ought to be improved. Comprehensively included education and sometimes small changes in much of nutritional and physical behaviour have influenced the reduction of the percentage of pupils/students with excessive body weight, despite the fact that the average BMI has basically remained on the same level.

**Key words:** *intervention, children, adolescents, nutrition, physical activity, obesity prevention*

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## STRESZCZENIE

**Wprowadzenie.** Oceniono efekty dwuletniego programu edukacyjnego „Zachowaj równowagę" skierowanego do dzieci i młodzieży. Jego celem było wdrożenie zasad prawidłowego żywienia i podniesienie poziomu aktywności fizycznej na poziomie populacji.

**Cel badań.** Głównym celem ewaluacji było wskazanie, czy po dwóch latach działań realizowanych w ramach programu osiągnięto założone rezultaty i wskaźniki.

**Materiał i metody.** Około 400 000 uczniów z 1600 placówek oświatowych z terenu całego kraju zostało objętych programem edukacyjnym. Ocenę efektywności przeprowadzono na próbie 1506 uczniów w grupie interwencyjnej i 1589 uczniów w grupie kontrolnej. Działania edukacyjne były kierowane do całego środowiska szkolnego - uczniów, rodziców, nauczycieli, dyrektorów oraz społeczności lokalnej. Do oceny efektów programu edukacyjnego w zakresie wiedzy i zachowań żywieniowych, w zakresie aktywności fizycznej wykorzystano metodologię obejmującą ankietę, pomiary masy ciała i wzrostu, wskaźnik BMI oraz testy sprawności fizycznej EUROFIT. Określono wskaźniki do osiągnięcia. Do oceny aktywizacji środowisk szkolnych została wykorzystana certyfikacja szkół/przedszkoli za pomocą „Certyfikatu Szkoły /Przedszkola Przyjaznego Żywieniu i Aktywności fizycznej".

**Wyniki.** W stosunku do założonych punktów docelowych nastąpiła poprawa poziomu wiedzy uczniów z zakresu żywienia i roli aktywności fizycznej, zmiany nawyków żywieniowych oraz wyników sprawdzianów sprawności fizycznej. Osiągnięto 20% wzrost wiedzy z zakresu żywienia i 5% wzrost aktywności fizycznej. Zaobserwowano zmiany w częstotliwości spożywania pierwszego śniadania przed pójściem do szkoły (wzrost o 25% wśród młodszych i o 17% wśród starszych uczniów), wzrost spożycia wody butelkowanej o 49% oraz zmniejszenie spożycia słodkich napojów o 19%. Odsetek uczniów spożywających zalecane 5 posiłków dziennie wzrósł o 33%. Wskaźnik sprawności fizycznej osiągnięto powyżej zakładanego 5% wzrostu w poszczególnych próbach wysiłkowych. Certyfikat Szkoły/ Przedszkola Przyjaznego Żywieniu, po spełnieniu kryteriów i udokumentowaniu trwałości zmian, uzyskało 65% z 1600 uczestniczących w Programie placówek. Zaobserwowano nieistotne statystycznie zmniejszenie częstości występowania nadwagi i otyłości w całej próbie interwencyjnej o 1% - większe o 3,3% wśród uczniów młodszych w porównaniu ze starszymi, gdzie nastąpił wzrost o 1%.

**Wnioski.** Po podsumowaniu wyników stwierdzono, że program edukacyjny „Zachowaj Równowagę" realizowany na poziomie populacji, skierowany do dzieci i młodzieży, okazał się skuteczny i w pełni zasługuje na jego kontynuację po drobnych jego korektach. Zaobserwowano wiele pozytywnych zmian. Wszechstronna edukacja i czasami niewielkie zmiany w większości zachowań żywieniowych i fizycznych wpłynęły na zmniejszenie odsetka uczniów z nadmierną masą ciała, mimo, że średni wskaźnik BMI w zasadzie pozostał na tym samym poziomie.


**Słowa kluczowe:** *interwencja, dzieci, młodzież, żywienie, aktywność fizyczna, prewencja otyłości*

## INTRODUCTION

Excessive body weight (obesity and overweight) at the developmental age has become now one of the most serious public health problems in all the regions of the world. The intensity of obesity in children and adolescents differs among countries, as there are countries with a low incidence of obesity below 10%, as well as those with a particularly high incidence approaching 40% [10 ]. However, regardless of the percentage, there is an increasing trend of overweight and obesity in all the regions of Europe, particularly intense in Eastern European countries [15]. Summarizing the most important issues of public health from the perspective of the population, the European Public Health Association (EUPHA) with the Section: Child and Adolescent Public Health (CAPH) indicated obesity as one of five priorities of children and adolescents' public health [5, 11].

The risk factors for the development of obesity in children and adolescents are mostly and comprehensively described with an indication to the dominating role of a lifestyle including unhealthy nutrition habits and a shortage of physical activity that would be optimal for health [7, 14, 15]. This knowledge causes the fact that intervention programmes are conducted in larger or smaller groups of children or adolescents in almost every country, as for which there is little information about their effectiveness and consequently, about durability in terms of a population [8, 9, 12]. A high variability in the intervention programmes applied, combating many factors often correlated with one another, the lack of a description of intervention tools used and the assessment of their effectiveness result in that practically little is known about the risk profile or protection factors operating in various countries [2]. The knowledge on the factors determining the effectiveness of specified methods of preventing the development of obesity in children and adolescents in various countries requires urgent supplementation.

Following the motivation above, an intervention programme addressed to the population of children and adolescents in Poland was initiated. Its main goal was to implement the principles of proper nutrition and physical activity in children and adolescents by shaping pro-health attitudes and, consequently, preventing the development of overweight and obesity as well as other chronic diseases with the help of educational tools.

The detailed goals were formulated in the form of assumed indicators to be achieved during two years of

its duration. They concerned the increase of changes in the scope of knowledge on healthy nutrition (outcome indicator: increase by 20%) and physical activity (by 5%), positive changes in behaviour in relation to nutrition and physical activity (outcome indicator: increase by 20%), the improvement of physical fitness results (outcome indicator: increase by 5%) and achieving good certification results of educational units by the assumed percentage (outcome indicator: 50% of certified institutions). The implementation of the objectives was directed at the entire population of pupils/students included in the programme and the entire school environment.

## MATERIAL AND METHODS

*The description of the programme*

The educational program for children and adolescents was a part of a larger and comprehensive Project of Swiss and Polish Cooperation (KIK/34 grant) called "Keep Balance", which included educational tasks addressed also to other demographic groups apart from adolescents, to pregnant and lactating women, obese and overweight adults, and the whole society. One of the tasks supported all the Project's goals in the form of a nationwide media campaign.

The educational program meant for children and adolescents was implemented within the years of 2013–2015 in kindergartens and schools. Joining the program was a voluntary, spontaneous initiative of a school or kindergarten, which provided the opportunity to act together in the structure built by the authors. The programme covered 1,600 municipal and rural education establishments from all the education levels, 100 in each of 16 administrative units in the country (provinces), which allowed the programme implementers to take into account existing regional inequities in the intensity of obesity [6]. Approximately 400,000 pupils attended the schools and kindergartens included in the programme in 2013.

In order to achieve the planned goals, a communications structure between the programme management centre and the programme implementers in the field was built. For this purpose, the Programme implementers from the institutions managing the Project from the National Food and Nutrition Institute (NFNI) and the University of Physical Education (UPE) trained 16 coordinators of the programme in each province twice.

Subsequently, a leader was selected, a teacher who was responsible for the implementation of the programme and educational materials in a facility in each of 1,600 schools/kindergartens included in the programme. The leaders were trained by way of e-learning, using 9 films sent on CD-ROMs, and then placed on the Internet website of the Project. The leaders' training was finished with an examination checking their knowledge, assessed by the project management team (from the NFNI and the UPE).

The educational programme was launched on 1 September 2013, and finished on 30 June 2015. It is worth noting that the educational programme and final examination after the end of the programme were completed in June 2015 before the Regulation on the sale and administration of food products at schools issued by the Minister of Health came out (15 August 2015).

The achievement of the planned objectives of the programme was assessed on the basis of a sample survey of students from the last grades of primary schools (13 years old) and from the last grades of junior high schools (16 years old). Sixty four classes (4 classes: 2 urban and 2 rural ones from each province) constituted a sample for evaluating the effects of the programme. The school classes were selected for the control and intervention group according to the principle of cluster sampling. The classes from the intervention group were subjected to a two-year education programme; the classes from the control group did not participate in the educational program. The students from the intervention group did not differ in their age from the students from the control group (Table 2). The information about the school's activities, the teachers' information on the knowledge and behaviour of pupils/students, the measurements of height and weight, and fitness tests were conducted by trained Leaders - School Teachers both in the intervention and control groups. The leaders received a detailed research instruction, necessary equipment, and documentation to complete.

The following methods were used to assess the effects of the activity of the educational programme:

1. surveys containing test questions including the 5-point *Likert* scale, as well as open questions were used in the assessment of the level of knowledge of pupils/students in the scope of nutrition and physical activity,
2. in the assessment of the certification process by a school or kindergarten, a description of the criteria in the scope of nutrition and physical activity fulfilled by a school or kindergarten with the attached documentation in the form of photographs, CD recordings etc., attendance at physical education classes, or talks with parents, etc. were taken into account.

The certificate was granted in the presence of a committee on the basis of the documentation: (1) the results of a test in the form of four EUROFIT tests were taken into account in the assessment of changes in physical fitness, (2) the anthropometric measurements of body height and body mass of pupils/students were

Table 1. The types of educational and intervention activities used in the two-year Educational Project "Keep Balance"

| **Addressed to teachers** |
|---|
| • e-learning for teachers with the help of 9 educational and instructional videos on the issues of physical activity and nutrition in educational institutions, and the rules for certifying kindergartens and schools, completed with a knowledge exam,<br>• a guidebook for teachers 'A school and kindergarten friendly to healthy nutrition and physical activity' with an attached CD-ROM containing scenarios for classes on the subject of proper nutrition on various educational levels,<br>• sending the criteria to be fulfilled so that a school/kindergarten can receive 'the Certificate of a School/ Kindergarten Friendly to Nutrition and Physical Activity' in the paper and electronic versions,<br>• the development of original scenarios and recording educational videos based on them with training programmes for children and school adolescents, for the youngest ones from kindergartens and the grades of 1-3 of primary schools, for junior high schools, and for the oldest students from secondary schools with the total length of 6 hours, 52 minutes, and 26 seconds of film material:<br>– 16 videos with the presentations of exercises, games, and plays for kindergarten children and the pupils of 1-3 grades with the total length of 1 hour, 0 min., 11 s.<br>– 15 videos with the presentations of mid-lesson exercises for younger children with the total length of 36 min., 50 s.<br>– 15 videos with the presentations of exercises, games, and plays for the pupils of 4-6 grades with the total length of 1 hour, 10 min., 45 s.<br>– 3 videos with dance animations for adolescents with the total length of 2 hours, 3 min., 4 s.<br>– 7 videos with fitness exercises for adolescents with the total length of 2 hours, 1 min., 36 s.<br>• the production and distribution of 9 videos with the character of 'mad' Professor FunFit, along with the scenarios of plays and physical games and exercises for younger students with elements of nutrition,<br>• 36 articles in the scope of physical activity and fitness on the Internet website of the project,<br>• a bookmark for School and Kindergarten Headmasters and for teachers on the project website www.zachowajrownowagę.pl with articles and current information, |
| **Addressed to pupils/students** |
| • the competition 'The Good Shape Contest' for the pupils from the 5-6 grades of primary schools and the students from the 1-3 grades of junior high school with four tasks to be performed by pupils/students: designing and conducting an educational campaign on the subject of healthy nutrition and physical activity addressed to the family/parents and siblings, and 3 other tasks to choose from. The competition provided for prizes and the announcement of results on the project Internet website,<br>• "The Good Shape" competition announced in the subsequent year for all the institutions participating in the project with prizes and the announcement of results on the project Internet website,<br>• an interactive booklet for kindergarten children entitled "Be active and eat healthily",<br>• an educational film for children about healthy nutrition and physical activity "Keep Balance" with animated elements with the participation of well-known chef Pascal Brodnicki for primary and junior high schools,<br>• 7 posters including 2 posters with the Healthy Eating Pyramid and the rules for healthy nutrition (for the age of kindergarten children and the children of younger 1-3 grades, and for adolescents separately); 2 posters with the Healthy Eating Pyramid and the rules for activity (for the age of kindergarten children and the children of younger 1-3 grades, and for adolescents separately), and 3 informative posters on the programme (for kindergartens, for the primary school 1-3 grades, for adolescents),<br>• the project website www.zachowajrownowagę.pl with a bookmark for pupils/students with articles and current information (3,791,279 visits to the website by 2016 stated),<br>• Facebook: zachowajrownowage.pl for pupils/students with everyday answers to questions from pupils/students or parents (41,000 users by 2016),<br>• YouTube with videos for the project (7000 hits a year). |
| **Addressed to parents** |
| • a brochure for parents entitled "The rules of healthy nutrition and physical activity of children and adolescents at the school age" in the paper and electronic version,<br>• leaflets - fridge magnets with healthy eating pyramids and physical activity for parents,<br>• a video with a celebrity, Pascal Brodnicki, 'Keep Balance – Elevenses' about the role of elevenses in pupil/student nutrition with recipes of dishes,<br>• leaflets in the paper and electronic version (a leaflet about the role of elevenses, 2 leaflets with the recipes presented by Pascal in the video),<br>• educational articles in the parents' bookmark on the project Internet website: zachowajrownowage.pl,<br>• a page on Facebook: zachowajrownowage.pl. |

| Addressed to the society |
|---|
| • articles for the press,<br>• press conferences,<br>• national and local radio and television interviews,<br>• after the completion of the Project, the creation of the National Centre for Nutritional Education and Lifestyle at the Food and Nutrition Institute (National Institute of Public Health - National Institute of Hygiene at present): www.ncez.pl (since 1 January 2017). |
| **Addressed to the school/ kindergarten** |
| • the development of requirements to be fulfilled by the school/kindergarten to obtain "The Certificate of a School/Kindergarten Friendly to Nutrition and Physical Activity",<br>• the development of criteria for certification in the scope of nutrition (from 6 to 10 criteria depending on the education level),<br>• the development of criteria for certification in the scope of physical activity (from 3 to 4 criteria depending on the education level). |

made according to the applicable methodology and after training teachers in the assessment of changes in body mass. The classification of overweight and obesity was made on the basis of the BMI index according to *Cole* et al. [3].

*Intervention*

The educational tools developed and applied during the two-year programme were directed to the entire school/kindergarten environment, to pupils/students, to their parents, to teachers and school headmasters, and to the local community. The culmination of the whole education process was the development of criteria to be met in the scope of nutrition and physical activity at school or kindergarten in order to receive the prestigious "Certificate of a School/Kindergarten Friendly to Nutrition and Physical Activity" to be hung outside and inside the building. The certificate was awarded after the initial evaluation after the first year of the programme; and it was granted after two years permanently after confirming the sustainability of pro-health changes in a school or kindergarten.

The educational materials used in the programme had a mixed character, i.e. taking into account new Internet technologies (digital ones), websites, social networking sites such as Facebook, YouTube, as well as traditional paper materials in the form of brochures, books or posters. The list and description of all the materials in a synthetic form used in the Programme are presented in the Table 1.

## RESULTS

As it has been mentioned earlier, the sample of pupils leaving the primary school (the average age of 13 years old) and students leaving the junior high school (the average age of 16 years) was selected to evaluate the efficiency of the education programme. The students from the intervention group participated in the school education program for two years of study. The intervention group did not differ in their age from the students in the control group (Table 2 ). The two-year education programme did not affect the changes of the average BMI index, which was practically the same, except for the larger average of 0.3 kg/m$^2$ in the case of boys aged 16 in comparison to 16-year-olds of the control group. Changes in the incidence of excessive body weight i.e. high BMI values, occurred despite the lack of significant differences between BMI averages.

There were fewer pupils/students with excessive body weight (overweight and obesity) in the groups of 13-year-old boys by 13%, by 3.4% among girls as well, and by 0.6% among 16-year-old girls in the intervention group after two years of the programme. 16-year-old boys among whom there was an increase in the percentage of excessive body mass in the intervention group by 2.6% were an exception.

The data provided in table 3 show that the programme's effects connected with the occurrence of excessive body weight were connected with the age of the pupils/students. The reduction of excessive body weight was greater (but statistically insignificant) in the group of younger 13-year-old pupils, while there was an increase among the 16-year olds (Table 3). The younger the pupils/students were, the greater the effects of the programme.

The effects of the educational programme set at the beginning of the programme as target points to be achieved are presented in Table 4. These effects were determined following the most frequent disorders in the nutrition manner and physical activity constituting the risk of developing obesity and other diet-related diseases in the population of the Polish children and adolescents.

In the case of an assumed 20% increase in knowledge in the scope of nutrition and 5% increase in physical activity, the objectives of the programme have been achieved regardless of the age (in the group in total). However, what is worth emphasizing, the effects achieved were greater in the younger age group

Table 2. Baseline frequency of excessive body weight in 13 and 16 years old students in the intervention and control groups

| | Intervention group n = 1506 | | | | Control group n = 1589 | | | |
|---|---|---|---|---|---|---|---|---|
| Sex | boys | | girls | | boys | | girls | |
| Age group | 13 years old n=377 | 16 years old n=393 | 13 years old n=354 | 16 years old n=382 | 13 years old n=401 | 16 years old n=393 | 13 years old n=408 | 16 years old n=387 |
| Age average in group | 12.9 | 15.9 | 12.8 | 15.9 | 13.0 | 16.1 | 13.0 | 16.0 |
| Height (cm ) | 160.0 | 176.0 | 159.0 | 165.0 | 160.4 | 176.5 | 160.0 | 165.4 |
| Body weight (kg) | 51.9 | 68.4 | 50.5 | 57.8 | 52.2 | 67.9 | 51.1 | 58.4 |
| BMI (kg/m$^2$) | 20.1 | 22.0 | 19.9 | 21.2 | 20.1 | 21.7 | 19.9 | 21.3 |
| Excessive body weight (overweight and obesity) (in %) | 25.9 | 24.2 | 18.8 | 14.7 | 29.3 | 21.6 | 22.2 | 15.3 |
| Excessive body weight boys along with girls (%) | 731 (22.4) | 775 (19.5) | - | - | 809 (25.7) | 780 (18.4) | - | - |

Statistical differences between the intervention and control groups statistically insignificant (p>0.05).
excessive body weight (overweight and obesity) BMI classification compliant with age and sex, according to *Cole* et al. 2000.

Table 3. Effects of intervention on excessive body weight occurrence (overweight and obesity) in intervention group in comparison with control group

| Age | Basic frequency before start with intervention (2013) | Intervention group (assessed in 2015) | Control group (assessed in 2015) | Reduction or increase in the intervention group in comparison to control group |
|---|---|---|---|---|
| 13 + 16 years old | 22.3 % n = 3266 | 20.9% n = 1506 | 21.9% n = 1589 | Reduction by 1 % |
| 13 years old | 25.3 % n = 1627 | 22.4% n = 731 | 25.7% n = 809 | Reduction by 3.3 % |
| 16 years old | 19.3 % n = 1639 | 19.5% n =775 | 18.4% n = 780 | Reduction by 1.1 % |

excessive body weight (overweight and obesity) BMI classification compliant with age and sex, according to *Cole* et al. [3]

Table 4. Positive changes (in %) in knowledge on healthy nutrition behaviour in intervention group after two years of education in comparison with the control group (considered as 100 %)

| Target points: | Increase achieved in intervention group in relation to control group | Assumed indicator to be achieved (increase or reduction by % ) |
|---|---|---|
| **Changes in the scope of knowledge** | | |
| **Knowledge in the scope of healthy nutrition rules** – Evaluation on the basis of 12 questions (one error allowed):<br>– total<br>– 13 years old<br>– 16 years old | <br><br>by 23%<br>by 28%<br>by 18.6% | by 20% |
| **Knowledge in the scope of physical activity**<br>– total<br>– 13 years old<br>– 16 years old | <br>by 7.2%<br>by 8.6%<br>by 5.8 % | by 5% |

| | | |
|---|---|---|
| **Changes in selected pupils'/students' nutrition behaviour** | | |
| 1. Increase in the consumption of 1st breakfast<br>– total<br>– 13 years old<br>– 16 years old | <br>by 19%<br>by 25%<br>by 17% | by 20% |
| 2. Increase in the consumption of 2nd breakfast at school<br>– total<br>– 13 years old<br>– 16 years old | <br>by 51%<br>by 70%<br>by 34% | |
| 3. Increase in the number of meals a day (up to 5 or more) | by 33% | |
| 4. Reduction in a small number of meals (1 to 2 ) | by 30% | |
| Change in the frequency of buying three products preferred by adolescents at a school shop<br>1. Increase in buying bottled water<br>2. Reduction in buying sweetened drinks<br>3. Reduction in buying chocolate bars<br>– total<br>– 13 years old<br>– 16 years old (increase ) | <br>by 49%<br>by 19%<br><br><br>by 5%<br>by 18%<br>by 12% | |
| **Changes in selected behaviour connected with physical activity** | | |
| – flexibility increase (test: a trunk bend in the sitting position)<br>– 13 years old<br>– 16 years old<br><br>– increase in abdominal muscles' strength (test: sit-ups)<br>– 13 years old<br>– 16 years old<br><br>– increase in back muscles' strength (test: a chin-up )<br>– 13 years old<br>– 16 years old<br><br>– increase in circulation-respiration stamina (test: a shuttle run x 20 m )<br>– 13 years old<br>– 16 years old | <br>by 50%<br>by 60%<br><br><br>by 7%<br>by 6%<br><br><br>by 44%<br>by 20%<br><br><br>by 22%<br>by 13% | by 5% |
| **Certification of Schools/Kindergartens** | | |
| Granting "The Certificates of a School/Kindergarten Friendly to Nutrition and Physical Activity" | by 15% (increase up to 65%) | 50% |

of 13-year-olds in comparison to older 16-year-old students.

Optimistic data concern the changes in the scope of nutritional behaviour. There have been important changes taking place in preventing the development of obesity in the frequency and regularity of consuming meals during the day including the increase in the consumption of the first breakfast before going to school (by 25% among the younger ones and by 17% among the older ones). There was an increase in the consumption of elevenses after 2-3 hours of staying at school as much as by 70% among the younger pupils and 34% among the older ones. Such a large increase in the frequency of consuming meals at school was associated with the school certification process, in which one of the important criteria was the organization of a sufficiently long break between classes and ensuring friendly conditions for pupils/students to consume a meal. The percentage of the pupils/students consuming the recommended 5 meals increased by 33%, and the percentage of the pupils/students eating too few meals during the day decreased by 30% complementarily. An important element of nutritional education was combating excessive sugar consumption by students, as a result of which there was a reduction in the purchase of sweetened drinks at school shops by 19%, chocolate bars by 5%, and an increase in the consumption of bottled water by 49%. The effects of changes were greater among the younger ones compared to the older students. The subsequent effects of the programme included the tests of the pupils'/students' physical fitness allowing to assess aerobic stamina, postural muscle strength, and flexibility of the lower spine section. The test of

sit-ups allowing for the evaluation of the abdominal muscles' strength in which the effects of change were the smallest, 6.8% among the 13-year-olds comparing to 6.1% among 16-year-olds. The progress was bigger in the test of chin-ups evaluating the muscle strength of the back and shoulder girdle (by 44% in 13-year-olds and by 19.6% among 16-year-olds). Both these tests referred to the evaluation of the muscle strength of the so-called postural muscles responsible for maintaining the correct posture. Strong back and abdominal muscles are, in turn, responsible for the safety and hygiene of the spine. The biggest changes were made in the subsequent test, a trunk bend in the sitting position, testifying to the fitness of the lower spine section (by 50.4% in 13-year-olds and by 60.5% in the group of 16-year-olds).

The changes presented in table 4 below and many others not discussed in this report were accompanied by the certification process of schools and kindergartens, in which educational units tried to fulfil quite demanding criteria in the scope of changes concerning nutrition and physical activity, adjusted to the education level and the infrastructure at a school or kindergarten on a different level (schools from the town/city and the country were included in the programme).

1027 units out of 1600 kindergartens and schools fulfilled the criteria of "The Certificate of a Kindergarten/School Friendly to Nutrition and Physical Activity" and confirmed the continuation of the changes after two years, which constituted 65% of the total; and it was 15% more than the assumed target point equal to 50%.

## DISCUSSION

In this programme, "Keep Balance" it was assumed that the whole school/kindergarten community, including pupils/students, their parents, and the employees of educational facilities, and even local communities would take mutual actions under the influence of the education conducted for the improvement of nutritional behaviour and the one connected with physical activity of children and adolescents. The effects of the two-year programme confirmed these expectations, and demonstrated the efficiency of the activities carried out, as the intensity of the main risk factors for the development of excessive body mass in children and adolescents was reduced by pro-health changes in nutrition and in physical activity and fitness. Certainly, the inclusion of the school environment with the parents of the pupils/students in the programme contributed to the desired changes in nutrition and physical activity in our programme. The large role in promoting healthy eating behaviour and physical activity was assigned to parents and the home environment [4, 16] in programmes conducted in other countries as well.

The certification of schools in the Polish "Keep Balance" programme launched the activity of the school environment, because it influenced the change in the attitude of schools' management and teachers towards the needs of students in the scope of nutrition and physical activity, the organization of places for consuming meals at school, the change of assortment at school shops, or an increase in the participation of pupils/students in obligatory classes and in extracurricular forms of physical activity.

Moreover, the schools and kindergartens received specially designed educational materials in the scope of nutrition and physical activity (intended for pupils/students, teachers, parents, personnel dealing with nutrition or physical activity), both in the printed form as well as CD-ROMs and contacts with social media portals (Facebook, YouTube) or the project Internet websites for permanent use. The mixed and multi-sectoral forms of education proved to be efficient, because they satisfied the expectations of people with various preferences regarding educational materials, as well as they ensured the variety of information provided in the project. The intervention changing the health behaviour of adolescents through online communications proved effective, as documented in a review of 27 studies with the use of such methods [12].

One of the measures of efficiency of educational programmes is change in the BMI. In literature, reports are not consistent; there were both no changes under the influence of a 3-year intervention in children [1] as well as a reduction in the average BMI and the incidence of overweight and obesity in the intervention group in comparison to the control group during a four-year follow-up observation [8] or lowering of the z-score of the BMI together with the accompanying beneficial changes in nutritional habits associated with the development of obesity [13]. In the "Keep Balance" programme, the incidence of obesity in the intervention group was reduced by 1% regardless of age and by 3% among younger students. The achievement of such effects during activities addressed to the population, and not to individual children or families, suggests that the impact on a larger scale may affect many small changes in behaviour conducive to the development of obesity simultaneously, which results in the inhibition of its development.

## CONCLUSION

Pro-health changes under the influence of the intervention applied in the programme "Keep Balance" have taken place in a relatively large number of pupils/students included in the programme. The results are a promising perspective in the aspect of public health

and the struggle against obesity in children and adolescents. The programme deserves to be continued after minor adjustments.

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ORIGINAL ARTICLE

# EFFECT OF DIETARY COMPONENTS AND NUTRITIONAL STATUS ON THE DEVELOPMENT OF PRE-SCHOOL CHILDREN

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## ABSTRACT

**Background.** The preschool period is a time of intensive changes: physical, motoric, cognitive, emotional and social development of the child. The diet should provide optimal energy andnutrient levels. Due to their properties, some of the dietary components may be particularly important in child development procesess. These include *omega*-3 fatty acids, B vitamins, vitamin D, antioxidants, iron, calcium, magnesium, zinc and copper.

**Objective.** The aim of the study was to determine the effect of selected dietary components, the nutritional status and sleep duration in children at pre-school ages (3-6-years old) on their emotional sphere, as well as the cognitive, physical and social development.

**Material and methods.** Anonymous research was carried out among 75 randomly selected children aged 3-6 years old in the Municipal Kindergarten in Ruciane-Nida. Research methods consited of a questionnaire, a 3-day food record, growth charts, and standardized development observation sheets. Software used for evaluation and analysis of obtained results was Diet 5.0. and Statistica 13.

**Results.** It was observed that the increase of the BMI percentile correlated with a lesser social development of children. Children who slept a recommended number of hours presented higher level of cognitive developmnent. High level of cognitive development was more common in children supplementing vitamin D. Higher intake of folates, vitamin D, vitamin E, magnesium, zinc and copper correlated positively with a higher level of cognitive development.

**Conclusions.** Application of the proper nutrition and healthy lifestyle principles supports a proper child development. All dietary components should be balanced, however some nutrients are of especial significance during the childhood development and therefore their optimal intake is essential for this developmental period.

**Key words:** *preschool children; child development; vitamins; minerals; nutritional status;*

## STRESZCZENIE

**Wprowadzenie.** Okres przedszkolny to czas intensywnego rozwoju: fizycznego, motorycznego, poznawczego, emocjonalnego i społecznego dziecka. Dieta powinna mieć optymalną wartość energetyczną i odżywczą. Właściwości niektórych składników diety wskazują, że mogą być one szczególnie istotne w procesach rozwojowych dziecka. Należą do nich: kwasy tłuszczowe *omega*-3, witaminy z grupy B, witamina D, antyoksydanty, żelazo, wapń, magnez, cynk i miedź.

**Cel badań.** Celem badań było ustalenie wpływu wybranych składników diety, stanu odżywienia oraz długości snu dzieci w wieku przedszkolnym (3-6-letnich) na ich poziom rozwoju poznawczego, fizycznego, a także sferę emocjonalną i rozwój społeczny.

**Materiał i metody.** Anonimowe badania przeprowadzono wśród wybranych losowo 75 dzieci w wieku 3-6 lat w Przedszkolu Miejskim w Rucianem-Nidzie. Narzędziami badawczymi, zastosowanymi w pracy były: autorski kwestionariusz ankiety, 3-dniowy dzienniczek żywieniowy, siatki centylowe oraz standaryzowane arkusze obserwacji rozwoju dzieci. Do oceny i analizy uzyskanych wyników użyto programów komputerowych: Dieta 5.0. i Statistica 13.

**Wyniki.** Stwierdzono, że wzrost centyla wskaźnika BMI korelował z gorszym rozwojem społecznym dzieci. Zalecany czas snu dla dzieci w tym wieku był skorelowany z wyższym poziomem ich rozwoju poznawczego. Wysoki poziom rozwoju kognitywnego występował częściej u dzieci suplementujących witaminę D. Zaobserwowano dodatnie korelacje pomiędzy większym spożyciem folianów, witaminy D, witaminy E, magnezu, cynku i miedzi a wyższym poziomem rozwoju poznawczego.

**Wnioski.** Stosowanie zasad prawidłowego żywienia i zdrowego stylu życia wspomaga odpowiedni rozwój dziecka. Dieta powinna być odpowiednio zbilansowana pod względem wszystkich składników diety, ale niektóre z nich wykazują szczególny wpływ na prawidłowy przebieg procesów rozwojowych w dzieciństwie i ich optymalna podaż jest bardzo istotna w tym okresie rozwojowym.

**Słowa kluczowe:** *dzieci w wieku przedszkolnym; rozwój dziecka; witaminy; składniki mineralne; stan odżywienia;*

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## INTRODUCTION

The pre-school period is characterized by intensive growth and development of a humanbody. Child development is healthy if it occurs correctly and is age-adequate in all spheres: physical, motor, emotional, cognitive and social. Any disfunctions in one of the spheres may adversely affect the others [34].

Diet and lifestyle affect the development processes. These factors also shape current behavior and future habits of a person and affect their health status not only in childhood, but also in adulthood. A child's diet should be based on healthy nutrition principles and adapted to their age-adequate energy and nutrient requirements. Home (25% of total daily requirement) and kindergarten (75% of total daily requirement) nutrition should complement each other and together, form a balanced daily food ration. The development process is also supported by non-nutritional factors, such as adequate physical activity, optimal sleep duration and avoidance of stress [6, 12, 37].

Due to their properties, some of the dietary components may be particularly important in child development procesess. *Omega*-3 fatty acids help ensure the proper functioning of neurons and neuronal membranes. Lipid mediators, which are *omega*-3 fatty acids derivatives, have anti-inflammatory and neuroprotective effects [1, 33]. B vitamins are involved in the metabolism of homocysteine, high concentrations of which may contribute to cognitive decline [1, 33]. Copper and antioxidant deficiencies may negatively affect brain function, while folic acid, vitamin $B_{12}$ and iron deficiencies may affect the learning outcomes of children of all ages [1, 33]. One of the consequences of insuficcient serum iron concentration is a reduced activity of brain enzymes, of which iron is one of the components [1]. Zinc deficiency may cause impairment of both cognitive and motor processes in children and increase the risk of hyperactivity or depression [1]. Vitamin D is associated with various neurobiological pathways and protects against neurodegeneration [33]. The active form of vitamin D is also responsible for proper bone mineralization, while calcium is the most important ingredient in the process of building bones and teeth. Magnesium has an effect on nerves and muscles functioning, and its deficiency leads to a decrease in bone mineral density [7].

The aim of the study was to determine the effect of selected dietary components, the nutritional status and sleep duration in children at pre-school ages (3-6-years old) on their emotional sphere, as well as the cognitive, physical and social development. The selection of dietary components for analysis was based on their role in development processes, according to scientific literature and the research conducted so far.

## MATERIAL AND METHODS

The research was carried out in the Municipal Kindergarten in Ruciane-Nida during October-December 2018. Out of 140 children, 75 (34 girls and 41 boys), aged 3-6 years old, were randomly selected. The study group consitsed of 29 three year olds, 12 four year olds, 20 five year olds and 14 six year olds.

Parents of the subjects were informed about the purpose and methodology of the study and gave written consent to carry it out. The research consisted of a questionnaire, a 3-day food record, anthropometric measurements, and child development assessement tools. The research was approved by the Bioethics Committee of the Medical University of Bialystok, approval No. R-I-002/240/2018.

A quantitative diet evaluation was carried out using a 24-hour food recall, which was collected from the entire study group (75 children) from 3 days – 2 week days and 1 weekend day. Parents recalled their children's meals eaten at home, which should typically constitute 25% of a child's total daily requirement, while the remaining 75% is covered by pre-school nutrition [6]. Information on this part of the food ration was obtained based on the menu implemented in the kindergarten, which was provided by the facility. The analysis of children's food ration was performed using the Diet 5.0 software, developed by the Food and Nutrition Institute in Warsaw. It takes into account losses of nutrients, vitamins and minerals arising from food processing and storage. The values of energy and selected dietary components were averaged and the level of norm implementation was assessed through comparison of nutrients supply with the values recommended in the "Nutrition standards for the Polish population" redacted by *Jarosz* [21]. Subjects were divided into two age groups (3-year-old children and 4-6-year-old children) according to the nutritional norms available. The group's energy requirement (EER) was established. It was assumed that protein should constitute 13% of total energy requirement fats - 35%, and digestible carbohydrates - 52%, and at the same time not less than 130g/day. The desired ratio of animal to plant protein is about 2:1. The calculated values of vitamins and minerals were compared with the Recommended Dietary Allowance (RDA) for calcium, magnesium, iron, zinc, copper, B vitamins, vitamin C, eicosapentaenoic and docosahexaenoic acids, and Adequate Intake (AI) for dietary fiber, vitamin E, vitamin D and iodine.

The proprietary questionnaire consisted ofquestions about vitamin and mineral supplementation among the subjects and their sleep duration.

Anthropometric measurements of subjects were taken, i.e. height and weight, using a scale with a stadiometer, and the Body Mass Index (BMI) was

calculated. The values obtained were comparedwith the reference values using the growth charts for children aged 3-18 years old, created based on the data from the "Olaf and Ola" projects, which were coordinated by the Children's Memorial Health Institute [9, 23, 24, 31].

The following percentile ranges for height and weight were used:

- <c3 – well below norm - developmental disorders
- c3-c10 – below norm - control and observation required
- c25-c75 – narrow norm (correct development - the most optimal range)
- c10-c90 – broad norm (proper development)
- c90-97 – above norm - control and observation required
- >c97 – well above norm - developmental disorders

The nutritional status of children was assessed based on curves on growth charts, marked as underweight, overweight and obesity cut-offs. They meet the standards adopted for adults, i.e. <18.5 kg/m$^2$ (underweight), 25.0-29.9 kg/m$^2$ (overweight), > 30 kg/m$^2$ (obesity). The area between the underweight and overweight cut-offs indicated the correct body weight. No specific reference points proposed by the World Health Organization (WHO) were adopted because, according to the authors of the growth charts, they are inadequate for the population of Polish preschool children and lead to over diagnosis of obesity [9, 23, 24, 31].

The development of the subjects was assessed using observation sheets for 3-, 4- and 5-year-olds and a of school readiness assessment for 6-year-olds. These assessment tools were developed by *Biela* and School and Pedagogical Publishers (WSiP), based on the core curriculum and further developed by kindergarten teachers [2, 3, 4, 5]. They assessed the adequacy of the skills of observed children to their age during a two-month observation (September and October). The assessment of physical development consisted of the analysis of skills in self-service activities, large and small motor skills. Child's emotional maturity was also checked by assessing their ability to experience and understand emotions, their independence and emotional resilience. Social development was verified based on the child's attitude towards peers and adults, as well as their compliance with the norms and principles in the kindergarten. Cognitive development level was assessed based on the skills and abilities in general knowledge, speech, memory, perceptiveness, visual-auditory coordination, readiness to speak a foreign language as well as mathematical skills and preparation for learning to read and write - depending on the child's age. The results were referred to the point scale prepared by the author of the sheets used, and converted into percentages.The level of child development (low, medium, high) was determined in the four studied areas [2, 3, 4, 5].

The results were statistically analyzed, using the Statistica 13 software, by StatSoft. The results are presented as means, standard deviations, minimum and maximum values and percentages. A *Chi*-square statistical test was used amongst nominal variables to check the relationship between the sleep duration, supplementation used and development level of children (low, medium, high). Spearman's rank correlation coefficient was also used to examine the correlation between the intake of selected dietary components (based on 24-hour fodd recall), nutritional status and the level of child development (presented as percentage). The results whose significance level was $p < 0.05$ were considered statistically significant.

## RESULTS

Table 1 presents the average age and basic anthropometric parameters of the study group by gender.

Height, weight and BMI values of all subjects (n = 75) were compared with reference values for boys and girls using growth charts. The height of 70.8% of the male subjects (n = 29) was normal in relation to age - 39% of them (n = 16) were within the narrow norm, and 31.8% (n = 13) – within the broad norm. On the other hand, 29.2% of boys (n = 12) exceeded the upper or lower limit of the norm, and growth disorders were noticed in 14.6% of male children (n = 6). The height of 61.7% of female subjects (n = 21) was normal - 38.2% (n = 13) in the narrow norm and 23.5% (n

Table 1. Characteristics of the studied group of 3-6-year-old children

| | Gender | n=75 | Mean ± SD | Range (min-max) |
|---|---|---|---|---|
| Age | Girls | 34 | 4.3±1.2 | 3-6 |
| Height [cm] | | | 106.2±10.2 | 82-124 |
| Body weight [kg] | | | 17.9±3.7 | 11-28 |
| BMI [kg/m$^2$] | | | 15.80±1.76 | 12.85-21.17 |
| Age | Boys | 41 | 4.2±1.2 | 3-6 |
| Height [cm] | | | 109.1±10.7 | 93-131 |
| Body weight [kg] | | | 19.8±5.4 | 11-36 |
| BMI [kg/m$^2$] | | | 16.35±2.20 | 11.45-24.59 |

= 8) - in the broad norm. The remaining percentage of the female subjects - 38.3% (n = 13) was outside the norm. In 14.8% of them (n = 5) the values of this anthropometric parameter exceeded the cut-offs, which meant that the deviations from the norm were so siginificantas to indicate the occurrence of growth disorders.

The weight of 73.2% of boys (n = 30) was age-adequate - 39% of boys (n = 16) were in the narrown norm range, and 34,2% (n=14) - in the broad norm. Deviations from the norms occurred in 26.8% of boys (n = 11), and 12.2% of them (n = 5) presented with abnormal body weight. The weight of 76.4% of girls (n = 26) was within the age-adequate norm - 52.9% (n = 18) in the narrow norm and 23.5% (n = 8) - in the broad norm. Body weight of 23.6% of female children (n = 8) exceeded the lower or upper limit of norm, with 11.8% of them (n = 4) presenting abnormal body weight. Figure 1 presents the weight-for-age and height-for-age growth charts (percentile) for girls and boys aged 3-18 years (Olaf and Ola), which were marked with the subjects' values of these parameters.

Normal BMI was found in 68.3% of boys (n = 28) and 73.5% of girls (n = 25). Overweight was found in 19.5% of boys (n = 8) and in 11.8% of girls (n = 4), obesity - in 7.3% of boys (n = 3) and 2.9% of girls (n = 1), and underweight in 4.9% of boys (n = 2) and 11.8% of girls (n = 4). Figure 2 presents body mass index-for-age growth charts (percentile) for girls and boys aged 3-18 years old (Olaf and Ola), which were marked with the subjects' BMI values.

The accurateness of the subjects'development (n = 75) was also assessed based on the skills they should have possessat the age of 3, 4, 5 and 6 years old in terms of physical, emotional, social and cognitive development. Figure 3 shows the percentage of children from each age group with low, medium and high degree of development.

An assessment of the energy and nutritional value of the daily food ration was performed. Table 2 presents the daily food ration of the subjects divided into two age groups- including both home and kindergarten nutrition. Energy requirement was met in accordance with the recommendations in both 3-year-old and 4-6-year-old children. The norm for protein was exceeded in all subjects, but more so in younger children. The animal to plant protein ratio was correct. The analysis shows that the study group had a dietary fat deficiency. The intake of available carbohydrates however, was appropriate. Dietary fiber intake in younger children was slightly above the norm, and in older children - it was adequate. Significant deficiencies of EPA and DHA as well as vitamin D were noticed in diets of all children.Vitamin E, calcium and iron deficienies also occurred in the whole study group. Iodine and folate intake were in line with requirements. In contrast, the remaining B

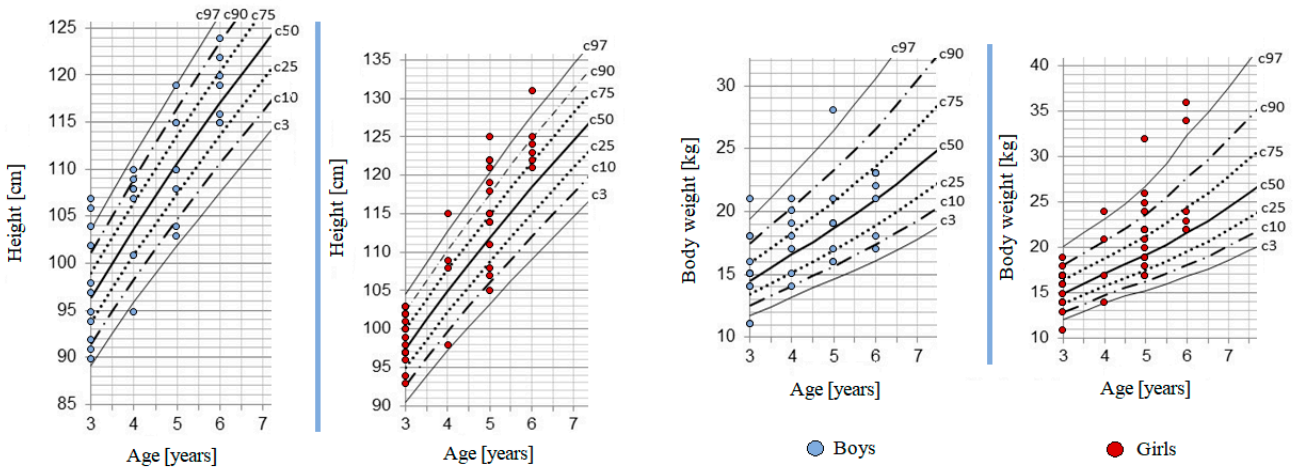



Figure 1. Percentiles of height and body weight of studied children

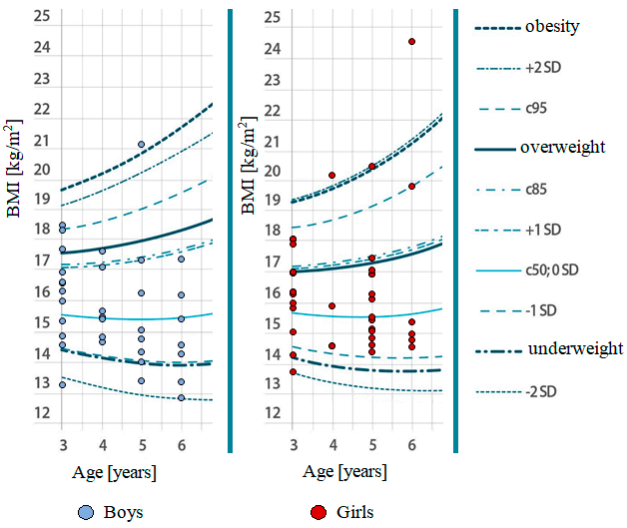
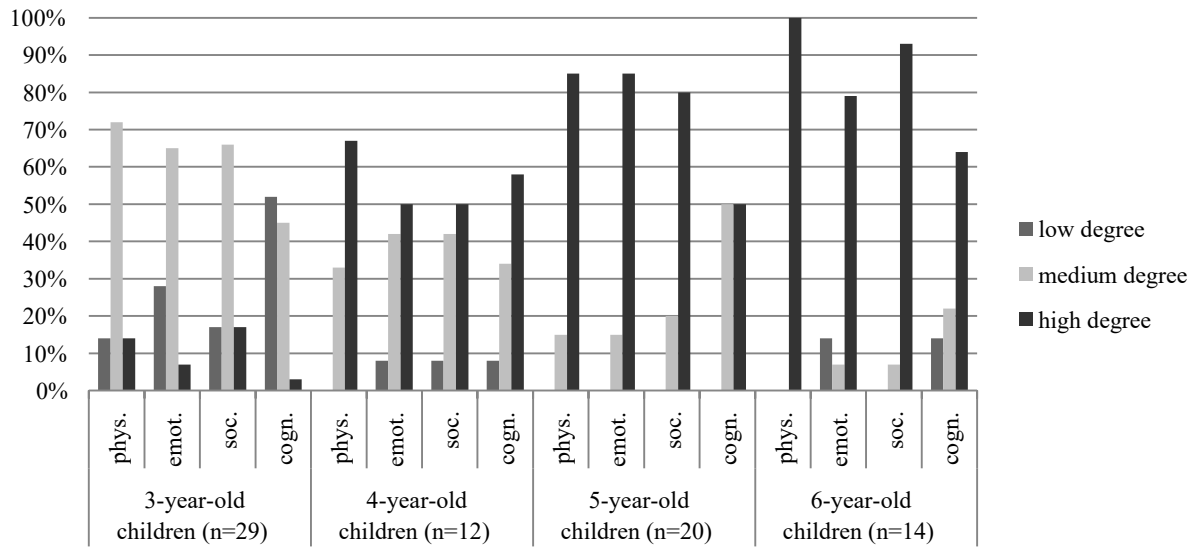



Figure 2. Nutritional status of studied children




phys. – physical development; emot. – emotional development
soc. – social development; cogn. – cognitive development

Figure 3. Degree of children development

Table 2. Daily food ration for 3-year-old and 4-6-year-old children

| | 3-year-old children (n=29) | | 4 - 6-year-old children (n=46) | |
|---|---|---|---|---|
| | Mean ± SD | % of standard* | Mean ± SD | % of standard* |
| Energy value of the diet [kcal] | 1170.33±183.99 | 102 | 1239.70±227.84 | 93 |
| Protein[g] | 49.56±8.80 | 132 | 52.67±10.82 | 121 |
| Animal protein [g] | 33.86±7.53 | 156 | 34.92±8.78 | 115 |
| Plant protein [g] | 15.71±3.05 | 158 | 17.75±4.47 | 116 |
| Fats [g] | 35.05±7.00 | 80 | 37.70±9.83 | 73 |
| EPA + DHA [mg] | 112.24±180.49 | 43 | 107.31±168.30 | 41 |
| Available carbohydrates [g] | 162.56±29.37 | 108 | 171.01±34.48 | 98 |
| Dietary fiber [g] | 13.05±2.29 | 112 | 13.55±2.91 | 100 |
| Vitamin E [mg] | 3.87±0.98 | 76 | 4.79±2.60 | 77 |
| Thiamine [mg] | 0.69±0.16 | 130 | 0.74±0.16 | 126 |
| Riboflavin [mg] | 1.39±0.25 | 257 | 1.42±0.26 | 242 |
| Niacin [mg] | 8.87±2.26 | 132 | 9.90±4.25 | 126 |
| Pyridoxine [mg] | 1.30±0.24 | 238 | 1.34±0.33 | 227 |
| Cobalamin [µg] | 3.57±0.82 | 346 | 3.66±0.98 | 314 |
| Vitamin C [mg] | 70.99±28.15 | 158 | 71.98±40.19 | 143 |
| Folate [µg] | 170.74±34.27 | 102 | 184.56±42.83 | 94 |
| Vitamin D [µg] | 1.58±1.34 | 10,5 | 1.15±0.69 | 8 |
| Calcium [mg] | 675.42±145.96 | 82 | 693.09±137.26 | 72 |
| Magnesium [mg] | 208.70±42.48 | 213 | 224.43±46.69 | 183 |
| Iron [mg] | 6.94±1.31 | 84 | 7.09±1.48 | 74 |
| Zinc [mg] | 6.14±1.19 | 163 | 6.38±1.13 | 138 |
| Copper [mg] | 0.88±0.20 | 260 | 0.92±0.21 | 235 |
| Iodine [µg] | 87.57±18.06 | 98 | 93.09±25.83 | 103 |

SD - standard deviation EPA - eicosapentaenoic acid DHA - docosahexaenoic acid
*Nutrition standards for the Polish Population, amendment 2017. Food and Nutrition Institute., Warsaw, Poland

vitamins, vitamin C, magnesium, zinc and copper were supplied in excess compared to the norms.

The next stage of the study was to determine the effect of dietary components taken into account in the quantitative assessment of children's food ration (Table 2) on the level of their cognitive, emotional and physical development. *Spearman's* rank correlation coefficient has been applied. Statistically significant correlations ($p < 0.05$) were observed only in children in the older age group, namely in 4-6 year olds (n = 46) and only in the case of cognitive development.

A positive correlation (r=0.42, p=0.004) was observed between the level of cognitive development and the vitamin D intake. A positive correlation (r=0.34, p=0.020) was also found between the level of cognitive development and folate intake. In addition, a positive correlation (r=0.36, p=0,014) was observed between the cognitive development level and vitamin E intake. A positive correlation (r=0.35, p=0.017) was observed between the cognitive development level and magnesium intake. A positive correlation (r=0.40, p=0.005) was found between the cognitive development level and zinc intake. A positive correlation (r = 0.31, p=0.034) was also observed between the cognitive development level and copper intake. An increased intake of the above-mentioned dietary components positively correlated with an increase in cognitive development in children aged 4-6. Correlations depict the intake of vitamins and mineral components in the diet, supplementation is not taken into account. Figure 4 presents scatter graphs of the above-mentioned correlations.

The influence of the body mass index (the BMI values were allocated to their corresponding percentiles) on the social development of the subjected children has been assessed. *Spearman's* rank correlation coefficient has been applied. A statistically insignificant (r=-0.17, p=0,148) negative correlation between the level of the social development (n=75) and the BMI was found. The increase of the BMI percentile was correlated to a lesser social development. Figure 5 presents the correlations graph.

Dietary supplements used by subjects were also assessed (n=75). Vitamin D supplements were used by 41.3% of respondents (n=31), *omega*-3 or fish oil - by 36% of respondents (n = 27), vitamin C – by 34.7% of

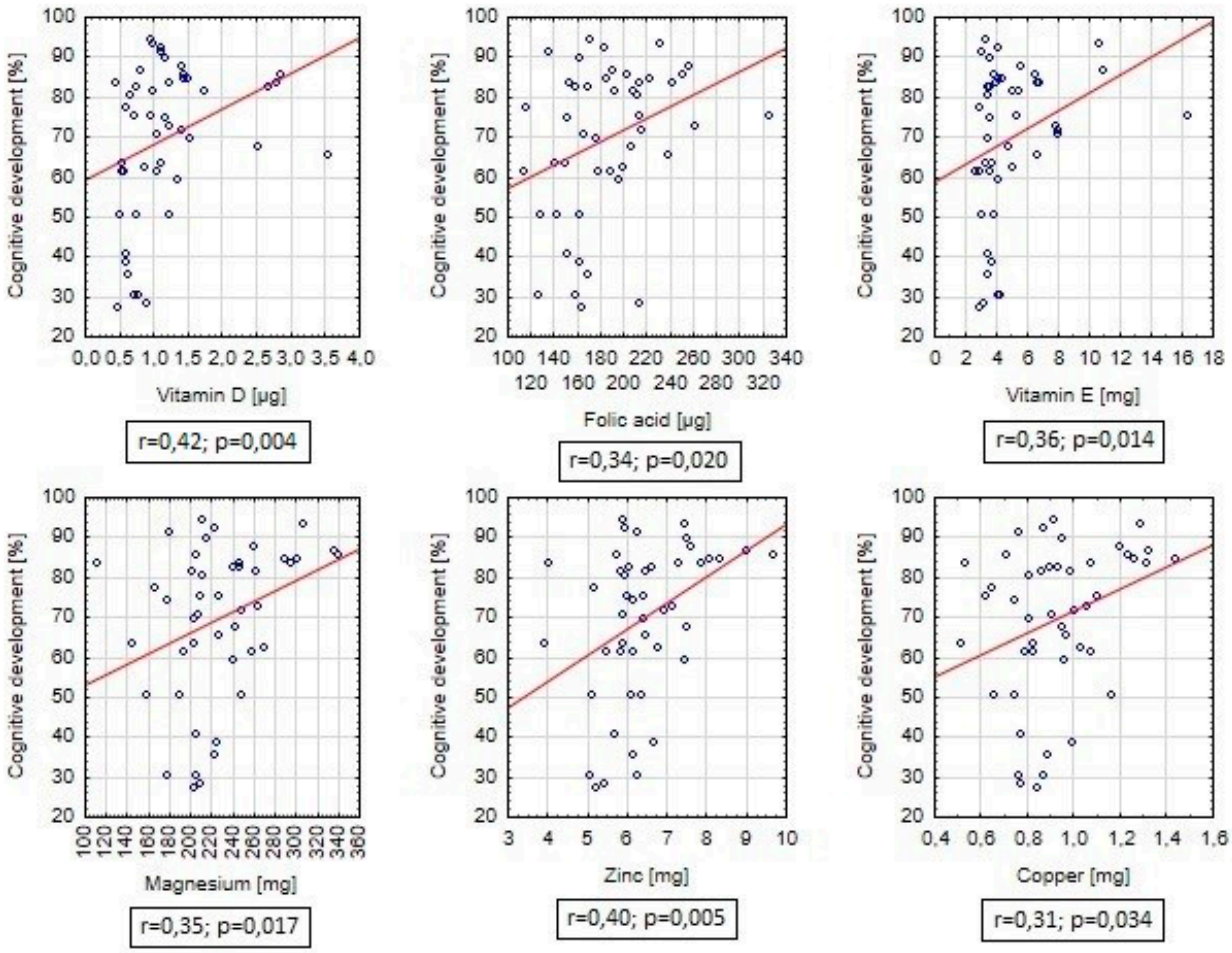



Figure 4. Correlations between the level of the cognitive development of children aged 4-6 and the intake of vitamins and minerals in the diet

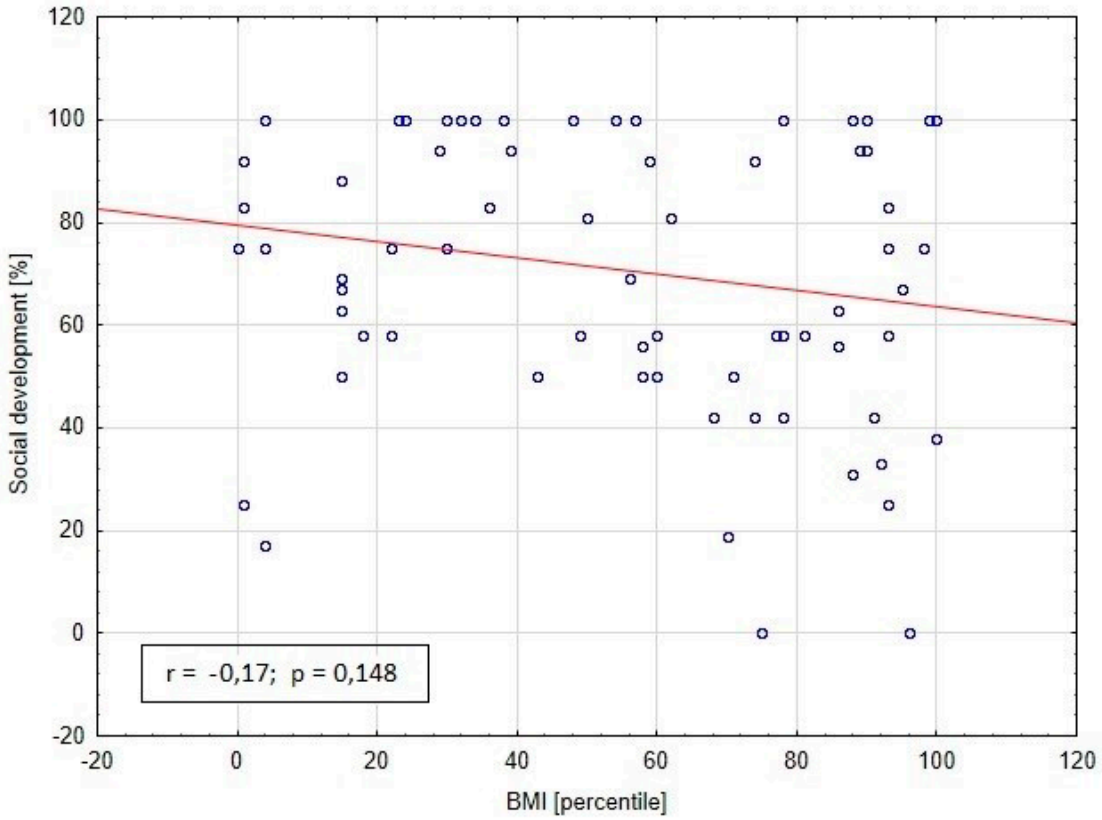



Figure 5. Correlation between children's social development and BMI percentile

respondents (n = 26). Whereas 16% of children (n=12) received vitamin and mineral supplements. Calcium, magnesium and B vitamins were supplemented by 5.3% of children (n=4) and iron preparations – by 4% (n=3) while 24% of respondents (n=18) did not use any supplements at all.

Among children who did not supplement vitamin D (n=44), the highest percentage was characterized by medium (47.7%, n=21) and low (27.3%, n = 12) cognitive development levels. In contrast, among children supplementing vitamin D (n=31), cognitive development level was high in 51.6% of them (n=16). These differences were close to statistical significance (p=0.05).

Parents also provided information regarding the sleep duration of their children (n=75). Sleep in 68% of them (n=51) lasted 9-10 hours. In contrast, 22.6% of children (n=17) slept 11-12 hours. The daily sleep duration of 6.7% of respondents (n=5) was 8 hours, and of 2.7% of children (n=2) - 6-7 hours.

Among children who slept 9-10 hours a day (n=51), the majority had a high (41.2%, n = 21) and medium (45.1%, n=23) level of cognitive development. However, among children whose sleep duration was too short (6-8 hours) or too long (11-12 hours) (total n=24), the 45.8% (n=11) had a low cognitive development level. These differences were statistical significance ($p<0.05$).

## DISCUSSION

During the first 4 years of life, a child's brain already reaches a mass only 200 grams smaller than that of the shaped adult brain. Because of this, during childhood special attention should be paid to intakes of all nutrients, minerals and vitamins essential for the proper structural and functional development of the brain [1].

The nutritional status of most of the subjects was normal. Underweight was observed in 5% of boys and 12% girls, overweight - in 20% of boys and 12% of girls, and obesity - in 7% and 3%, respectively. Therefore, the abnormal nutritional status occurred in a much smaller percentage of children. However, given the fact that these data relate persons in a developmental period, which in turn affects all subsequent stages of life, these findings are disconcerting. A statistically significant negative correlation was found between the social development level and the body mass index, while increased body mass index correlated positively with the development of children. In their research, Pratt et al. explored the relationship between the quality of life of children and adolescents aged 8-18 years old and a normal BMI or excessive body weight. One of the components assessed with a questionnaire was social development, which was lower in those with abnormal body mass index [29].

The present study assessed the intake of dietary components that play a significant role in child development. Siginificant deficiencies of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) have been reported in children's diets. However, 36% of children surveyed supplemented *omega*-3 or fish oil. In our own research, no effects of EPA and DHA acid intake on cognitive development were found. The results of other authors' research are contradictory. *Oyen* et al. [28] observed a relationship between the consumption of oilyfish, which are a good source of *omega*-3, and the level of cognitive development of preschool children. However, *Gispert* et al. [16] did not find such relationship in school-age children, but noticed a positive effect of fish consumption on their emotional and social development.

The quantitative analysis of daily food rations of the subjects showed that their folate intake was sufficient. A statistically significant positive correlation was found between the level of cognitive development of 4-6-year-old children and the intake of dietary folate. No other authors' studies, in which the subjects were children, were found. Therefore, further research in this area is necessary.

In own research, a substantial deficiency of vitamin D in daily food rations of the subjected children was observed. However, some of their parents declared supplementation. The insufficient intake of the vitamin in children of a similar age group was also observed by Marcinek et al. [27]. According to the latest recommendations from 2018, a supplementation of 600-1000 IU of vitamin D is reccomended for preschool children from September to May. The precise dose of supplemenation depends on weight and dietary intake of vitamin D, In the months from May to September, with sufficient sunlight, supplementation in this age group is not necessary, but is recommended [32]. However, only 41% of the subjects supplemented vitamin D. *Roszko-Kirpsza* et al. [30] assessed vitamin D supplementation among 2-3-year-old children. Supplemenents were usedby less than 35%. Our own research did not investigate the concentration of vitamin D metabolite in children's blood serum. However, taking into account the nutritional deficiencies in the study group and reduced skin synthesis during the time of research, i.e. in the autumn and winter, one can suppose that vitamin D levels would have been too low. In the research conducted by *Łupińska* et al., the level of dietary intake of this vitamin and the concentration of its metabolite in the blood serum of school-age children were analyzed. Subjects had both dietary and serum deficiencies. Only 8.5% of subjects had adequate vitamin D levels (≥ 30 ng / ml) [26, 32].

In this study, a statistically significant relationship was found between vitamin D supplementation in children and their cognitive development level. Among the subjects who did not supplement this vitamin, the highest percentages were characterized by medium and low levels of cognitive development, where as most children supplementing the vitamin had a high level of cognitive development. A statistically significant positive correlation was found between the level of cognitive development of 4-6-year-old children and dietary intake of vitamin D. Its increased intake positively correlated with an increase in cognitive development in children aged 4-6 years old. *Zhu* et al. observed the relationship between vitamin D concentration in umbilical cord blood of newborns and their subsequent neurocognitive development [39]. Other researchers have also noticed the relationship between vitamin D concentration in umbilical cord blood of newborns and speech development in early childhood [17].

Dietary intake of antioxidant vitamins was analyzed. No vitamin C deficiencies were observed. The recommended daily intake for this vitamin was exceeded in both younger and older children. However, the insufficient intake of the vitamin C in children of a similar age group was also observed by *Marcinek* et al. [27]. My own research has not confirmed an influence of the vitamin C intake on the cognitive development level. Liu et al. did not observe such a relationship either [25]. In own research, insufficient intake of vitamin E was noted. The requirement was met in 76-77%. The results of *Marcinek* et al. research have also indicate the existence of diet insufficiencies vitamin E in children aged 1-4 [27]. In own research, a statistically significant correlation was observed between the vitamin E intake in the older group of children and their cognitive development level, which increased with increased intake of said vitamin. *Liu* et al. [25] observed the effect of prenatal vitamin E exposure on the intelligence quotient of pre-school children.

Magnesium intake in the subjects' food rations exceeded the recommended daily amounts. A statistically significant positive correlation was found between the cognitive development level of 4-6-year-old children and dietary magnesium intake. Increased intake of said mineral correlated with a higher level of cognitive development. Results of studies by other authors showed that children with attention deficit hyperactivity disorder (ADHD) had significantly lower serum magnesium levels compared to healthy children [10]. *El Baza* et al. [11] assessed the effect of magnesium supplementation in magnesium-defficient children with ADHD. An improvement in cognitive function was observed in the group of children who used supplementation. In contrast, no such improvement was observed in the control group. However, the size of the study group was small.

Randomized, blinded studies have not demonstrated the effectiveness of supplementation in treating such disorders in children with ADHD [14].

In own research, iron deficiencies were noted in both younger and older children. No relationship was found between dietary iron intake of children and their cognitive processes. Fuglestad et al. observed though, that iron deficiency in adopted children correlated with their worse cognitive development [13].

Dietary zinc intake in the studied group exceeded the recommended values. It has been observed that its increase positively correlates with the level of cognitive development of 4-6-year-old children. *Fuglestad* et al. [13] found that zinc deficiency affected the neurodevelopmental functions of adopted children. It was correlated with impairment of their memory. *De Moura* et al. [8] conducted a research on zinc supplementation among preschool and early school-age children without identified deficiencies. Their results showed the impact of supplementation on improvement of long-term memory and logical thinking.

In own research, copper requirement was exceeded more than two-fold, in both 3-year-olds and 4-6-year-olds. A statistically significant positive correlation was found between the level of cognitive development of 4-6-year-old children and dietary copper intake. An increased intake of said mineral positively correlated with an increase in cognitive development. Adequate copper intake has a positive effect on cognitive functions, as copper is essential for normal brain function [1]. However, an excessive intake of this micronutrient can negatively affect cognitive processes and cause cognitive disorders. *Zhou* et al. [38] observed that excessive levels of copper in the blood serum have a negative effect on memory in school-age children.

The systematic review of research of *Guzek* et al. has indicated a correlation between a proper intake of fruit and vegatables by children at a pre-school and school age and a lower risk of behavioural and emotional problems or depression. Fruit and vegatables are a source of numerous vitamins and minerals, including those previously analysed in own research (folic acid, vitamin E, calcium, magnesium or copper) [20].

In the present study, the average sleep duration of the subjects was assessed. Sleep in 68% of them lasted 9-10 hours. In contrast, 22.6% of children slept for 11-12 hours. The daily sleep duration of 9.4% of respondents was 6-8 hours. A statistically significant correlation was shown between children's sleep duration and their cognitive development. Among children who slept 9-10 hours a day, most were characterized by a high and medium degree of cognitive development. However, majority of children whose sleep was shorter (6-8 hours) or longer (11-12 hours) had a low level of cognitive development. Based on the conducted research, *Kocevska* et al. found that not only insufficient, but also excessive sleep duration adversely affects children's cognitive functions. The effect of sleep duration of 2-year-old children on their cognitive development at the age of 6 was studied [22]. According to the results of other authors' studies conducted among children up to the age of two, short sleep duration correlated with worse cognitive development. In addition, they observed that night sleep had a greater impact on child development than day time sleep [35]. *Velten-Schurian* et al. [36] also noted the effect of sleep duration on the cognitive processes in children. Insufficient sleep was associated with inappropriate behavior and problems with concentration. *Gruber* et al. [19] confirmed the occurrence of more frequent concentration disorders among children with insufficient sleep duration. The results of other studies by this author also indicate a relationship between sleep duration and emotional stability [18]. *Giganti* et al. observed the positive effect of naps on conscious memory functions in pre-school children [15].

To date, little research has been done on effects of dietary components, supplementation and various lifestyle components on child development. Own research, and research conducted by other authors so far, indicate the existence of such relationship. Therefore, further research in this topic is necessary.

## CONCLUSIONS

1. The diet of the subjected children was not properly balanced. There was an insufficient intake of fats, EPA and DHA acids, vitamin D, vitamin E, calcium and iron. To meet the demand, the supply of the given ingredients should be higher.
2. It was found that an adequate intake of folates, vitamin D, vitamin E, magnesium, zinc and copper in the diet correlated with a higher level of cognitive development of 4-6-year-old children. The research emphasize how important it is to control the intake of the vitamins and minerals by children to ensure their proper development.
3. A positive influence of vitamin D supplementation on the cognitive development of the subject group was observed. Children who received supplements of the vitamin displayed a higher level of the cognitive development in comparison to those who did not. It is essential to promote the realization of the current recommendations for the supplementation of the vitamin D.
4. Excessive body weight correlated with a lower level of social development in pre-school children.
5. The influence of the daily sleep length on the cognitive development of the children subjected

to the study was observed. Both too short and too long sleep lengths were connected with a lower level of development.

6. Application of the proper nutrition and healthy lifestyle principles supports a proper child development. All dietary components should be balanced, however some nutrients are of especial significance during the childhood development and therefore their optimal intake is essential for this developmental period.

**Conflict of interests**

*The authors declare no conflict of interest.*

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ORIGINAL ARTICLE

# EMOTIONAL AND HABITUAL OVEREATING AND DIETARY RESTRICTIONS IN THE EATING HABITS OF GIRLS AND BOYS

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## ABSTRACT
**Background.** Eating habits are mainly shaped at the first stages of human life. Incorrect eating habits in young individuals may in the future lead to eating disorders and predispose to abnormal body weight.
**Objective.** The aim of the study was to investigate eating habits among adolescents and verify whether there are any differences in eating habits between girls and boys.
**Material and methods.** The study was conducted among 337 post-primary school students, including 126 girls and 211 boys. A standardised questionnaire "My eating habits" was used as a research tool.
**Results.** Secret snacking was slightly more common among girls (27.78%) than boys (24.17%). It was also girls who mostly admitted that other people comment on their diet, as indicated by 33.33% of girls and 18.96% of boys. Girls are also more likely to be dissatisfied with their body weight (41.27% vs. 27.49%) and to occasionally avoid eating despite feeling hungry (42.06% vs. 27.01%) compared to boys.
**Conclusions.** The eating habits of young people are mostly varied. There are differences in the dietary habits of girls and boys; girls are more likely than boys to overeat under the influence of emotions and to apply dietary restrictions to themselves. In order to promote healthy eating habits and support the mental well-being of young people, it is recommended to provide nutritional education and to implement psychological support for those in need.

**Key words:** *eating habits, eating disorders, dietary restrictions, adolescents*

## STRESZCZENIE
**Wprowadzenie.** Kształtowanie zwyczajów żywieniowych zachodzi głównie w pierwszych etapach życia człowieka. Nieprawidłowości odżywiania u osób młodych w przyszłości mogą prowadzić do zaburzeń odżywiania oraz predysponować do nieprawidłowej masy ciała.
**Cel badań.** Celem badania było poznanie zwyczajów żywieniowych młodzieży oraz stwierdzenie czy istnieją różnice pomiędzy zwyczajami żywieniowymi dziewcząt i chłopców
**Materiał i metody.** Badanie zostało przeprowadzone wśród 337 uczniów szkoły ponadpodstawowej, w tym wśród 126 dziewcząt oraz 211 chłopców. Narzędziem badawczym był standaryzowany kwestionariusz ankiety „Moje Zwyczaje Żywieniowe".
**Wyniki.** Nieznacznie większe skłonności do podjadania w tajemnicy przed innymi wykazują dziewczęta (27,78%), niż chłopcy (24,17%). To dziewczęta w przewadze przyznają, że inni ludzie komentują ich sposób odżywiania, na taką odpowiedź wskazało 33,33% dziewcząti 18,96% chłopców. Dziewczęta także częściej, niż chłopcy wykazują niezadowolenie ze swojej masy ciała (odpowiednio 41,27% i 27,49% z nich) oraz pomimo odczuwania głodu unikają czasami jedzenia (42,06% i 27,01%)
W**nioski.** Zwyczaje żywieniowe młodzieży są w większości zróżnicowane. Istnieją różnice w zwyczajach żywieniowych dziewcząt i chłopców; dziewczęta w porównaniu do chłopców wykazują większe skłonności do przejadania się pod wpływem emocji oraz do stosowania względem siebie restrykcji dietetycznych. W celu promowania prawidłowych zwyczajów żywieniowych oraz wspierania dobrej kondycji psychicznej młodzieży zaleca się prowadzenie edukacji żywieniowej oraz wdrożenie pomocy psychologicznej dla osób jej potrzebujących.

**Słowa kluczowe:** *zwyczaje żywieniowe, zaburzenia odżywiania, restrykcje dietetyczne. młodzież*

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## INTRODUCTION

Eating habits are mainly shaped at the first stages of human life [4]. We enter adulthood with an already developed system of eating habits. Therefore, monitoring and correction of poor eating habits among young individuals is needed as they may lead to future eating disorders and predispose to abnormal body weight [1].

Eating disorders are significantly more common in women than in men, and usually manifest in late adolescence or early adulthood. Fear of excess calories may lead to dietary restrictions, such as intentional limitation of food intake or skipping meals [13]. Common unawareness of eating disorders, such as for example anorexia and bulimia, may result in a failure to initiate appropriate treatment and, consequently, the development of chronic diseases [9, 21]. Eating disorders not necessarily lead to weight loss. Increased calorie intake due to eating disorders causes excess fat accumulation and, consequently, overweight and obesity [18]. This problem is currently seen in most European countries, posing one of major public health issues [24]. Excess body weight predisposes to multiple diet-related diseases, such as cardiovascular diseases, diabetes mellitus, and cancer. Therefore, maintenance of normal body mass index (BMI) is strongly recommended [11, 25]. Prevention of overweight and obesity is primarily based on education and promotion of healthy lifestyle. Educational programmes should inform about, among other thing, its consequences, whereas prevention should provide guidance on changes in eating habits and physical activity [2].

Eating disorders and increased body weight may also be of psychological aetiology. Emotional eating involves consuming meals depending on mental state. In this type of disorders, dietary restrictions involving reduced intake of dietary calories should be preceded by psychological therapy to support emotional stability [26].

Habitual overeating, emotional eating, and dietary restrictions are risk factors for eating disorders. The measurement of the above factors allows for the diagnosis of the problem among selected groups of society, followed by implementation of preventive and educational measures [16]. Preventing bad eating habits, promoting the Pyramid of Healthy Eating and physical activity may help introduce eating habits that support health and good mental wellbeing [3, 4, 20].

The aim of this study was to investigate eating habits among adolescents and verify whether there are any differences in eating habits between girls and boys.

## MATERIALS AND METHODS

The study was conducted in the first quarter of 2020 among 337 post-primary school students from the Silesia Province, including 126 girls and 211 boys. The study was approved by the school principal.

A standardised questionnaire "My Eating Habits" by *Ogińska-Bulik* and *Putyński* [16] was used as a research tool. The questionnaire includes 30 yes/no questions. The questions were classified into three categories related to emotional overeating, habitual overeating and dietary restrictions. Each "yes" answer was scored 1 (except for 5 appropriately marked questions). The total score was used to calculate the mean and standard deviation for each category for all respondents and separately for sex groups. The answers were collected and analysed using Microsoft Excel 2010 spreadsheet software. Statistica 13 software was used to calculate mean, standard deviation, and for statistical analysis. Correlations between sex and different eating habits were verified using the *Chi*-squared test. A p-value $<0.05$ was considered statistically significant for all analyses.

## RESULTS

Means and standard deviations for factors in the groups are shown in Table 1. The mean value of answers to questions on habitual overeating was similar for girls and boys, i.e. 3.72 and 3.75, respectively. There were differences in the mean values of answers to questions on emotional overeating and dietary restrictions (4.07 and 3.09; 3.84 and 3.04, respectively). The highest standard deviation for all respondents was reported for the group of questions on habitual overeating, whereas the lowest standard deviation was reported for the group of questions on dietary restrictions, i.e. 2.49 and 2.15, respectively.

Table 1. Mean values of answers to questions on habitual overeating, emotional overeating and dietary restrictions for girls and boys

| Factor | Total | | Girls | | Boys | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Habitual overeating | 3.74 | 2.49 | 3.72 | 3.74 | 3.75 | 2.40 |
| Emotional overeating | 3.46 | 2.23 | 4.07 | 2.23 | 3.09 | 2.15 |
| Dietary restrictions | 3.34 | 2.15 | 3.84 | 2.16 | 3.04 | 2.08 |

The study showed that 24.60% of girls and 24.64% of boys attach too much importance to food, with 59.52% and 64.93% of them, respectively, considering

food to be an important part of their lives. However, uninhibited eating is more common among boys than girls, with such tendencies reported by 40.28% and 30.16% of them, respectively. Girls, on the other hand, are slightly more prone to snacking in secret than boys (27.78% vs. 24.17%). A total of 27.16% of respondents, including 30.16% of girls and 26.07% of boys, admitted to eating despite satiety; 75.88% of respondents (77.77% of girls and 65.40% of boys) rarely overeat (Table 2).

In the part of the questionnaire on emotional overeating, the responses of the two groups differed (Table 3). Overeating anxiety was significantly more common in girls than boys (41.27% vs. 16.11%). The urge to dispose of unnecessary calories after having a large meal was also more common among girls (50%) than boys (37.44%). Half (50%) of students, including 65.87% of girls and 41.23% of boys, would like to weigh less than they do. Only 19.29% of students, including 22.22% of girls and 17.54% of boys, admitted that they start eating meals when they get upset, and 64.69% of all students, including 59.52% of girls and 67.77% of boys, reported eating as a way to improve mood.

The part of the questionnaire on dietary restrictions (Table 4) also revealed some differences. A total of 46.83% of girls and 64.45% of boys are rarely concerned about their body weight, and dissatisfaction with one's figure was reported by 67.46% and 40.28% of them, respectively. Girls are also more likely than boys to show dissatisfaction with their body weight (41.27% and 27.49%, respectively) and sometimes avoid meals despite feeling hungry (42.06% and

Table 2. Answers to questions on habitual overeating for girls and boys

| Answers to questions | Habitual overeating | | | | | |
|---|---|---|---|---|---|---|
| | Total | | Girls | | Boys | |
| | n=337 | % | n=126 | % | n=211 | % |
| I often think about eating | 203 | 60.24 | 73 | 57.94 | 130 | 61.61 |
| Eating is an important part of my life | 212 | 62.91 | 75 | 59.52 | 137 | 64.93 |
| Sometimes I snack in secret from others | 86 | 25.52 | 35 | 27.78 | 51 | 24.17 |
| I eat often, even when I feel full | 93 | 27.16 | 38 | 30.16 | 55 | 26.07 |
| I rarely overeat *) | 115 | 34.12 | 42 | 33.33 | 73 | 34.60 |
| I eat often, although I am not hungry | 132 | 39.17 | 55 | 43.65 | 77 | 36.49 |
| Sometimes I eat uninhibited | 123 | 36.50 | 38 | 30.16 | 85 | 40.28 |
| I rarely feel overeaten *) | 131 | 38.87 | 54 | 42.86 | 77 | 36.49 |
| Food is too important to me | 83 | 24.63 | 31 | 24.60 | 52 | 24.64 |
| My stomach is like a bottomless sack | 82 | 24.63 | 28 | 22.22 | 55 | 26.07 |

*) The question is scored for "NO" answer

Table 3. Answers to questions on emotional overeating for girls and boys

| Answers to questions | Emotional overeating | | | | | | |
|---|---|---|---|---|---|---|---|
| | Total | | Girls | | Boys | | p-value |
| | n=337 | % | n=126 | % | n=211 | % | |
| I often feel anxious when I eat too much | 86 | 25.52 | 52 | 41.27 | 34 | 16.11 | 0.00 |
| Other people comment on my diet | 82 | 24.33 | 42 | 33.33 | 40 | 18.96 | 0.00 |
| I eat more than normal when I am anxious or upset | 68 | 20.18 | 31 | 24.60 | 37 | 17.54 | >0.05 |
| Sometimes when I start to eat, I feel that I won't be able to tell myself "enough" | 69 | 20.47 | 27 | 21.43 | 42 | 19.91 | >0.05 |
| I would prefer to weigh less than I do now | 170 | 50.45 | 83 | 65.87 | 87 | 41.23 | 0.00 |
| My diet generally depends on my mood | 162 | 48.07 | 72 | 57.14 | 90 | 42.65 | 0.01 |
| In the company, I eat medium but „allow" myself more when I am alone | 104 | 30.86 | 40 | 31.75 | 64 | 30.33 | >0.05 |
| When I get angry, I start eating | 65 | 19.29 | 28 | 22.22 | 37 | 17.54 | >0.05 |
| I would like to get rid of unnecessary calories after having a large meal | 142 | 42.14 | 63 | 50.00 | 79 | 37.44 | 0.02 |
| Food puts me in a good mood | 218 | 64.69 | 75 | 59.52 | 143 | 67.77 | >0.05 |

Table 4. Answers to questions on dietary restrictions for girls and boys

| Answers to questions | Dietary restrictions | | | | | | p-value |
|---|---|---|---|---|---|---|---|
| | Total | | Girls | | Boys | | |
| | n=337 | % | n=126 | % | n=211 | % | |
| I rarely follow diets *) | 86 | 25.52 | 27 | 21.43 | 59 | 27.96 | >0,05 |
| I read and collect diets from magazines and books | 41 | 12.17 | 16 | 12.70 | 25 | 11.85 | >0.05 |
| I rarely worry about my weight *) | 142 | 42.14 | 67 | 53.17 | 75 | 35.55 | 0.00 |
| I am not satisfied with my figure | 170 | 50.45 | 85 | 67.46 | 85 | 40.28 | 0.00 |
| Sometimes I avoid eating, even when I'm hungry | 110 | 32.64 | 53 | 42.06 | 57 | 27.01 | 0.00 |
| I put too much weight on my body weight | 110 | 32.64 | 52 | 41.27 | 58 | 27.49 | 0.01 |
| I rarely feel guilty after overeating * | 190 | 56.38 | 73 | 57.94 | 117 | 55.45 | >0.05 |
| I like to feel empty in my stomach | 51 | 15.13 | 24 | 19.05 | 27 | 12.80 | >0.05 |
| I often follow diets | 64 | 18.99 | 20 | 15.87 | 44 | 20.85 | >0.05 |
| I consciously limit my food consumption | 161 | 47.77 | 67 | 53.17 | 94 | 44.55 | >0.05 |

*) The question is scored for "NO" answer

27.01%). A total of 18.99% of all respondents, including 15.87% of girls and 20.85% of boys, often use diets; 15.13% (19.05% and 12.80%, respectively) of respondents like the empty stomach feeling; and 45.62% (42.06% and 44.55%, respectively) rarely feel guilty after overeating.

## DISCUSSION

The study showed that habitual overeating behaviours dominated in the group of students (M = 3.74), whereas dietary restrictions were less common (M = 3.34). Similar findings were presented by *Kobos* et al. [8] with behaviours associated with habitual overeating and dietary restrictions declared by M = 3.66 and M = 3.59 secondary school students. As reported by the authors, emotional overeating was more common compared to our study (M = 4.84 and M = 3.46, respectively). Different results compared to our study were obtained by *Ogińska-Bulik* and *Putyński* [16] with dominant emotional overeating (M = 4.67), and less common habitual overeating (M = 2.94).

Analysis of our findings showed that 60.24% of students participating in the study often think about food. Similar results were obtained by *Porwolik* et al. [22] who assessed the impact of the place of birth and upbringing on eating habits among 267 students of Medical Faculty of Wroclaw Medical University. The authors showed that 66.3% of students often think about food. They also showed that 20.8% of respondents practised secret snacking. This is comparable to our findings (25.52%). Our respondents were also asked about the importance of food in their life, with 24.63% of them admitting that they attach too much importance to food.

Different findings were presented by *Sekuła* et al. [23] with 56.8% of respondents reporting that they attach too much importance to food. These differences may have resulted from the choice of sample as the study enrolled individuals with obesity, as well as from the type of questionnaire used by the authors. The study showed that 39.17% of students eat despite not being hungry. A significant difference was found in the frequency of affirmative answers provided by girls and boys (43.65% vs. 36.49%). Similar results were obtained by *Porwolik* et al. [22] with such answer provided by 37.6% of students.

A total of 24.63% of respondents agreed with the statement "my stomach is like a bottomless pit". Different findings were presented by *Sekuła* et al. [23], with the above mentioned statement confirmed by 62.2% of respondents. It should be noted, however, that this question was addressed to obese patients in the cited article, which could have influenced the obtained results. No reduction in ghrelin levels occurs after food intake in obese individuals, which results in persistent hunger [6].

Our study showed that 62.91% of students considered eating to be an important part of life. A higher percentage was reported by *Sekuła* et al. [23], with 70.3% of respondents indicating this answer, whereas *Porwolik* et al. [ 22] showed that 35.3% of respondents attach too much importance to food. On the other hand, 27.16% of students agreed with the statement "I eat often, even when I already feel full". Similar findings were presented by *Porwolik* et al. [22], while different results were obtained by *Sekuła* et al. [23]

In the present study, the students were also asked questions on the frequency of overeating and the resulting feeling of guilt. Our study showed that 34.12%

of respondents often overeat, and 56.38% of them feel guilty about it. Furthermore, 61.13% of respondents claimed that they rarely feel extremely full. Similar results were obtained by *Porwolik* et al. [22], who showed that 30.6% of students admitted that they often overeat, and 69.4% reported that they rarely feel extremely full. More affirmative answers in relation to overeating were obtained by *Sekuła* et al. [23] with 56.8% of respondents declaring frequent overeating, and 51.4% of respondents feeling guilty about it. Both overeating and dietary restrictions are influenced by different emotions. Many studies have shown that increased appetite, which leads to an increased intake of food, is primarily caused by experiencing negative emotions [15, 17, 27].

The obtained results showed that 36.50% of students occasionally overeat. By contrast, *Sekuła* et al. showed that this fact was confirmed by 59.50% of respondents [23]. As demonstrated by other authors, situations such as social gatherings or activities involving attention, such as watching TV, cause loss of control over eating. As a result, there is a reduction in self-awareness, when the person pays no attention to the quality or quantity of food consumed [15].

In our study, 24.33% of students reported that others comment on their diet. This was also confirmed by 54.1% of respondents in the study by *Sekuła* et al. [23]. Everyone has an influence on how they look, but is at the same time subject to pressure and comparisons with common body standards. Overweight and obesity are often viewed negatively by society [10].

The statement "when I feel anxious or upset, I eat more than I normally do" was confirmed by 20.18% of students. Additionally, 19.29% of students admitted that they start to eat after getting upset. Both of these phenomena were more common in the study by *Porwolik* et al., with 36.4% and 31.2% of students confirming such statements [22]. *Sekuła* et al. showed in their study that 56.8% of respondents eat more than they normally do when feeling anxious, and that they start eating after getting upset [23]. Psychological stress is one of the factors that contribute to obesity and overweight. Furthermore, confusing emotions with feeling hungry often leads to higher food intake [7].

It is disturbing that 50.45% of study participants declared dissatisfaction with their body and would like to weigh less than they do. Similar findings were obtained by *Porwolik* et al. [22], who showed that 53.8% of students would also like to weigh less than they do, whereas up to 74% of respondents confirmed this fact in a study by *Kobos* et al. [8]. Criticism of one's own figure was more common among girls than boys (67.46% vs. 40.28%). Dissatisfaction with one's body among girls may be due to the image created by the media, with a slim woman considered to be a canon of beauty. *Materna* et al. [12], who assessed the awareness of middle school girls about bulimia and anorexia, showed that 48% of them wished they had a figure of a fashion model and that 75% of them do not tolerate their own body.

In our study, 48.07% of students declared that their eating habits generally depended on their mood and, additionally, 64.69% of them confirmed that eating improves their mood. Different findings were presented by *Sekuła* et al. [23], with 70.3% of respondents admitting that their eating habits depend on their mood, and 67.6% of them declaring that eating improves their mood [23]. However, this question was addressed to patients with morbid obesity in the cited study. Individuals suffering from this condition often have a tendency to over-experience emotions, which, in addition to a tendency to impulsive behaviour, can have a significant impact on eating habits depending on mood [19].

The statement "I eat moderately in the company of others, but I allow myself for more when alone" was confirmed by 30.86% of our respondents. Such declaration was made by 21.41% of respondents in the study by *Porwolik* et al. [22] and 59.5% in the study by *Sekuła* et al. [23]

Our study showed that 32.64% of students avoid food despite feeling hungry and 47.77% of respondents deliberately use dietary restrictions. A higher percentage of affirmative answers (59.5%) regarding limited food intake despite hunger and a similar percentage (43.2%) for the question on intentional dietary restrictions were reported by *Sekuła* et al. [23].

N*iewierska* et al. [14], who conducted their study among secondary-school students, reported that 26% of girls and 12% of boys declared the use of slimming diets. These results differ from our findings, according to which boys were more likely to use diets (20.85% vs. 15.87%). Alarming data were also presented by *Jodkowska* [5], who assessed the use of slimming diets among boys and girls aged 11-15 years. The author showed that up to 35.8% of girls and 14.3% of boys used slimming diets. In the context of dieting among girls, these results are twice higher compared to our study. It should be noted, however, that our questionnaire did not specify the type of diet used, which may have contributed to these differences.

Incorrect eating habits are one of the causes of diet-related diseases [8, 9]. Similarly to other authors, our findings point to issues that need to be considered when shaping correct eating habits.

## CONCLUSIONS

Eating habits of adolescents are mostly varied.

There are some differences in eating habits between boys and girls, with the latter more prone to emotional overeating and more likely to use dietary restrictions.

Nutritional education and, if needed, psychological help are recommended to promote healthy eating habits and support good mental health in adolescents.

**Conflict of interest**
*None declared.*

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ORIGINAL ARTICLE

# EFFECT OF EATING HABITS, BMI VALUE, PHYSICAL ACTIVITY AND SMOKING CIGARETTES ON BLOOD LIPID INDICES OF ADOLESCENT BOYS FROM POLAND

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## ABSTRACT

**Background.** The lifestyle of young boys has impact on the risks of cardiovascular diseases.

**Objective.** The aim of the study was to evaluate the effect of atherosclerosis risk factors determined by overweight and obesity and lifestyle, i.e.: eating habits, low physical activity and smoking cigarettes, on blood lipid profile of boys at the age of 16 to 18.

**Material and Methods.** The study covered 369 boys from secondary schools. They were evaluated for the supply of dietary constituents with atherogenic and protective actions, for nutritional status acc. to *Cole's* criteria, the level of physical activity, and smoking cigarettes. Lipid metabolism was determined based on criteria recommended by the American National Cholesterol Education Program (NCEP). Logistic regression analysis was conducted and risk odds ratio [OR] was determined.

**Results.** Analyses showed the boys to be characterized by overweight (10.8%) and obesity (2.7%), and by inappropriate concentration of total cholesterol (26.5%), LDL (13.3%), HDL (21.7%) and triglycerides (41.7%). High BMI turned out to be a significant risk factor of an elevated total cholesterol concentration: [aOR]=2.27; triglycerides: [aOR]=2.35 and LDL: [aOR]=2.41. Low physical activity was found to negatively affect the concentration of LDL: [aOR]=1.88. The boys smoking cigarettes were shown to have a reduced HDL: [aOR]=1.65. The total content of fat and saturated fatty acids in diet exerted a significantly negative impact on blood lipid profile of the boys.

**Conclusions.** The lifestyle of the young boys was demonstrated to determine the risk of cardiovascular diseases. Overweight and obesity, abdominal obesity in particular, were found to be a significant risk factor of disorders in their lipid metabolism.

**Key words:** *boys, eating habits, BMI, risk factors, blood lipid indices*

## STRESZCZENIE

**Wprowadzenie.** Styl życia młodych chłopców ma wpływ na ryzyko chorób sercowo-naczyniowych.

**Cel.** Celem pracy była ocena wpływu czynników ryzyka miażdżycy zależnych od nadwagi i otyłości oraz stylu życia, tj.: nawyków żywieniowych, niskiej aktywności fizycznej i palenia papierosów, na profil lipidowy krwi u chłopców w wieku od 16 do 18 lat.

**Materiał i metody.** Badaniem objęto 369 chłopców ze szkół średnich. Zostali oni ocenieni pod kątem podaży składników diety o działaniu aterogennym i ochronnym, pod kątem stanu odżywienia według kryteriów *Cole'a*, poziomu aktywności fizycznej i palenia papierosów. Metabolizm lipidów określono na podstawie kryteriów zalecanych przez kryteria zalecane przez National Cholesterol Education Program (NCEP). Przeprowadzono analizę regresji logistycznej i określono iloraz ryzyka [OR].

**Wyniki.** Analizy wykazały, że chłopcy charakteryzują się nadwagą (10,8%) i otyłością (2,7%) oraz niewłaściwym stężeniem cholesterolu całkowitego (26,5%), LDL (13,3%), HDL (21,7%) i triglicerydów (41,7%)). Wysokie BMI okazało się istotnym czynnikiem ryzyka podwyższonego stężenia cholesterolu całkowitego: [aOR] = 2,27; triglicerydów: [aOR] = 2,35 i LDL: [aOR] = 2,41. Stwierdzono, że niska aktywność fizyczna negatywnie wpływa na stężenie LDL: [aOR] = 1,88. Wykazano, że chłopcy palący papierosy mają obniżoną HDL: [aOR] = 1,65. Całkowita zawartość tłuszczu i nasyconych kwasów tłuszczowych w diecie wywarła znacząco negatywny wpływ na profil lipidowy krwi chłopców.

**Wnioski.** Wykazano, że styl życia młodych chłopców determinuje ryzyko chorób sercowo-naczyniowych. Stwierdzono, że nadwaga i otyłość, w szczególności otyłość brzuszna, stanowią istotny czynnik ryzyka zaburzeń metabolizmu lipidów.

**Słowa kluczowe:** *chłopcy, nawyki żywieniowe, BMI, czynniki ryzyka, wskaźniki lipidów we krwi*

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## INTRODUCTION

The atherosclerotic process begins already in the childhood or in the early adolescence and is proceeding with age [10, 16]. Results of pathophysiological and epidemiological investigations show explicitly that early dysfunctions of arterial vessels endothelium and arterial hypertension commence much earlier [6, 35]. A number of cross-sectional cohort studies [7, 45], have enabled determining risk factors of atherosclerosis in the adolescents. Results of multiple earlier investigations conducted in the XXth and XXIst century, among others: research by *Lutsey* et al. [26], *Li* et al. cross-sectional studies [23], research by *Kouki* et al. [22], and that by *Hu* et al. [17,18], have pointed to dependencies between lifestyle and anthropometric and biochemical indices as well as development of cardiovascular diseases (CVD). The composition of food products affects lipid metabolism of a body to a various extent, it may both enhance and inhibit atherogenic processes [39, 46]. The health-promoting effect of fruits and vegetables has also been thoroughly documented [14, 34, 36].

The objective of the study was to evaluate the effect of atherosclerosis risk factors determined by lifestyle, i.e.: eating habits, overweight and obesity, low physical activity and smoking cigarettes, on blood lipid profile of boys at the age of 16 to 18 years from the area of Poland.

## MATERIAL AND METHODS

The study was conducted from 2008 to 2018 in a randomly selected group of 369 boys at the age of 16-18 years attending secondary schools in Poland (the city of Wrocław). Numbers of boys in particular age groups were as follows: 103 boys at the age of 16 (27.9% of total group), 104 boys at the age of 17 (28.2%), and 162 boys at the age of 18 (43.9%).

*Ethical aspects*

Parents, guardians or students who were of age, provided written informed consent to the study. In a statement provided guarantees covering confidentiality. The study was approved by the Research Ethics Committee of the Medical University in Wrocław, which is affiliated with the Council for National Research Ethics in Poland.

*Nutritional survey*

Eating habits of the boys were evaluated by means of a triple direct nutritional interview conducted 24 hours before examination. The nutritional value of daily food rations of the boys was determined with the use of "Dietetyk" software [33]. Results of eating habits assessments were compared with dietary allowances and recommendations [3, 20, 47].

*Nutritional status*

Values of Body Mass Index - BMI (body mass/ body height$^2$) were computed based on measurements of body mass [kg] and body height [m] of the boys. Distributional cutoff values, such as the 85$^{th}$ or 95$^{th}$ percentiles of reference data, have been used most often. More recently, gender- and age- specific cutoff values that are tied to the adult overweight (25 kg/m$^2$) and obesity (30 kg/m$^2$) thresholds were developed. In these studies the BMI values obtained were evaluated using standards elaborated by *Cole* et al. [5].

The BMI values indicating overweight and obesity of the boys reached, respectively: 23.90 and 28.88 mg/kg$^2$ - for the 16-year-olds; 24.46 and 29.41 mg/kg$^2$ - for the 17-year-olds; and 25.00 and 30.00 mg/kg$^2$ - for the 18-year-olds. The evaluation of waist circumference values was conducted according to criteria postulated by *Katzmarzyk* et al. [21]. Threshold values above which an increase is observed in the risk of the incidence of metabolic disorders and arterial hypertension reached: 79.0 cm - for the boys at the age of 16, 79.8 cm - for those at the age of 17 and 80.4 cm for those at the age of 18.

*Blood lipid profile*

Blood biochemical indices determined in the study were evaluated based on guidelines of a Group of Experts of the American National Cholesterol Education Program (NCEP) [35]. The criteria of lipid metabolism assessment were as follows: concentration of total cholesterol - threshold 170-199 mg/dl, high ≥ 200 mg/dl; concentration of triglycerides - threshold 90-129 mg/dl, high ≥ 130 mg/dl; concentration of LDL-cholesterol - threshold 110-129 mg/dl, high ≥ 130 mg/dl; and concentration of HDL-cholesterol - threshold 45-35 mg/dl, low < 35 mg/dl.

*Risk factors*

Nutritional risk factors adopted in the study included:

- high energy value of diet >110 % of EAR (Estimated Average Requirement) (>3740 kcal)
- excessive intake of total fats >30 % of due energy
- excessive intake of SFA (Saturated Fatty Acids) ≥10% of due energy
- excessive intake of cholesterol >300 mg
- high contribution of energy derived from monosaccharides (saccharose) ≥10% of due energy
- low intake of PUFA (Polyunsaturated Fatty Acids) < 6% of due energy
- low intake of dietary fiber < 20 g
- small consumption of fruits and vegetables < 400 g

- overweight and obesity acc. to threshold values by *Cole's* [5]
- high values of waist circumference acc. to *Katzmarzyk* et al. [21]
- smoking cigarettes – irrespective of the number and frequency
- lack or low physical activity - exemption from classes of physical education and exercising only during school classes.

*Statistical analysis*

Results obtained were subjected to a statistical analysis with the use Statistica 10.0 software by StatSoft Inc. USA. Analysis of logistic regression was conducted and risk Odds ratio (OR) was determined. The level of statistical significance was stipulated at $p<0.05$.

## RESULTS

Table 1 presents data on selected elements of the nutritive value of an average food ration and mean indices of the nutritional status of the 16-18-year-old boys surveyed in the study (n=369). Figure 1 depicts the percentage of boys with nutritional risk factors and Figure 2 - those with incorrect blood lipid profile, high values of waist circumference as well as overweight and obesity. The energy value of an average food ration reached 3631.2 ±1171 kcal, which constituted 107.0% of the (EAR). Considerable individual differences were observed in energy intake, which was indicated by minimal and maximal energy values accounting for 972.1 and 7161.4 kcal, respectively. In 43.1% of the food rations, the EAR for energy intake was exceeded (Table 1, Figure 1).

The content of total fat in the food rations examined turned out to be high. The contribution of fat-derived energy in the total energy value of an average daily food ration reached 36.4 ±5.8%. The recommended level of 30% of energy derived from fats was exceeded in as many as 85.1% of the food rations. Inappropriate values were also recorded in the structure of fatty acids intake. Especially alarming appeared to a high contribution of SFA - 14.4 ± 3.4% of energy in respect of the recommended level of <10%. A high content of SFA was demonstrated in 90.2% of the food rations. In contrast, analyses showed a low contribution of energy derived from PUFA in an average food ration, i.e. 5.1% of energy, with extreme values reaching 2.0% and 16.1%. Deficiency of PUFA was observed in 75.3% of the food rations. In the food rations analyzed, the mean content of cholesterol (554.5 mg) exceeded the recommended dietary allowances to a considerable extent (184.8%). The intake of that component with diet was highly diversified and ranged from 51.6 to 1394.2 mg. Its excessive content (>300 mg/day) was demonstrated in 84.3% of the food rations. Dietary fiber content of an average food ration reached 28.9 ±10.6 g. It was consistent with the adopted recommended values of 20 - 40 g, yet the minimal content of this component in the food ration accounted for as little as 9 g, whereas the maximal one - for ca. 69 g. A low content of dietary fiber (<20 g/day) was demonstrated in 19.2% of the food rations. Mean intake of monosaccharides, determined based on the content of saccharose, reached 11.4 ± 5.1 g, and their excessive concentrations were observed in 59.6% of the food rations. The content of fruits and vegetables in an average food ration of the boys examined reached 653.7 g, which appeared to be correct in respect of

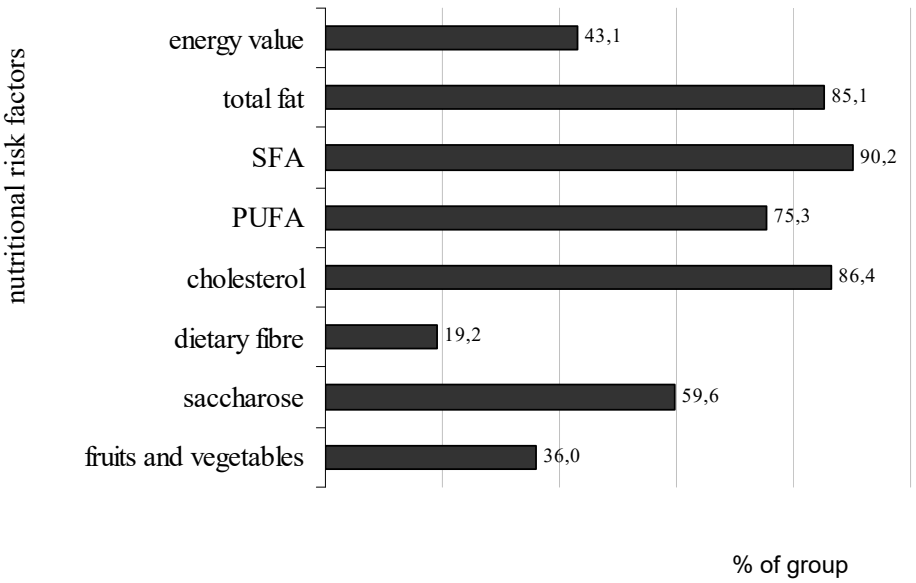


Figure 1. Nutritional risk factors in the boys examined (n=369)

Table 1. Selected components of an average daily food ration and mean indices of the nutritional status of the 16-18-year-old boys examined (n=369)

| Dietary components | Unit | Dietary allowances and recommendations | Mean | SD | Min. | Max. | % of dietary allowances and recommendations |
|---|---|---|---|---|---|---|---|
| *Diet assessment* | | | | | | | |
| energy value | kcal<br>MJ | 3400<br>14.2 | 3631.2<br>15.2 | 1171.0<br>4.9 | 972.1<br>4.1 | 7161.4<br>30.0 | 107.0 |
| total fat | % of energy | <30 | 36.4 | 5.8 | 19.1 | 65.2 | 121.3 |
| saturated fatty acids | % of energy | <10 | 14.4 | 3.4 | 3.9 | 29.3 | 144.0 |
| polyunsaturated fatty acids | % of energy | 6-10 | 5.1 | 1.8 | 2.0 | 16.1 | 85.0 |
| saccharose | % of energy | <10 | 11.4 | 5.1 | 1.3 | 33.9 | 114.0 |
| dietary fibre | g | 20-40 | 28.9 | 10.6 | 9.0 | 68.6 | 96.3 |
| cholesterol | mg | ≤300 | 554.5 | 253.1 | 51.6 | 1394.2 | 184.8 |
| fruits and vegetables | g | >400 | 659.3 | 535.2 | 0.0 | 3342.4 | 164.7 |
| *Nutritional status* | | | | | | | |
| body height | m | | 1.8 | 0.1 | 1.6 | 2.0 | |
| body mass | kg | | 69.3 | 11.2 | 41.0 | 111.0 | |
| BMI | kg/m$^2$ | Acc. to Cole | 21.6 | 3.0 | 15.8 | 34.8 | |
| waist circumference | cm | Acc. Katzmarzyk | 79.8 | 8.2 | 64.0 | 119.0 | |
| cholesterol | mg/dl | < 170 | 156.8 | 93.0 | 269.0 | 26.9 | |
| HDL-cholesterol | mg/dl | ≥ 45 | 52.4 | 15.0 | 106.0 | 10.9 | |
| LDL-cholesterol | mg/dl | < 110 | 86.8 | 40.0 | 400.0 | 28.1 | |
| triglycerides | mg/dl | < 90 | 92.9 | 14.0 | 417.0 | 52.1 | |

WHO recommendations (≥400 g/day). Still, analyses showed great differences in their intake that ranged from 0.0 g to 3342.4 g. In 36% of the food rations, quantities of fruits and vegetables were found to be low (< 400 g/day).

In the examined group of boys, mean body mass accounted for 69.3 ±11.2 kg and mean body height for 1.80 ±0.1 m. The mean value of BMI was at a level of 21.6 ±3 kg/m$^2$. Overweight was demonstrated in 10.8%, and obesity in 2.7% of the boys surveyed. The mean value of waist circumference reached 79.8 ± 8.2 cm, and high values of that parameter were observed in 42.3% of the surveyed (Table 1, Figure 2).

The mean concentration of cholesterol in blood plasma of the 16-18-year-old boys was at a level of 156.8 ±26.9 mg/dl; with the minimum value of 93.0 mg/dl and the maximum value of 269.0 mg/dl. The threshold concentration of cholesterol, which acc. to current health criteria already requires correction by applying a diet and physical activity, was demonstrated in 18.4 % of the boys, whereas a high concentration of cholesterol - in 8% of the surveyed.

The mean concentration of the "atherogenic" LDL fraction of cholesterol reached 86.8 ± 28.1 mg/dl. In some of the boys, the concentration of that cholesterol fraction exceeded the values recommended for adolescents at this age The threshold concentration of LDL-cholesterol was demonstrated in 8.7% and its high concentration - in 4.6% of the group examined. The mean concentration of the HDL-cholesterol reached 52.4 ±10.9 mg/dl, with the extreme values being 15.0 and 106.0 mg/dl. The threshold concentration of HDL-cholesterol was observed in ca. 24.0% and its low concentration - in ca. 2% of the group surveyed. The average concentration of triglycerides in blood plasma of the boys examined was 92.9 ±52.1 mg/dl; and the extreme value was highly divergent (14-417 mg/dl). A considerable percentage of the boys (23.8% of the group) were characterized by an elevated concentration of triglycerides that ranged from 90 to 129 mg/dl. In turn, their high concentration was shown in 17.9% of the group surveyed. The habit of smoking cigarettes, irrespective of the number of smoked cigarettes, was observed in 28.4% of the group examined. A lack or low physical activity, undertaken only at school classes (3 times x 45 min/week) was demonstrated in 17.3% of the boys (Figure 2).

**Risk factors**

Analyses were also conducted for the effect of selected factors attributable to diet, low physical activity, smoking cigarettes, and high BMI values (overweight acc. to *Cole* et al. [5]) on blood lipid profile of the boys examined. In addition, the likelihood of blood lipid disorders was estimated by determining the Odds ratio. To this end, an analysis of logistic regression was conducted, the results of which were presented in Table 2.

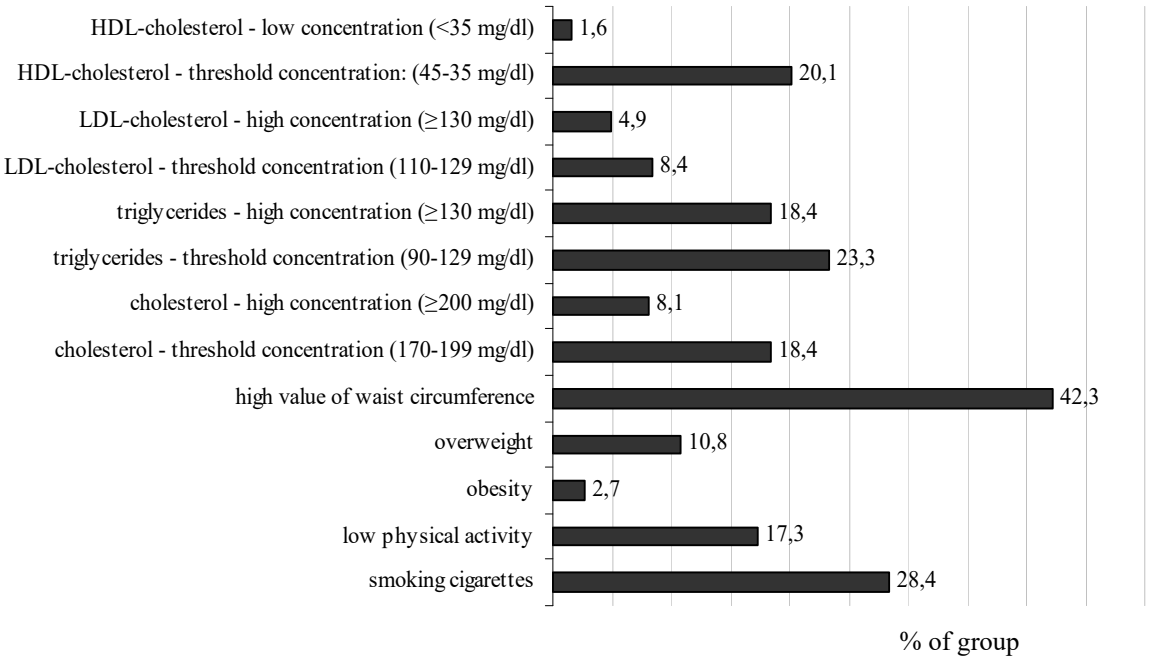


Figure 2. Percentage of boys with incorrect blood lipid indices, high value of waist circumference, overweight and obesity as well as with low physical activity and smoking cigarettes (n=369)

Table 2. Effect of selected factors of lifestyle on an increase in the likelihood of the risk of a high concentration of cholesterol, triglycerides, LDL- and HDL-cholesterol in blood of the 16-18-year-old boys examined (n=369)

| Risk factors | Cholesterol | | Triglycerides | | LDL-Cholesterol | | HDL-Cholesterol | |
|---|---|---|---|---|---|---|---|---|
| energy | 0.88[a] (0.55-1.41) | NS[b] | 0.81 (0.53-1.24) | NS | 0.74 (0.39-1.38) | NS | 1.05 (0.66-1.7) | NS |
| monosaccharides | 0.73 (0.45-1.17) | NS | 0.88 (0.57-1.34) | NS | 0.89 (0.48-1.64) | NS | 1.09 (0.67-1.78) | NS |
| total fat | 1.75 (0.84-3.6) | NS | 0.91 (0.51-1.63) | NS | 2.97 (1.01-9.96) | SS | 0.71 (0.38-1.33) | NS |
| cholesterol | 1.16 (0.58-2.34) | NS | 0.61 (0.34-1.12) | NS | 1.14 (0.46-2.85) | NS | 0.84 (0.43-1.65) | NS |
| SFA | 2.40 (1.02-6.39) | SS[c] | - | - | 1.76 (0.52-6.01) | NS | 0.74 (0.35-1.58) | NS |
| PUFA | 0.81 (0.48-1.38) | NS | 0.88 (0.54-1.43) | NS | 1.01 (0.48-2.09) | NS | 1.26 (0.72-2.22) | NS |
| dietary fibre | 1.54 (0.88-2.7) | NS | 1.18 (0.7-1.99) | NS | 1.25 (0.60-2.60) | NS | 1.43 (0.81-2.54) | NS |
| vegetables and fruits | 1.11 (0.68-1.78) | NS | 0.88 (0.57-1.37) | NS | 1.14 (0.61-2.13) | NS | 0.91 (0.55-1.50) | NS |
| overweight, obesity | 2.27 (1.22-4.23) | SS | 2.35 (1.28-4.34) | SS | 2.41 (1.15-5.03) | SS | 1.48 (0.77-2.80) | NS |
| waist circumference | 2.03 (1.26-3.24) | SS | 1.80 (1.18-2.76) | SS | 2.19 (1.19-4.04) | SS | 1.96 (1.21-3.16) | SS |
| smoking cigarettes | 1.38 (0.84-2.27) | NS | 1.34 (0.85-2.11) | NS | 1.18 (0.62-2.26) | NS | 1.65 (1.1-2.70) | SS |
| physical activity | 0.53 (0.30-0.94) | SS | 0.78 (0.45-1.34) | NS | 1.88 (1.06-3.36) | SS | 0.76 (0.42-1.40) | NS |

[a] – adjusted odds ratio (95% Cl), [b] – no statistical significance (NS), [c] – statistical significance (SS), SFA – saturated fatty acid, PUFA – polyunsaturated fatty acid

The nutritional risk factors adopted in the study included: high energy value of diet, high contribution of energy derived from saccharose (monosaccharides), high intake of total fats, SFA and cholesterol as well as low contents of PUFA, dietary fibre, fruits and vegetables. Analyses showed that with a high intake of SFA the likelihood of a high concentration of cholesterol in blood of the examined group of boys increased over 2 times (age-adjusted odds ratio [aOR]=2.4; 95% confidence interval [Cl] [1.02-6.39]). They also demonstrated a statistically significant effect of excessive body mass, determined by the BMI value (aOR=2.27 [1.22-4.23]), and high values of waist circumference (aOR=2.03 [1.26-3.24]) on the increase in cholesterol concentration in blood plasma. The likelihood of a high concentration of triglycerides was shown to increase over 2 times at overweight and obesity (aOR=2.35 [1.28-4.34]), and especially at increased values of waist circumference (aOR=1.8 [1.18-2.76]). This risk of a high concentration of LDL-cholesterol was observed to increase with an increasing intake of total fat (aOR=2.97 [1.01-9.96]), high BMI values (aOR=2.41 [1.15-5.03]) and high values of waist circumference (aOR=2.19 [1.19-4.04]), and at a low physical activity (aOR=1.88 [1.06-3.36]). In the group of the examined 16-18-year-old boys analyses showed about 2-fold increase in the risk of a low concentration of HDL-cholesterol at high values

of waist circumference (aOR=1.96 [1.21-3.16]). Of importance appeared to be also the habit of smoking cigarettes that reduced significantly the concentration of that cholesterol fraction (aOR=1.65 [1.21-2.70]) in respect of its concentration recorded in the non-smoking boys.

Results of the logistic regression analysis indicate that overweight and obesity, high values of waist circumference in particular, affected blood lipid parameters to the most significant effect. Analyses were also conducted for effects of lifestyle factors (diet, physical activity, smoking cigarettes) on the nutritional status of the boys (BMI, waist circumference).

Results of odds ratio analysis demonstrated that the likelihood of high BMI values was increasing 2.5 times at a low intake of dietary fibre (aOR=2.53 [1.31-4.91]) (Table 3).

Table 3. Effect of selected factors of lifestyle on an increase in the likelihood of overweight and obesity and a high value of waist circumference in the 16-18-year-old boys examined (n=369)

| Risk factors | BMI | | Waist circumference | |
|---|---|---|---|---|
| energy | 0.25 (0.12-0.53) | SS[c] | 0.68 (0.45-1.04) | NS |
| monosaccharides | 0.58 (0.32-1.05) | NS[b] | 0.79 (0.52-1.22) | NS |
| total fat | 0.57 (0.27-1.19) | NS | 1.02 (0.52-1.99) | NS |
| cholesterol | 0.57 (0.27-1.23) | NS | 1.24 (0.66-2.30) | NS |
| SFA | 0.76 (0.30-1.94) | NS | 1.07 (0.52-2.18) | NS |
| PUFA | 0.82 (0.41-1.61) | NS | 0.87 (0.54-1.40) | NS |
| dietary fibre | 2.53 (1.31-4.91) | SS | 1.36 (0.81-2.29) | NS |
| vegetables and fruits | 0.45 (0.22-0.95) | SS | 0.92 (0.59-1.40) | NS |
| smoking cigarettes | 1.72 (0.93-3.19) | NS | 0.84 (0.49-1.46) | NS |
| physical activity | 0.62 (0.30-1.26) | NS | 1.17 (0.74-1.85) | NS |

[a] – adjusted odds ratio (95% Cl), [b] – no statistical significance (NS), [c] – statistical significance (SS), SFA – saturated fatty acid, PUFA – polyunsaturated fatty acid

## DISCUSSION

The mean concentration of cholesterol in blood plasma of the boys examined in the study reached 156.8 mg/dl. Yet, abnormalities, including threshold concentration and high concentration of cholesterol, were observed in a considerable percentage of the boys, i.e. in 18.4% and 8.1% of the group, respectively. The report by *Nguyen* et al. [32] shows that there is a high concentration of total cholesterol among American children and adolescents was 7.4%. Adolescents aged 16-19 (8.9%) had a higher incidence of high total cholesterol than children aged 6-8 (6.0%) [32]. Analyses carried out on two subsamples consisting of the Beijing Child and Adolescent Metabolic Syndrome (BCAMS) in 2004 and the China Child and Adolescent Cardiovascular Health (CCACH) study in 2014 for children and adolescents aged 6-18 [9] showed that the mean concentration of cholesterol in their blood plasma reached 155 and 162 mg/dl (research in 2004 and 2014, respectively), which was similar to that in the reported study. Similar values of cholesterol concentration were shown in blood plasma of boys living in Germany (156.0 mg/dl) [37]. Identical average total serum cholesterol (156 ± 28 mg/dl) was found in a study of children and adolescents (6-14 years) from primary and secondary schools in a community of 14 cities in the south of Italy [28]. A study by *Murakami* et al. [30] showed that mean cholesterol values in children (n=324) and adolescents (n=523) are 164.0 mg/dl and 155.5 mg/dl, respectively. I n the group of 1427 participants (715 boys and 712 girls) aged 6-20 years, the average total serum cholesterol concentration was 157.9 mg/dl [48].

Ample epidemiological surveys showed differences in lipid profile as affected by race, gender, ethnic group and sexual maturation [12, 15, 42]. In turn, the National Health and Nutrition Examination Survey (NHANES) investigations conducted in the years 1999 to 2006 demonstrated that of 9.6% to 10.7% of the examined adolescents had a high concentration of total cholesterol (≥200 mg/dl), whereas later surveys (NHANES 1999-2000) did not demonstrate any significant changes in this respect [12].

In the reported study, the mean concentration of LDL-cholesterol reached 86.8 mg/dl, with its threshold concentration demonstrated in 8.7% and a high concentration in 4.6% of the boys examined. Amongst the American schoolchildren examined in the National Health and Nutrition Survey (NHANES) in 2011-2014, the mean concentration of LDL-cholesterol was similar to that recorded in Polish boys and reached 87 mg/dl [48]. Results of NHANES 1999 to 2006 investigations demonstrated that mean Concentrations of Low-Density Lipoprotein Cholesterol in US Adolescents accounted for 89.3 mg/dl (16-year-olds) and 88.9 mg/dl (17-year-olds), respectively. Based on

statistical data collected in America, diversification of LDL-cholesterol concentration was demonstrated in a group of adolescents depending on their origin. Its mean concentration in 12-17-year-old boys of white race accounted for 89.7 mg/dl, in the Mexicans - for 88.9 mg/dl, and in the adolescents of black race - for 91.4 mg/dl [10]. Higher LDL cholesterol values were recorded among boys from 11-18 years of age in research *Murakami* et al. - 99.4 mg / dl [30].

In our study, the mean concentration of HDL-cholesterol reached 52.4 mg/dl, with the threshold concentration noted in 23.6% and a low concentration - in 1.6% of the boys examined. The value of the mean concentration was less favorable as compared to the Japanese 16-year-old adolescents (59.6 mg/dl), in which as many as 50% of the subjects displayed a low concentration of that cholesterol fraction [1]. Results of the NHANES 2011-2014, the *Ito* et al. and the *Murakami* et al. research investigations were alike (53.5 ± 12.4 mg/dl 59 ± 11 mg/dl and 48.0 mg/dl, respectively) [19, 30, 48].

The mean concentration of triglycerides in the boys surveyed in our study was at a level of 92.9 mg/dl. A considerable percentage of the boys were displaying their threshold and high concentrations, i.e. 23.8% and 17.9% of the group, respectively. According to *Abe* et al. [1] the mean concentration of triglycerides in 16-year-old boys from Japan was 99.7 mg/dl, and with a high level observed in nearly 25% of respondents from this age group. From cross-sectional studies based on data from the National Diet and Nutrition Survey (NDNS), the concentration of triglycerides among 11-19-year-old British boys was comparable with results reported in Poland - 90.34 mg/dl [30].

Disorders in the lipid profile occur with a greater frequency in adolescents with overweight and obesity [29, 41]. *Sarganas* et al. found that about 34% of boys aged 11-17 years had low physical activity (up to 4 hours/week) [37]. Research conducted by *de Moraes* et al. [8] and *Sulo* et al. [44] indicate a decrease in morbidity and mortality due to cardiovascular diseases. However, there are regions at the festival in which this rate continues to increase. It depends mainly on the proper control of health habits, such as reducing smoking, increasing and regularly exercising, and avoiding overweight and obesity. A study on children and adolescents from Florianopolis risk factors of cardiovascular diseases demonstrated that 3.5% of the study group were smoking cigarettes, spend about 2.6 ± 2.3 hours/day on inactive free time, and as much as 48% had a positive family interview in terms of circulatory system diseases [13]. The evaluation of the nutritive value of an average food ration in *Murakami* et al. research indicated a high contribution of energy derived from total fats - 34.6%. It was shown that dietary fiber intake was not less than 26.6 g /10 MJ [28].

Our survey demonstrated even higher intake of total fats (36.4% of energy), including those from SFA (14.4% of energy), by the boys from Poland. Ca. 30 % of the respondents were smoking cigarettes, and 17.3% of the boys displayed a low physical activity. Worthy of notice is also the effect of dietary fibre content of food rations on the nutritional status of the boys examined. Results of the odds ratio demonstrated a 2.5-fold increase in the likelihood of high BMI values at a low intake of dietary fibre (aOR=2.53 [1.31-4.91]).

*Savva* [38] was searching for relationships between biochemical and anthropometric factors of 10-14-year-old participants of the Research and Education Program for Child Health from Cyprus. In the boys examined, the mean concentration of cholesterol accounted for 170.8 mg/dl, that of LDL-cholesterol - for 95.3 mg/dl, that of HDL-cholesterol - for 62.0 mg/dl, and that of triglycerides - for 67.7 mg/dl. The BMI value reached 19.3 kg/m$^2$ and waist circumference - 70.7 cm on average. Likewise in our study, at high BMI values, results of the odds ratio demonstrated a few fold increase in the risk of a high concentration of cholesterol (aOR=1.62 [1.20-2.17]), LDL-cholesterol (aOR=2.31 [1.69-3.16]) and triglycerides (aOR=4.65 [2.96-7.29]) in blood of the surveyed subjects. A high risk of health complications was also indicated at high values of waist circumference, adopted at a level of ≥75$^{th}$ percentile: for a high concentration of total cholesterol (aOR=1.58 [1.17-2.12]), LDL-cholesterol (aOR=2.11 [1.54-2.89]), and triglycerides (a OR=4.10 [2.63-6.41]), at $p<0.005$. In the reported own study, especially boys with overweight and obesity were characterized by an increased likelihood of a high concentration of total cholesterol (aOR=2.27 [1.22-4.23]), triglycerides (aOR=2.35 [1.28-4.34]), and LDL-cholesterol (aOR=2.41 [1.15-5.03]). A high value of waist circumference, acc. to *Katzmarzyk* et al. [21], also posed a risk of a high concentration of cholesterol (aOR=2.03 [1.26-3.24]), triglycerides (aOR=1.8 [1.18-2.76]), and LDL-cholesterol (aOR=2.19 [1.19-4.04]) as well as of a low concentration of HDL-cholesterol (aOR=1.96 [1.21-3.16]).

Investigations of *Raitakari* et al. [34] addressing risk factors of the circulatory system in children and adolescents from Finland confirmed that the impact of those factors at young age determined their health status in the adulthood.

Results of a research by *Nemet* et al. [31] demonstrated that a complex modification of a diet, eating habits and physical activity in obese children brought long-standing health benefits. Three-month intervention was found to yield noticeable effects in reduction of body mass (on average from 63.8 to 61.0 kg), BMI value (from 28.5 to 26.8 kg/m$^2$). What is more, positive changes were observed in blood lipid profile, i.e.: concentration of total cholesterol (170.1

- 147.8 mg/dl), LDL-cholesterol (106.5-89.7 mg/dl), HDL-cholesterol (43.6-44.8 mg/dl) and triglycerides (93.6-79.7 mg/dl). Changes in lifestyle continued over a long time span were observed to result in the successive, beneficial reduction of body mass and lipid indices observed after a year since the intervention.

A proper body mass, insulin-susceptibility, blood lipid profile and arterial blood pressure in the childhood and adolescence minimize the risk of the incidence of a metabolic syndrome in the adulthood and are implicated in a fewer likelihood of the incidence of circulatory system diseases [25, 42].

## CONCLUSIONS

Results obtained in the study enabled concluding that the lifestyle of young boys was determining the risk of their cardiovascular diseases. Overweight and obesity, visceral obesity in particular, were demonstrated to be significant risk factors of disorders in lipid metabolism of the boys surveyed in the study.

**Conflict of interest**
*None declared.*

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ORIGINAL ARTICLE

# THE ROLE OF MACRONUTRIENTS IN THE IMPLEMENTATION OF THE CORRECTIVE EFFECT OF LOW-MINERALIZED WATER IN EXPERIMENTAL METABOLIC SYNDROME

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## ABSTRACT

**Background.** Metabolic Syndrome (MS) is a widespread pathological condition, a group of interconnected metabolic disorders that contribute to the development of a number of severe noncommunicable diseases. Natural mineral waters of various compositions are widely used in the correction of MS. Their biological activity and specificity of action is associated with the presence of specific components (micronutrients, biologically active substances). At the same time, many researchers do not pay enough attention to the role of the biological activity of macro nutrients in low mineralized mineral waters.

**Objective.** To assess the corrective effect of macro-components of mineral waters based on a comparative analysis of changes in the structure of internal organs of white rats with the MS model, receiving mineral waters of the same balneological type, but with different quantitative composition of macro components.

**Materials and methods.** The material for histological and histochemical tests were the internal organs of male white rats with body weight 280–320 g. Animals were ranked into 4 groups: I - rats served as a control, II - rats with a model of MS; III and IV - rats received the mineral waters against the background of MS modeling. The mineral waters used in the work were characterized by an increased (in close amounts) content of organic substances (C org.), similar in chemical but different in quantitative macro-component composition. At the same time, mineral waters practically did not differ in terms of total mineralization. Modeling of MS was carried out for 60 days by replacing 10% fructose solution in drinking water bowls, introducing white bread crackers into the diet, and excluding green mass from the diet. In groups where animals were corrected for MS, mineral waters were administered with an intragastric tube with olive at a dose of 1% of body weight daily, starting from the 60th day of the experiment, for 12 days. Upon completion of the experiment on day 72, histological sections (which were stained with hematoxylin-eosin) were prepared from the extracted pieces of the heart, stomach, liver and kidneys tissues. The succinate-dehydrogenase (SDH) and lactate-dehydrogenase (LDH) activity were determined on the prepared cryostat sections.

Using a light microscope, changes in the structure of the above organs and changes in the activity of oxidative-restorative enzymes were evaluated.

**Results.** The activity of oxidative-restorative enzymes was approaching normal; some manifestations of changes in water metabolism in the animal organism persisted. At the end of the use of both mineral waters, a significant decrease was found in the content of visceral fat around the intestines, renal capsule, under the pericardium, which correlated with a decrease in the animal's body weight and restoration of the fasting blood glucose level to the cereal level. The authors believe that the established features of the corrective effect of both mineral waters on changes in the structure of internal organs are explained not so much by the difference in the content and ratio of the bioactive component (C org.), but by differences in the content of macronutrients. In mineral waters obtained by rats of group III, the content of Cl– and SO4+2 ions is 2.30 and 3.67 times, and Ca2+ and Mg2+ ions are 2.75 and 4.57 more than in mineral waters, which received rats of group IV. However, the content of HCO3–, Na+, K+ is 1.14 and 1.30 times higher in the mineral waters obtained by rats of group IV.

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**Conclusions.** The authors believe that the macronutrients involved in the implementation of MWs biological activity affect the metabolic background of the organism, which creates the bioactive element - C org. conditions for the performance of more intensive corrective action.

**Key words:** *metabolic syndrome, macronutrients, low-mineralized mineral waters*

## INTRODUCTION

Metabolic syndrome (MS) - a common pathological condition, which is a group of interconnected metabolic disorders; high blood pressure, an increase in fasting levels of triglycerides and a decrease in fasting levels of high density lipoproteins; increased glucose obesity (excess primarily visceral fat), the development of insulin resistance [1, 3, 7, 31]. These metabolic features contribute to the development of non-alcoholic fatty liver disease, type 2 diabetes mellitus, atherosclerosis, arterial hypertension, and cancer pathology [23, 26]. According to the International Diabetes Federation, MS occurs in 20–25% of the world's population. Moreover, among people aged 18 to 30 years, MS suffers up to 7% of their total number [22].

In the pathogenesis of MS, today, along with malnutrition, an essential role is given to the metabolism of minerals [15, 32]. Moreover, as indicated in the available literature, mineral waters (MW), due to the high bioavailability of the minerals contained in them, can effectively correct metabolic disturbances characteristic of MS [2, 19, 25]. Among the many ions contained in mineral waters, significant for the correction of MS, along with $Ca^{+2}$, $Mg^{+2}$ consider ions $HCO_3^-$, $Cl^-$, $Na^+$ [6, 8, 11]. It should be noted that in accessible publications the emphasis is on the influence of the above ions on metabolic parameters. At the same time, the state of metabolism is closely related to the state of the substrate of metabolic processes, that is, with the structural and functional characteristics of internal organs.

Since in the available literature we did not meet data on the effect of mineral waters of various compositions on the structural and functional state of internal organs during the development of MS, the goal of our work was formulated as follows.

On the basis of a comparative analysis of changes in the structure of internal organs of white rats with a model of the metabolic syndrome treated with mineral waters, to evaluate the corrective effect of macro-ions contained in these waters on these changes.

## MATERIALS AND METHODS

The material of this study was the data obtained during the study of white male Wistar rats of outbred breeding weight 240 - 270 g. Certified animals were obtained from the kennel of the emergency „Biomodelservice" GI „Pharmacology and toxicologists of NAMSof Ukraine", Kyiv.

The work with the animal was carried out in accordance with the requirements of the European Parliament Directive [9] and the Order of the Ministry of Education and Science, Youth and Sports of Ukraine [20].

In accordance with the objectives of the work, animals were ranked in 4 groups.

I group - 15 intact rats, kept under vivarium conditions, but were not exposed to any treatment and served as a control. II group - 10 rats in which metabolic syndrome (MS) was simulated for 60 days. III group - 10 rats, which, against the background of MS modeling, received mineral water of sample No. 1. IV group - 10 rats, which against the background of the simulation of MS received mineral water of sample No. 2.

Modeling of a metabolic syndrome was carried out for 60 days by replacing drinking water with a 10% solution of fructose and introducing white bread crackers into the standard diet. In groups where animals were corrected for MS, mineral waters were injected with an intragastric tube with olive at a dose of 1% of body weight daily, starting from the 60th day of the experiment, for 12 days. Weighed animals weekly. At the end of the experiment on day 72, the animals were removed from the experiment by decapitation under ether anesthesia. At an autopsy, after a visual assessment of internal organs, pieces of the heart, stomach, liver, and kidneys were taken in a volume of 1 $cm^3$. A piece of organ was divided into two parts. One part was fixed in 4% steam with formaldehyde for 48 hours, then it was passed through alcohols of increasing concentration and poured into celloidin according to the generally accepted method. Sections 7–9 μm thick were made from the obtained blocks, which were stained with hematoxylin-eosin. The resulting preparations were examined under a light microscope to determine structural changes in the internal organs. The second part of the piece was frozen with dry carbon dioxide (t = - 44°C). Cryostat sections 11 μm thick were made from the obtained blocks, on which the activity of succinate-dehydrogenase (SDH) and lactate-dehydrogenase (LDH) were determined according to the Lloyd K. prescriptions; enzyme activity was evaluated by the semi-quantitative method, the data were given in arbitrary units of optical density (conventional units) [17, 21]. The concentration of glucose in the blood was determined on an empty stomach using the glucose oxidant method [12]. Statistical processing of the obtained data was carried out using the biomedical

research programms Statistica and Exel. Significant changes were considered those that were within the confidence limits according to *Student* tables <0.05.

In the work we used mineral waters of two samples with a high content of organic substances (C org.), low mineralization, the physicochemical characteristics of which are shown in Table 1. A sample of mineral water No. 1 was taken from well No. 77 of the Romanovka village, Chemerovetsky district, Khmelnitsky region (Ukraine). Mineral water sample No. 2 was taken from well No. 357 Skhidnytsyavillage, Drohobych district, Lviv region (Ukraine). The content of organic carbon in both waters is balneologically significant, which, with a total mineralization of up to 1 g/dm3, determines their name and classifies them as low-mineralized waters with a high content of organic substances (better known as mineral waters of the Naftusya type) [27]. In mineral water No. 1, it is more (by 20%). Moreover, the content of biologically active components such as $H_2S$ and $H_2SiO_3$ is significantly higher in mineral waters No. 2, however, their concentration is lower than balneological significant. The content of other biologically active components and compounds in both waters is also below the balneological norm [30]. In general, we can assume that in terms of their physicochemical composition and biological activity these waters are fairly close.

## RESULTS AND DISCUSSION

Before proceeding to the presentation of the research results, we considered it necessary to conduct a comparative analysis of the mineral waters used in the work. According to the data in Table 1, the total mineral content in both waters is almost the same - 835.00 mg/dm$^3$ in mineral water of sample No. 1 and 827.00 mg/dm$^3$ in mineral water of sample No 2. However, the content of individual ions varies. In mineral waters No. 1, in comparison with mineral waters No. 2, the content of chlorine ions ($Cl^-$) and $SO_4^{+2}$ sulfates are 2.30 and 3.67 times higher, while the content of calcium ($Ca^{2+}$) ions of magnesium ($Mg^{2+}$) is 2.75 and at 4.57. At the same time, the content of bicarbonates ($HCO_3^-$), sodium and potassium ($Na^+$ + $K^+$) is 1.14 and 1.30 times higher in mineral water No 2.

In animals of group II (model MS without correction) it was found that within two months they gained more weight than animals of group I of the control group. If the initial weight of animals of this group was (305.0 ± 0.85) g, and animals of group II - (283.1 ± 0.21) g, then on the 60th day of the experiment the body weight of animals of group I was - (325.3 ± 1.04) g, and group II - (323.5 ± 0.44) g (Figure 1). The increase in body weight of animals with the MS model was 2 times greater in comparison with animals of group I. This is not a large increase in body weight, as fructose diet does not lead to a large weight gain, as noted by other authors, but the data are contradictory [5, 28, 29]. A more pronounced weight gain provides a variety of diets with fructose, glucose or sucrose, and high fat (fast food diet, or cafe diet) [11, 18]. In rats of the III and IV groups, weight gain on the 60th day of the experiment was similar to that of the group with MS. In rats of group III, it increased from (293.6 ± 1.13) g to (343.2 ± 1.02) g, and in animals of group IV, body weight increased from (299.8 ± 1.15) g to (349.5 ± 0.87) g.

At the same time, the glucose concentration in the blood of animals of the II, III and IV groups on the

Table 1. Macro elemental, micro elemental composition and biologically active components, and mineral waters compounds, mg/dm$^3$

| Indicators | Macro elemental composition | | Indicators | Micro elemental composition | | |
|---|---|---|---|---|---|---|
| | Mineral water sample number 1 | Mineral water sample number 2 | | Mineral water sample number 1 | Mineral water sample number 2 | Balneological significant concentration no less |
| Overall mineralization | 835.00 | 827.00 | Organic materials (carbon org.) | 14.00 | 11.40 | 5.0 - 30.0 |
| Bicarbonates ($HCO_3^-$) | 476.70 | 542.90 | Hydrogen sulfide, ($H_2S$) | 0.36 | 2.54 | 10.0 |
| Chlorides ($Cl^-$) | 56.73 | 24.80 | Orthoboric acid ($H_3BO_3$) | 13.98 | 15.45 | 35.0 |
| Sulfates ($SO_4^{2-}$) | 33.00 | 9.00 | Metasilicic acid, ($H_2SiO_3$) | 16.46 | 26.86 | 50.0 |
| Sodium & potassium (Na+, $K^+$) | 163.62 | 213.60 | Bromine, (Br) | 0.08 | 0.08 | 25.0 |
| Calcium ($Ca^{2+}$) | 33.00 | 12.00 | Total iron, (Fe) | 0.20 | 0.50 | 10.0 |
| Magnesium ($Mg^{2+}$) | 27.80 | 6.10 | Iodo, (I) | 0.127 | 0.127 | 0.7 - 1.5 |

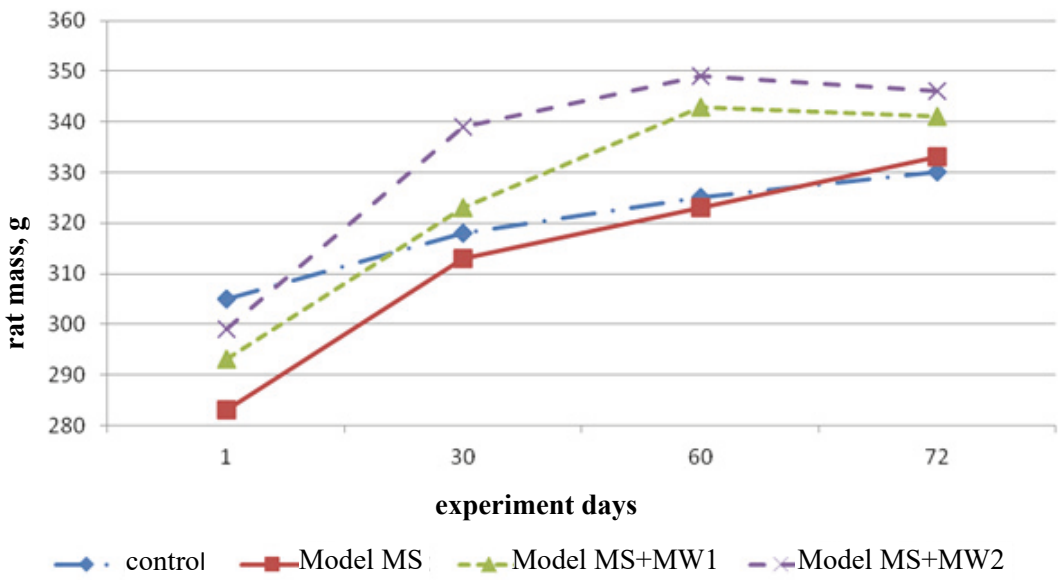


Figure 1. Dynamics of rat mass model MS and rats with MS in correction of mineral waters (MW1 and MW2) with increased organic content and various quantitative macro composition

60th day of the experiment was (8.06 ± 0.33) mmol/L, which was 2.95 per mmol/L higher than the data of the 1st control group (Figure 2). The data we have obtained on elevated glucose levels are cited by other researchers [4, 14].

Autopsy of animals of group II at the end of the experiment revealed that the main increase in adipose tissue was due to visceral fat in the renal capsule and its surrounding space so much that renal excretion becomes difficult; a lot of fat on the surface of the intestine, quite a lot under the pericardium. The liver did not visually change its size and shape, although its tissue acquired a yellow-brown color.

In microscopic examination of the wall of the stomach showed swelling of the submucosal plate, the nuclei of the fibroblasts are dark, elongated, small, their number is moderate. In the mucous membrane, the broadening of interstitial layers and their turbidity attracted attention.

Glands of the gastric mucosa of a tubular shape, their location due to varying degrees of expansion of the interstitial layers is disordered. The epithelium in some glands is desquamated. In the epithelial cells, the nuclei are small dark, in the cytoplasm of many cells, small vacuoles. SDH activity in epithelial cells

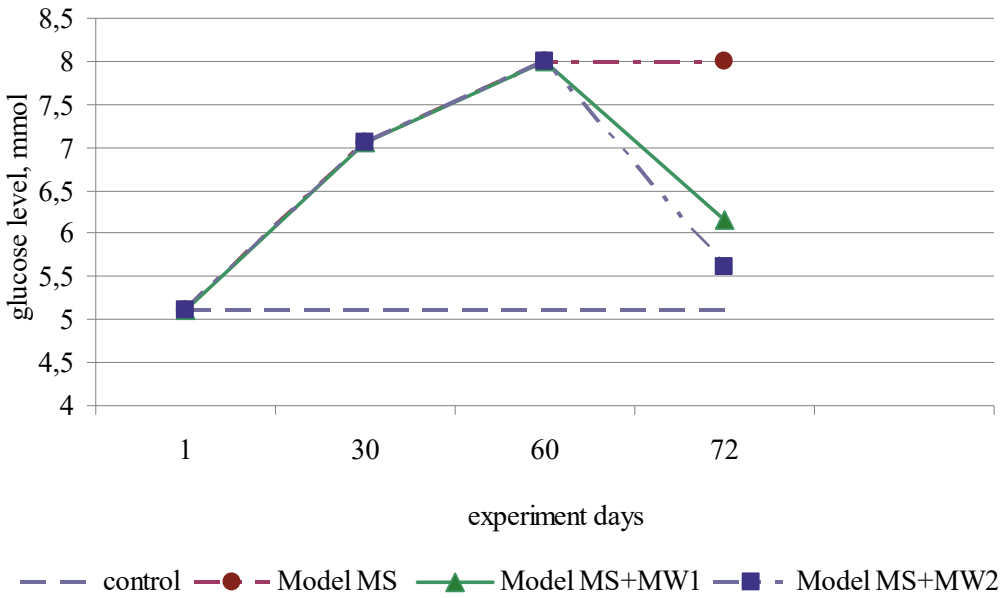


Figure 2. Dynamics of glucose levels in rats with MS and rats with MS during correction of mineral waters (MW1 and MW2) with an increased content of organic substances and various coliseum macro composition

(7.0 ± 0.21) conv. units; LDH activity - (7.00 ± 0.12) conv. units (increased).

In microscopic examination of the liver it is established that the dolce organization of the parenchyma of the liver is preserved. Between the wedge layers are thin, dense vessels of the triad and the central vein of moderate blood filling. Hepatocytes in slices are small, collected in beams. The nuclei of hepatocytes are small, dark-colored, cytoplasm weakly basophil lumpy organization, contain small and medium vacuoles. Between beam spaces are slit, *Kupffer's* cells are swollen (the nuclei are rounded). Small eosinophil inclusions are defined in parenchyma. The activity of SDH in hepatocytes is - (7.0 to 0.31) Ed.; LHG's activity is (6.0 to 0.13) units.

In myocardium, in microscopic examination of the myocardium indicates the preservation of the layered and bundle organization, interbeam interlayers are broadened due to their swelling. Cardiomyocytes are characterized by fuzzy transverse streakiness and an oval shape of enlarged nuclei (swelling). SDH activity in cardiomyocytes (7.0 ± 0.19) conv. units; LDH activity - (6.0 ± 0.25) conv. units.

In the kidneys, the distribution of renal bodies is uneven. In capillary glomeruli, endotheliocytes are swollen; small vacuoles are determined in their cytoplasm. Bowman's space is slit-like, apparently due to swelling of the capillary glomerulus. The interstitial layers are expanded due to the presence of lymphocytes in them. In part of the convoluted tubules in the lumen, eosinophilic homogeneous cylinders are determined. The tubule epithelium with swelling of the cytoplasm and small dark nuclei. In some tubules, the lumen is expanded to the state of lacunae. The activity of SDH in the tubular epithelium 6.0 ± 0.30 conv. units; LDH activity in them 6.0 ± 0.11 conv. units. In our previous work it is shown that rats on the background of MS develop pathological disorders of urinary and excretory functions of the kidneys, which led to a violation of the water-ion balance in the body [13].

In general, we observed the presence of signs of dystrophy in the studied internal organs of animals with a model of MS. The evidence we have established is confirmed by other researchers, who cite evidence that during fructose metabolism there is an arthosis depletion, which causes oxidative stress and inflammatory response, disrupting the functions of local tissues and organs, causing overproduction of inflammatory cytokines, adiponectin, leptin and endotoxin, which act as indirect dangerous factors. Fructose and its metabolites both directly and indirectly cause oxidative stress, chronic inflammation, endothelial dysfunction of autophagy and increased intestinal permeability, which further aggravates the course of metabolic syndrome with subsequent dysfunction of organs and tissues, namely liver, fatty tissue, islets of the pancreas, skeletal muscles, kidneys, heart, brain and bowel[16, 33].

By the end of the experiment (72nd day), the animals of the control group added another 5 g in weight, which amounted to (330.3 ± 0.09) g of body weight, animals of the II group with the MS model added 10g in weight (333.5 ± 0.07) g (Figure 1). The use of mineral water as a corrective agent, according to our observations, influenced body weight gain. If in the control group for the entire duration of the experiment the animals gained (30.0 ± 0.14) g, in the group with uncorrected MS, the weight gain was (50.7 ± 0.19) g, then in the groups where animals with the MS model received the corresponding mineral water, the weight gain was less, and was - (28.0 ± 0.42) g in the III group and - (30.2 ± 0.18) g in animals of the IV group receiving mineral water No. 2.

This was manifested primarily in a smaller amount of visceral fat and was accompanied by positive changes in the structural characteristics of the internal organs of animals. It should be noted that there were some features of these changes in animals treated with mineral water No. 1 (MW1) and mineral water No 2. (MW2).

Microscopic examination of the stomach wall of animals of the experimental group showed that the submucosal plate is dense, it is not possible to visually separate individual bundles of fibrous fibers. It determines a moderate amount of dark elongated fibroblast nuclei. In the mucous membrane of the gland of the usual tubular form. The interstitial layers are not wide. In the deep layers of the mucosa, the glands in their appearance correspond to the descriptions of the literature. The glands of the surface layers are characterized by light-colored cytoplasm, a homogeneous structure, in some small vacuoles are determined. Nuclei in medium sized epithelial cells of moderate color. The activity of SDH in the epithelial cells of the glands of the deep layers of the mucosa is (7.0 ± 0.21) conv. units; activity of SDH in the surface layers - (5.0 ± 0.11) conv. units LDH activity in the epithelial cells of the deep layers - 6.0 ± 0.19 conv. units, in the surface - (5.0 ± 0.20) conv. units.

Microscopic examination of the liver showed lobular organization of the parenchyma. Between the lobular layers are thin, dense. Vessels of triads of moderate blood filling. Hepatocytes in lobules are collected in beams, most of them are medium-sized. Regarding the lobules, the hepatocytes are of the usual type, their cytoplasm is homogeneous, the nuclei are of medium size, moderate in color. In part of the lobules, along with the usual type of hepatocytes, cells with a lumpy cytoplasm, in which there are single small vacuoles, are determined. The inter-beam spaces are slit-like, the nuclei of *Kupffer* cells are flattened, dark. In segments with the usual type of hepatocytes, the

activity of SDH is - (6.0 ± 0.13) conv. units; in segments of hepatocytes with vacuoles - (5.0 ± 0.13) conv. units; LDH activity is uniform in all segments and is - (6.0 ± 0.30) conv. units.

When examining the myocardium, violations of its layered and bundle organization were not detected. Interbeam interlayers are thin, dense, vessels of moderate blood filling. Cardiomyocytes of the usual form. SDH activity - (7.0 ± 0.16) conv. units; LDH activity in cardiomyocytes is slightly increased, and is - (7.0 ± 0.21) conv. units.

In the study of the kidneys, it was determined that the renal corpuscles are distributed fairly evenly. In most of them, capillary glomeruli are rounded in shape, with endothelial cells of the usual form. In individual renal bodies, the swelling of the endothelial cells of the glomeruli of capillaries and the presence of small vacuoles in them are determined. The tubules of the kidneys are of normal appearance, their gaps are free. The activity of SDH in the epithelium of the tubules is - (7.0 ± 0.19) conv. units; LDH activity - (5.0 ± 0.30) conv. units.

In general, we observed the positive effect of drinking mineral water of sample No. 1 on the structural characteristics of the internal organs of animals with the MS model (group 3 rats).

Assessing the structural and functional characteristics of the internal organs of rats with a model of MS treated with mineral water No. 2 (group 4 animals), a number of positive changes can be noted. Under microscopy of the stomach, the submucosal plate is dense, the fibrous fibers are packed without breaks, it is impossible to visually separate individual bundles or fibers. In the mucous membrane of the gland of the usual tubular form, the epithelium lines them in one layer. Epithelial cells with a homogeneous weakly basophilic cytoplasm, medium sized nuclei are juicily stained. The interstitial layers remain broadened, as in animals with an uncorrected metabolic syndrome. The activity of SDH in epithelial cells is (7.0 ± 0.19) conv. units, LDH activity in them - (6.0 ± 0.27) conv. units.

In the liver, microscopic examination determines the lobular organization of the parenchyma. The interlobular layers are thin dense. The vessels of the triads, the central vein are sharply full-blooded. Hepatocytes are collected in beams on most of the lobules. Medium sized hepatocytes, their lumpy cytoplasm, nuclei of medium and small sizes, juicyly painted over. The cytoplasm of the hepatocytes contains small vacuoles, swollen. In lobules, single small homogeneous structures of eosinophilic inclusions are determined. Between the beam spaces are slit-like. *Kupffer* cell nuclei are flattened, darkly stained. The activity of SDH in hepatocytes compared with that of the control group is reduced, and is (5.0 ± 0.17) conv. units; LDH activity is - (6.0 ± 0.10) conv. units.

Myocardial examination showed that its layer and bundle organization is not changed. Interbeam interlayers are thin and dense. In cardiomyocytes, the cytoplasm with pronounced transverse striation, the nuclei are small, darkly colored, oval in shape. The activity of SDH in cardiomyocytes is (7.0 ± 0.35) conv. units; LDH activity - (6.0 ± 0.34) conv. units, i.e., the activity of oxidative-restorative enzymes corresponds to the norm.

Microscopic examination of the kidneys revealed the uneven distribution of renal bodies. In the renal corpuscles, capillary glomeruli are rounded, endotheliocytes in the capillaries are swollen, in some of them small vacuoles are observed, the nuclei of the endotheliocytes are small, darkly colored. Most tubules are of a normal form, however, tubules with swollen, unclear cytoplasm are found in the lumen of which desquamated epithelial cells are determined. The interstitial layers are mostly thin, but broadened layers with swollen fibrous fibers are also found. The activity of SDH in the tubule epithelial cells is (7.0 ± 0.19) conv. units; LDH activity in them is reduced to - (5.0 ± 0.10) conv. units.

In general, we can talk about the approximation of the structure of internal organs to normal. Only in the liver and kidneys are manifestations of dystrophic processes preserved.

A feature of correcting mineral water No. 1 was its uneven expression in different parts of the same organ (group 3 of rats), which distinguished the effect of this mineral water from the effect of mineral water No. 2 (group 4 animals). It should be emphasized that in rats of groups 3 and 4, at the end of the use of both mineral waters, a significant decrease in the content of visceral fat in the renal capsule, under the pericardium and around the intestines was detected, which correlated with a decrease in animal body weight and restoration of fasting blood glucose levels (Figure 2). At the end of the experiment, in rats of the III group, the glucose concentration was (6.16 ± 0.13) mmol/L, and in rats of the IV group - (5.62 ± 0.19) mmol/L, which did not significantly differ from the control group.

Mineral waters containing organic substances, as the main bioactive agent, have a positive effect on the structural characteristics of the internal organs of rats with the MS model. It was manifested in a decrease or absence of signs of dystrophic processes. It should be noted that there were differences in the prevalence of these positive changes. In both cases, after the application of these mineral waters in the myocardium, no manifestations of dystrophy were detected. In the stomach wall, residual manifestations of dystrophy when applying mineral water No. 1 were noted in the glands of the surface layers of the gastric mucosa, and when using mineral water No. 1, they were not detected. In the liver parenchyma, residual

manifestations of dystrophic processes were noted in the cases of using both mineral waters, however, in the case of using mineral water No. 1, they are determined in the parenchyma of part of the lobules, and in the case of using mineral water No. 2 in all segments.

Accordingly, in the kidneys in both cases, the use of mineral water in the capillaries of the glomeruli of the renal corpuscles retains residual manifestations of dystrophic changes, but in the tubules when using mineral water No. 2, they are more common. In our opinion, it is incorrect to associate the revealed differences with different amounts of the bioactive component, since according to the data in Table 2, the difference does not exceed 2.45 mg / $dm^3$ (20%). At the same time, the difference in the content of the components of the macronutrient component used mineral water is very significant. In mineral water No. 1, in comparison with mineral water No. 2, $SO_4^{+2}$ and $Cl^-$ ions are 3.67 and 2.30 times more, and $Ca^{2+}$ and $Mg^{2+}$ ions are 2.75 and 4.55 times more, respectively. At the same time, mineral water No. 357 contains more $HCO_3^-$, $Na^+$ + $K^+$ ions and biologically active components in the form of $H_2S$, and $H_2SiO_3$.

Since $SO_4^{+2}$ ions affect the metabolic processes in hepatocytes, it can be assumed that their higher content in mineral water No. 1 determines the features of structural changes in the liver; the higher $Cl^-$ content in the same mineral water obviously causes a difference in the structural structure of the renal tubules. Differences in the content of $Ca^{2+}$and $Mg^{2+}$, $H_2S$, and $H_2SiO_3$ ions - affecting the course of metabolic processes and hemodynamic characteristics, obviously also affect the revealed differences in the structural changes in the internal organs of experimental rats.

The data we have obtained on the corrective effect of MW on the body of rats with the MS model largely coincide with the few on this problem data of studies conducted studies on rats with fructose MS. The authors point to the significant positive effect of the use of MW on the metabolic rates studied in the development of MS [24].

## CONCLUSIONS

Thus, the research results show that when assessing the biological activity of low-mineralization MW (up to 1 g/$dm^3$) it is necessary to take into account that the macronutrient composition of MW, influencing the metabolic background of the body, creates conditions for enhancing the curative effect of a specific bioactive element (C org.). Therefore, the amount and ratio of macroelements should be taken into account when assessing this type of mineral waters biological activity.

**Conflict of interest**

*The authors declare no conflict of interest.*

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ORIGINAL ARTICLE

# KNOWLEDGE ON RISK FACTORS FOR TYPE 2 DIABETES MELLITUS AMONG SECONDARY SCHOOL STUDENTS

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## ABSTRACT

**Background.** Diabetes is a set of metabolic diseases characterized by hyperglycemia caused by improper action and/or secretion of insulin. Currently, diabetes is becoming a serious challenge in modern medicine, this disease affects 425 million people, and the forecasts indicate that by 2045 the number of cases will increase to 629 million.
**Objective.** The aim of the study was to evaluate the knowledge about risk factors for type 2 diabetes among secondary school students in the Silesian Province in Poland and to determine whether there are differences between the level of knowledge between girls and boys and between first-, second- and third-grade students.
**Material and methods.** The survey was conducted among 650 high school students. The research tool was the author's questionnaire. The obtained results were developed using Microsoft Excel 2010 and Statistica 13.3 (TIBCO Inc.).
**Results.** The definitions of type 2 diabetes were known to 63.9%. 91.8% of high school students indicated excessive body mass as a risk factor for morbidity, while 18.8% of people indicated the appropriate type of obesity increasing the risk of type 2 diabetes. Most of the students considered abnormal eating habits as an important factor increasing the occurrence of the disease (92.4%). The most numerous group of high school students were people with average level of knowledge (89.6%).
**Conclusions.** The knowledge of high school students about risk factors for type 2 diabetes was varied. The most numerous group were high school students characterised by the average level of knowledge. There were no statistically significant differences between the proportion of correctly provided responses by women and men. There were statistically significant differences between the proportion of correctly provided responses by first-, second- and third-graders. Our research shows that educational activities should be undertaken, especially about modifiable risk factors for type 2 diabetes.

**Key words:** *knowledge, high school students, type 2 diabetes mellitus, risk factors*

## STRESZCZENIE

**Wprowadzenie.** Cukrzyca stanowi zespół chorób metabolicznych, charakteryzujący się hiperglikemią spowodowaną nieprawidłowym działaniem i/lub wydzielaniem insuliny. Obecnie cukrzyca staje się poważnym wyzwaniem współczesnej medycyny, choroba ta dotyka 425 milionów osób, a prognozy stanowią, że do 2045 roku liczba zachorowań wzrośnie do 629 milionów.
**Cel badań.** Ocena wiedzy uczniów szkół licealnych w Polsce na temat czynników ryzyka zachorowalności na cukrzycę typu 2 oraz stwierdzenie czy istnieją różnice między poziomem wiedzy dziewcząt i chłopców oraz pierwszo-, drugo- i trzecioklasistów.
**Materiał i metody.** Badanie zostało przeprowadzone wśród 650 licealistów. Narzędzie badawcze stanowił autorski kwestionariusz ankiety. Uzyskane wyniki opracowano z wykorzystaniem Microsoft Excel 2010 oraz Statistica 13.3 (TIBCO Inc.).
**Wyniki.** Definicję cukrzycy typu 2 znało 63,9% uczniów. 91,8% licealistów wskazało nadmierną masę ciała jako czynnik ryzyka zachorowalności, natomiast 18,8% osób wskazało odpowiedni typ otyłości zwiększający ryzyko cukrzycy typu 2. Większość uczniów uznało nieprawidłowe nawyki żywieniowe jako istotny czynnik sprzyjający występowaniu choroby (92,4%). Najliczniejszą grupę badanych stanowiły osoby charakteryzujące się średnim poziomem wiedzy (89,6%).
**Wnioski.** Wiedza badanych uczniów na temat czynników ryzyka zachorowalności na cukrzycę typu 2 była zróżnicowana. Najliczniejszą grupę stanowili licealiści charakteryzujący się średnim poziomem wiedzy. Nie stwierdzono występowania istotnych statystycznie różnic między odsetkiem prawidłowo udzielonych odpowiedzi przez dziewczęta i chłopców. Stwierdzono występowanie istotnych statystycznie różnic między odsetkiem prawidłowo udzielonych odpowiedzi przez

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pierwszo-, drugo- i trzecioklasistów. Z przeprowadzonych badań wynika, że należy podejmować działania edukacyjne, ze szczególnym uwzględnieniem modyfikowalnych czynników ryzyka cukrzycy typu 2.

**Słowa kluczowe:** *wiedza, licealiści, cukrzyca typu 2, czynniki ryzyka*

## INTRODUCTION

Diabetes mellitus is referred to as a non-contagious epidemic of the 21st century. According to epidemiological data, the problem of diabetes affects 425 million people, with 90% being type 2 of the disease [1, 14]. As reported by the International Diabetes Federation, there were above 2 million adults with type 2 diabetes in Poland in 2019. It was also estimated that 990,000 individuals were undiagnosed [15]. In 2015 diabetes was diagnosed and treated more often among women (55%) than men. The studies conducted so far reveal that most of the society are unaware of the risk factors leading to this disease. Excessive body weight, incorrect eating habits and sedentary lifestyle are the main factors that contribute to the risk of diabetes. When detected too late (with already present complications), the treatment presents significantly more difficulties and generates higher costs. Due to the growing prevalence of the disease, prevention and prophylactics of type 2 diabetes should be the key elements of health-oriented education [33]. The awareness of the risk among young people is important as the prevalence can potentially be reduced, which entails a future treatment cost reduction. Moreover, previous studies have mainly assessed the knowledge of adults or people with diabetes. It was therefore decided to evaluate the knowledge about type 2 diabetes and its prevention among secondary school pupils. So far, no specific educational program for young people has been developed. The results of the research could allow for the preparation of educational programs that could potentially reduce the risk of developing this disease in the future [3, 13, 39].

The progress of research on the pathogenesis of type 2 diabetes emphasizes the special importance of environmental factors in the early diagnosis, prevention and treatment of the disease, therefore their detailed analysis is significant [27, 38].

Excessive body weight is considered to be one of the major contributors to the development of type 2 diabetes. Recommendations suggest starting a diagnosis for diabetes in people whose BMI exceeds 25 kg/m2 - which is overweight according to the WHO scale. Overweight and obesity are found in the majority of patients, with central obesity having a higher diabetogenic effect than gluteal-femoral obesity [11, 38]. Therefore, the ratio of the waist circumference to the hip circumference WHR - Waist Hip Ratio should be checked.-Waist values in women over 80 cm and 94 cm in men place them in the group at increased risk of developing type 2 diabetes. Numerous studies suggest that weight loss is highly effective in preventing and treating type 2 diabetes. People at risk due to this action, they can effectively delay or arrest the onset of the disease. This is due to the increase in tissue insulin sensitivity, which is one of the key mechanisms in the pathogenesis of type 2 diabetes. Weight loss increases glucose and insulin homeostasis, reversing abnormalities in their function and secretion. It is assumed that a 10% reduction in body weight can effectively prevent the onset of type 2 diabetes in the group of people with pre-diabetes [7,10].

Lifestyle is a key element in the prevention of non-communicable diseases. Modifying risk factors such as physical inactivity, stress, inappropriate eating habits, smoking or excessive alcohol consumption may reduce the risk of many chronic diseases, including type 2 diabetes [23, 35]. One of the most serious risk factors for developing type 2 diabetes is low physical activity. Activating the muscles increases the need for glucose by using excess glucose in the body, which prevents hyperglycemia in the body. Increasing physical activity by reducing adipose tissue effectively reduces the risk of developing the disease even up to 35% [48]. Studies show a positive correlation between a daily 30-minute additional physical activity and a reduction in the risk of developing type 2 diabetes [8, 44]. Another factor contributing to the occurrence of type 2 diabetes is the presence of long-term stress, which significantly affects the carbohydrate metabolism. Stressful situations contribute to an increase in glycaemia, which results in increased insulin secretion and impairment of insulin sensitivity of tissues. This factor also causes „snacking", especially sweet, low-value products. Irregular meals in combination with the inclusion of sweet snacks between meals in the diet may contribute to an increased risk of developing type 2 diabetes [8]. Inappropriate eating behavior is a leading risk factor for premature death and disability worldwide [9]. There are a number of nutritional factors that can prevent diabetes in healthy people and control glycemia in patients [40].

Lifestyle includes a range of everyday behaviors related to motivation, accepted values and needs, which include, among others, eating behavior. Unfavorable eating behavior contributing to the development of diabetes is primarily too much energy consumed with food. Excessive amount, exceeding the body's energy expenditure, in combination with low physical activity leads to the development of

overweight and obesity. Irregularity in meals can not only result in nutrient deficiencies, but also contribute to weight gain and the occurrence of diet-related diseases. Consuming a high-energy meal after a long break leads to a rapid, high increase in glycemia, which results in a rapid insulin release, which activates the process of fatty acid formation, resulting in the accumulation of excessive body fat. However, adherence to the recommended number of meals and regularity of eating them is not sufficient to maintain health. A properly balanced diet should contain wholesome protein, fats with a predominance of mono and polyunsaturated fatty acids and complex carbohydrates along with dietary fiber. There is a lot of scientific evidence confirming the adverse effects of certain groups of nutrients, which, if consumed in excessive amounts, can induce the development of type 2 diabetes. The most important of them are simple sugars, trans fats and saturated fatty acids [46].

Simple sugars are one of the main ingredients that increase the risk of developing type 2 diabetes. These substances are found in fruit juices, sweet fizzy drinks and sweets. In food products, they appear as added sugars, sweeteners or glucose-fructose syrup. The mechanism of action of these substances is based on the direct action of simple carbohydrates, which rapidly increase the level of glycemia, contributing also to weight gain and the development of diabetes. The high proportion of sweet drinks and sweets significantly increases the glycemic load of the diet, which in turn impairs glucose tolerance and the sensitivity of tissues to insulin. Moreover, coloring substances, such as caramel, found in sweet drinks, promote the development of diabetes by increasing the inflammation of the immune system [11, 22]. The effects of fatty acids can have both positive and negative effects on insulin secretion and its reception by tissues. Therefore, it is important to know the types of fats that may have a health-promoting or anti-health effect on the development of type 2 diabetes. The ingredients that should be significantly reduced in the diet are saturated fatty acids and trans fats. Saturated fatty acids are substances found mainly in animal fats such as butter, lard and fatty meats, while trans fats are most often found in hydrogenated margarines and processed foods [2, 12]. These ingredients not only contribute to the development of diabetes, but also disturb the lipid metabolism and increase the risk of cardiovascular complications [40].

Epidemiological studies increasingly indicate the dangers of smoking and alcohol consumption [18]. However, there are conflicting studies on the effects of alcohol on the human body. Some of them suggest that alcohol in moderate amounts reduces the risk of developing type 2 diabetes, even by 33-56% [34]. Nevertheless, many authors confirm that alcohol consumed in excess has negative effects on human health. It leads to an increased risk of diabetes, diseases of the cardiovascular system and the liver. Therefore, it should be emphasized that alcohol should be eliminated in the prevention of chronic diseases or limited to a minimum [40]. The mechanism by which smoking tobacco influences the increased risk of developing diabetes is not fully understood. Research suggests that smoking causes increased accumulation of visceral fat, which increases insulin resistance and leads to disease development. It should be noted that smoking cessation significantly reduces the risk of developing many diseases associated with type 2 diabetes, such as cardiovascular or lipid profile disorders [45].

The aim of the study was to evaluate the knowledge about risk factors for type 2 diabetes among secondary school students and to determine whether there are differences between the level of knowledge between girls and boys and between first-, second- and third-grade students.

## MATERIAL AND METHODS

The authors obtained the consent of the management to conduct the research. Moreover, study participants gave their written consent to participate in the study. The study involved 650 students (at the age of 16.9 ± 0.8 years) of comprehensive secondary schools in the Silesian Province, Poland. A self-constructed questionnaire consisted of the demographic part and the proper questions, enquiring about risk factors and potential complications of type 2 diabetes mellitus. The proper part was preceded by a pilot study among 30 students. Finally, 643 respondents, who answered the questions as instructed, were included in the analysis.

The characteristics of the studied group are presented in Table 1.

Table 1.Characteristics of the studied group

| Feature | | n | % |
|---|---|---|---|
| Gender | Women | 413 | 64.2 |
| | Men | 230 | 35.8 |
| Class | I | 227 | 35.3 |
| | II | 227 | 35.3 |
| | III | 189 | 29.4 |
| Total | | 643 | 100.0 |

When evaluating the students' knowledge, a correct answer was awarded 1 point, while wrong answers were not given any points. The maximum score was 36. The knowledge of students was determined using three levels: low <0–40%), average (40–70%) and (70–100%) high. The responses were analysed jointly

and after sex- and grade-based division. The results were collected in Microsoft Excel 2010, and statistical calculations were performed in Statistica 13.3 (TIBCO Inc.). First, it was checked if quantitative variables meet the normal distribution assumption; this was done with the *Shapiro-Wilk* W test and normality diagrams. Differences in the percentages of correct answers provided by girls and boys were evaluated with the *Mann-Whitney U* test. As for determining differences between the percentages of correct answers provided by first-, second- and third-graders, *the Kruskal-Wallis* ANOVA was applied; a two-sided post hoc test was used with Bonferroni correction. For all analyses, the value of $p<0.05$ was considered statistically significant.

## RESULTS

The joint analysis of the students' responses to the proper part of the questionnaire is presented in Tables 2–4.

The correct definition of type 2 diabetes was indicated by 63.9% of the respondents, more girls than boys (66.8% vs 58.7%), with most correct answers given by third-grade students (66.1%). The responses concerning risk factors for type 2 diabetes varied; 62.5% of the respondents stated that the risk increased with age. This answer was provided by more boys (69.1%) than girls (58.8%), and mostly by second-grade students (66.5%). The correct answer about age after which the risk of the disease increases was indicated by 40.9% of the students, including 40.4% of girls and 41.7% of boys. Most such answers were given by second-grade students (43.2%). The relationship between excessive body weight and increased risk of type 2 diabetes was indicated by 92.9% of the students, including 91.8% of girls and 94.8% of boys. Most correct answers were noted in third-graders. The abdominal type of obesity (android-type) was indicated as a risk factor for diabetes by 18.5% of the respondents, more girls (19.6%) than boys (16.5%), with most such answers given by first-grade students (20.7%). Cardiovascular diseases were selected by 52.3% of the students, including 52.1% of girls and 52.6% of boys; most correct answers were noted in the group of third-graders (61.9%). Hypertension as a risk factor for diabetes was indicated by 56% of the respondents, more girls than boys (57.6% vs 53.5%), with most such answers given by second-grade students (60.4%). Dyslipidaemia as a disease predisposing to type 2 diabetes was indicated by 67.7% of the students, including 69.5% of girls and 64.8% of boys; most such answers were noted in the group of first-grade students (69.6%) (Table 2).

Polycystic ovary syndrome (PCOS) as a disease that raises the risk of type 2 diabetes was indicated by only 4.8% of the respondents, more girls than boys (5.3% vs 3.9%), with most such answers given by third-graders (9.5%). Most of the students indicated a relationship between long-term use of steroid drugs and increased risk for type 2 diabetes. This response was provided by 74% of the students, including 77% of girls and 68.7% of boys, with most such answers in the group of third-graders (82%). Smoking was selected by 28.8% of the students, including 27.1% of girls and 31.7% of boys, and most second-graders (31.3%). Genetic predisposition was selected by 27.5% of the students, including 27.6% of girls and 27.4% of boys, and most second-graders (30.8%). Gestational diabetes as a risk factor for type 2 diabetes was indicated by 60% of the girls and boys, with most such responses in the group of third-graders, while neonatal birth weight (over 4 kg) was selected by 26.3% of the respondents, including 26.4% girls and 26.1% of boys, and most first-grade students (29.1%). The effect of eating habits on the occurrence of type 2 diabetes was indicated by 92.4% of the respondents, including 93.2% of girls and 90.9% of boys, and most third-graders - 93.7% (Table 3).

The responses concerning selected nutritious factors conductive to type 2 diabetes varied. Too calorific foods were selected by 27.6% of the students, including 27.3% of girls and 28.2% of boys. Most correct answers were noted in first-graders. Too high intake of mono- and disaccharides was selected by 92.6% of the students, including 92.7% of girls and 92.3% of boys; most such answers were noted in the group of third-graders (95.5%). Dietary fibre restriction as a factor leading to diabetes was indicated by 27.4% of the respondents, more girls than boys (28.6% vs 25.4%). Most correct answers were noted in first-graders (29.5%). Too high fat intake was selected by 43.9% of the students, including 45.7% of girls and 40.7% of boys, and most second-graders (46.9%). Too low physical activity levels were indicated by 85.7% of the students, more girls than boys: 86% and 85.2%, respectively. Most correct answers were noted in first-graders (87.2%). Chronic stress as a risk factor for type 2 diabetes was indicated by 51.2% of the respondents, more boys than girls (53% vs 50%), with most correct answers given by third-grade students (57.1%) (Table 4).

Prediabetes as a factor preceding diabetes was selected by 77.3% of the students, including 77.2% of girls and 77.4% of boys, and most second-graders (81.9%). Nerve injury as a consequence of untreated or inappropriately treated diabetes was indicated by 13.2% of the students, more boys than girls (17% vs 11.1%). Most correct answers were given by second-grade students (15%). Diabetic foot syndrome was selected by 73.4% of the students, including 73.4% of girls and 73.5% of boys, and most second-graders (74%). Kidney diseases as a complication of type 2

Table 2. The joint analysis of the students' responses to the selected questions evaluating the students' knowledge (part 1)

| Possible answers | Gender | | | | Class | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Women | | Men | | I | | II | | III | | | |
| | n | % | n | % | n | % | n | % | n | % | n | % |
| **1. Type 2 diabetes is a disease caused by:** | | | | | | | | | | | | |
| It decreases with age | 54 | 13.1 | 37 | 16.1 | 31 | 13.7 | 32 | 14.1 | 28 | 14.8 | 91 | 14.2 |
| Taking too much sugar | 83 | 20.1 | 58 | 25.2 | 55 | 24.2 | 50 | 22.0 | 36 | 19.1 | 141 | 21.9 |
| Progressive impairment of insulin secretion in conditions of insulin resistance | 276 | 66.8 | 135 | 58.7 | 141 | 62.1 | 145 | 63.9 | 125 | 66.1 | 411 | 63.9 |
| **2. The influence of age on the risk of developing type 2 diabetes:** | | | | | | | | | | | | |
| It decreases with age | 3 | 0.7 | 5 | 2.2 | 5 | 2.2 | 2 | 0.9 | 1 | 0.5 | 8 | 1.3 |
| It grows with age | 243 | 58.8 | 159 | 69.1 | 130 | 57.3 | 151 | 66.5 | 121 | 64.0 | 402 | 62.5 |
| It does not affect the occurrence of the disease | 167 | 40.5 | 66 | 28.7 | 92 | 40.5 | 74 | 32.6 | 67 | 35.5 | 233 | 36.3 |
| **3. There is an increased risk of developing type 2 diabetes in people :** | | | | | | | | | | | | |
| Over 45 years old | 167 | 40.4 | 96 | 41.7 | 87 | 38.3 | 98 | 43.2 | 78 | 41.3 | 263 | 40.9 |
| Over 60 years old | 85 | 20.6 | 63 | 27.4 | 53 | 23.3 | 54 | 23.8 | 41 | 21.7 | 148 | 23.0 |
| Regardless of age | 161 | 39.0 | 71 | 30.9 | 87 | 38.3 | 75 | 33.0 | 70 | 37.0 | 232 | 36.1 |
| **4. The effect of excessive body weight on the risk of developing type 2 diabetes:** | | | | | | | | | | | | |
| ↑ risk of getting illness | 379 | 91.8 | 218 | 94.8 | 207 | 91.2 | 209 | 92.1 | 181 | 95.8 | 597 | 92.9 |
| ↓ risk of getting illness | 5 | 1.2 | 3 | 1.3 | 1 | 0.4 | 4 | 1.8 | 3 | 1.6 | 8 | 1.2 |
| It does not affect the occurrence of the disease | 7 | 7.0 | 9 | 3.9 | 19 | 8.4 | 14 | 6.2 | 5 | 2.6 | 38 | 5.9 |
| **5. The influence of obesity on the risk of developing type 2 diabetes:** | | | | | | | | | | | | |
| Type 2 diabetes leads to obesity | 91 | 22.0 | 53 | 23.0 | 49 | 21.6 | 48 | 21.1 | 47 | 24.9 | 144 | 22.4 |
| Gynoid obesity ↑ ↑ risk of getting illness | 19 | 4.6 | 20 | 8.7 | 13 | 5.7 | 20 | 8.8 | 6 | 3.2 | 39 | 6.1 |
| Abdominal obesity ↑ risk of getting illness | 81 | 19.6 | 38 | 16.5 | 47 | 20.7 | 37 | 16.3 | 35 | 18.5 | 119 | 18.5 |
| It does not affect the occurrence of the disease | 222 | 53.8 | 119 | 51.8 | 118 | 52.0 | 122 | 53.7 | 101 | 53.4 | 431 | 53.0 |
| **6.1. Diseases predisposing to type 2 diabetes - cardiovascular diseases:** | | | | | | | | | | | | |
| Yes | 215 | 52.1 | 121 | 52.6 | 109 | 48.0 | 110 | 48.5 | 117 | 61.9 | 336 | 52.3 |
| No | 198 | 47.9 | 109 | 47.4 | 118 | 52.0 | 117 | 51.5 | 72 | 38.1 | 307 | 47.7 |
| **6.2. Diseases predisposing to type 2 diabetes - arterial hypertension:** | | | | | | | | | | | | |
| Yes | 238 | 57.6 | 123 | 53.5 | 130 | 57.3 | 137 | 60.4 | 94 | 49.7 | 361 | 56.0 |
| No | 175 | 42.4 | 107 | 46.5 | 97 | 42.7 | 90 | 39.6 | 95 | 50.3 | 282 | 44.0 |
| **6.3. Diseases predisposing to type 2 diabetes - dyslipidaemia:** | | | | | | | | | | | | |
| Yes | 287 | 69.5 | 149 | 64.8 | 158 | 69.6 | 157 | 69.2 | 121 | 64.0 | 436 | 67.8 |
| No | 126 | 30.5 | 81 | 35.2 | 69 | 30.4 | 70 | 30.8 | 68 | 36.0 | 207 | 32.2 |

Table 3. The joint analysis of the students' responses to the selected questions evaluating the students' knowledge (part 2)

| Possible answers | Gender | | | | Class | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Women | | Men | | I | | II | | III | | | |
| | n | % | n | % | n | % | n | % | n | % | n | % |
| **6.4. Diseases predisposing to type 2 diabetes - polycystic ovary syndrome:** | | | | | | | | | | | | |
| Yes | 22 | 5.3 | 9 | 3.9 | 8 | 3.5 | 5 | 2.2 | 18 | 9.5 | 31 | 4.8 |
| No | 391 | 94.7 | 221 | 96.1 | 219 | 96.5 | 222 | 97.8 | 171 | 90.5 | 612 | 95.2 |
| **6.5. Diseases predisposing to type 2 diabetes - respiratory diseases:** | | | | | | | | | | | | |
| Yes | 15 | 3.6 | 11 | 4.8 | 9 | 4.0 | 11 | 4.8 | 6 | 3.2 | 26 | 4.0 |
| No | 398 | 96.4 | 219 | 95.2 | 218 | 96.0 | 216 | 95.2 | 183 | 96.8 | 617 | 96.0 |
| **7.1. Selected factors affecting the prevalence of type 2 diabetes - long-term use of steroid drugs**: | | | | | | | | | | | | |
| Yes | 318 | 77.0 | 158 | 68.7 | 166 | 73.1 | 155 | 68.3 | 155 | 82.0 | 476 | 74.0 |
| No | 95 | 23.0 | 72 | 31.3 | 61 | 26.9 | 72 | 31.7 | 34 | 18.0 | 167 | 26.0 |
| **7.2. Selected factors affecting the prevalence of type 2 diabetes - long-term smoking:** | | | | | | | | | | | | |
| Yes | 112 | 27.1 | 73 | 31.7 | 58 | 25.6 | 71 | 31.3 | 56 | 29.6 | 185 | 28.8 |
| No | 301 | 72.9 | 157 | 68.3 | 169 | 74.4 | 156 | 68.7 | 133 | 70.4 | 458 | 71.2 |
| **7.2. Selected factors affecting the prevalence of type 2 diabetes - genetic determinants:** | | | | | | | | | | | | |
| Yes | 114 | 27.6 | 63 | 27.4 | 54 | 23.8 | 70 | 30.8 | 53 | 28.0 | 177 | 27.5 |
| No | 299 | 72.4 | 167 | 72.6 | 173 | 72.6 | 157 | 69.2 | 136 | 72.0 | 466 | 72.5 |
| **8.1. Pregnancy related factors affecting the prevalence of type 2 diabetes - prevalence of gestational diabetes mellitus:** | | | | | | | | | | | | |
| Yes | 248 | 60.0 | 138 | 60.0 | 126 | 55.5 | 134 | 59.0 | 126 | 66.7 | 386 | 60.0 |
| No | 165 | 40.0 | 92 | 40.0 | 101 | 44.5 | 93 | 41.0 | 63 | 33.3 | 257 | 40.0 |
| **8.2. Pregnancy related factors affecting the prevalence of type 2 diabetes - birth weight of the child:** | | | | | | | | | | | | |
| Less 4 kg | 25 | 6.1 | 17 | 7.4 | 17 | 7.5 | 14 | 6.2 | 11 | 5.8 | 42 | 6.5 |
| Above 4 kg | 109 | 26.4 | 60 | 26.1 | 66 | 29.1 | 49 | 21.6 | 54 | 28.6 | 169 | 26.3 |
| It does not affect the occurrence of the disease | 279 | 67.6 | 153 | 66.5 | 144 | 63.0 | 164 | 72.2 | 65 | 65.6 | 432 | 67.2 |
| **9. The influence of eating habits on the prevalence of type 2 diabetes:** | | | | | | | | | | | | |
| Yes | 385 | 93.2 | 209 | 90.9 | 210 | 92.5 | 207 | 91.2 | 177 | 93.7 | 594 | 92.4 |
| No | 28 | 6.8 | 21 | 9.1 | 17 | 7.5 | 20 | 8.8 | 12 | 6.3 | 49 | 7.6 |

Table 4. The joint analysis of the students' responses to the selected questions evaluating the students' knowledge (part 3)

| Possible answers | Gender | | | | Class | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Women | | Men | | I | | II | | III | | | |
| | n | % | n | % | n | % | n | % | n | % | n | % |
| **10.1. Selected nutritional factors that can lead to type 2 diabetes - too energetic meals::** | | | | | | | | | | | | |
| Yes | 105 | 27.3 | 59 | 28.2 | 59 | 28.1 | 57 | 27.5 | 48 | 27.1 | 164 | 27.6 |
| No | 280 | 72.7 | 150 | 71.8 | 151 | 71.9 | 150 | 72.5 | 129 | 72.9 | 430 | 72.4 |
| **10.2. Selected nutritional factors that can lead to type 2 diabetes - excessive amounts of simple sugars and disaccharides:** | | | | | | | | | | | | |
| Yes | 357 | 92.7 | 193 | 92.3 | 193 | 91.9 | 188 | 90.8 | 169 | 95.5 | 550 | 92.6 |
| No | 28 | 7.3 | 16 | 7.7 | 17 | 8.1 | 19 | 9.2 | 8 | 4.5 | 44 | 7.4 |
| **10.3. Selected nutritional factors that can lead to type 2 diabetes - dietary fiber restriction:** | | | | | | | | | | | | |
| Yes | 110 | 28.6 | 53 | 25.4 | 62 | 29.5 | 51 | 24.6 | 50 | 28.2 | 163 | 27.4 |
| No | 275 | 71.4 | 156 | 74.6 | 148 | 70.5 | 156 | 75.4 | 127 | 71.8 | 431 | 72.6 |
| **10.4. Selected nutritional factors that can lead to type 2 diabetes - excessive water supply:** | | | | | | | | | | | | |
| Yes | 10 | 2.6 | 5 | 2.4 | 3 | 1.4 | 9 | 4.3 | 3 | 1.7 | 15 | 27.4 |
| No | 375 | 97.4 | 204 | 97.6 | 207 | 98.6 | 198 | 95.7 | 174 | 98.3 | 579 | 97.5 |
| **10.5. Selected nutritional factors that can lead to type 2 diabetes - excessive consumption of animal fats:** | | | | | | | | | | | | |
| Yes | 176 | 45.7 | 85 | 40.7 | 90 | 42.9 | 97 | 46.9 | 74 | 41.8 | 261 | 43.9 |
| No | 209 | 54.3 | 124 | 59.3 | 120 | 57.1 | 110 | 53.1 | 103 | 58.2 | 333 | 56.1 |
| **11.1. Selected factors that can lead to type 2 diabetes - too little physical activity:** | | | | | | | | | | | | |
| Yes | 355 | 86.0 | 196 | 85.2 | 198 | 87.2 | 190 | 83.7 | 163 | 86.2 | 551 | 85.7 |
| No | 58 | 14.0 | 34 | 14.8 | 29 | 12.8 | 37 | 16.3 | 26 | 13.8 | 92 | 14.3 |
| **11.2. Selected factors that can lead to type 2 diabetes - extreme sports:** | | | | | | | | | | | | |
| Yes | 9 | 2.0 | 5 | 2.0 | 4 | 1.8 | 6 | 2.6 | 4 | 2.1 | 14 | 2.2 |
| No | 404 | 98.0 | 225 | 98.0 | 223 | 98.2 | 221 | 97.4 | 185 | 97.9 | 629 | 97.8 |
| **11.3. Selected factors that can lead to type 2 diabetes - chronic stress:** | | | | | | | | | | | | |
| Yes | 206 | 50.0 | 123 | 53.0 | 120 | 52.9 | 101 | 44.5 | 108 | 57.1 | 329 | 51.2 |
| No | 207 | 50.0 | 107 | 47.0 | 107 | 47.1 | 126 | 55.5 | 81 | 42.9 | 314 | 48.8 |
| **11.4. Selected factors that can lead to type 2 diabetes - maintaining body weight below the recommended standard:** | | | | | | | | | | | | |
| Yes | 70 | 16.9 | 42 | 18.3 | 50 | 22.0 | 31 | 13.7 | 31 | 16.4 | 112 | 17.4 |
| No | 343 | 83.1 | 188 | 81.7 | 177 | 78.0 | 196 | 86.3 | 158 | 83.6 | 531 | 82.6 |
| **11.5. Selected factors that can lead to type 2 diabetes - the occurrence of the disease in your spouse:** | | | | | | | | | | | | |
| Yes | 12 | 2.9 | 12 | 5.2 | 8 | 3.5 | 7 | 3.1 | 9 | 4.8 | 24 | 3.7 |
| No | 401 | 97.1 | 218 | 94.8 | 219 | 96.5 | 220 | 96.9 | 180 | 95.8 | 619 | 96.3 |

diabetes was selected by 37.5% of the respondents, more boys than girls (45.7% vs 32.9%), with most correct answers given by second-grade students (46%). Depression was selected by a total of 17.4% of the students, including 18.2% of girls and 21.3% of boys, and most third-graders (22.8%). Eye diseases were selected by 17.4% of the students, more boys than girls (19.1% and 16.5%). Most such answers were given by second-grade students (20.3%). Recurrent infections as a complication of diabetes were indicated by 21.3% of the students, more girls than boys: 23.5% and 17.4%, respectively, with most such answers in the group of first-graders (24.7%) (Table 5).

Table 5. The joint analysis of the students' responses to the selected questions evaluating the students' knowledge (part 4)

| Possible answers | Gender | | | | Class | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Women | | Men | | I | | II | | III | | | |
| | n | % | n | % | n | % | n | % | n | % | n | % |
| **11.6. Selected factors that may lead to type 2 diabetes - pre-diabetes:** | | | | | | | | | | | | |
| Yes | 319 | 77.2 | 178 | 77.4 | 175 | 77.1 | 186 | 81.9 | 136 | 72.0 | 497 | 77.3 |
| No | 94 | 22.8 | 52 | 22.6 | 52 | 22.9 | 41 | 18.1 | 53 | 28.0 | 146 | 22.7 |
| **12.1. Complications of type 2 diabetes - nerve damage:** | | | | | | | | | | | | |
| Yes | 46 | 11.1 | 39 | 17.0 | 23 | 10.1 | 34 | 15.0 | 28 | 14.8 | 85 | 13.2 |
| No | 367 | 88.9 | 191 | 83.0 | 204 | 89.9 | 193 | 85.0 | 161 | 85.2 | 558 | 86.8 |
| **12.2. Complications of type 2 diabetes - chronic obstructive pulmonary disease:** | | | | | | | | | | | | |
| Yes | 31 | 7.5 | 18 | 7.8 | 17 | 7.5 | 22 | 9.7 | 10 | 5.3 | 49 | 7.6 |
| No | 382 | 92.5 | 212 | 92.2 | 210 | 92.5 | 205 | 90.3 | 179 | 94.7 | 594 | 92.4 |
| **12.3. Complications of type 2 diabetes - asthma:** | | | | | | | | | | | | |
| Yes | 44 | 10.7 | 36 | 15.7 | 38 | 16.7 | 28 | 12.3 | 14 | 7.4 | 80 | 12.4 |
| No | 369 | 89.3 | 194 | 84.3 | 189 | 88.3 | 199 | 87.7 | 175 | 92.6 | 563 | 87.6 |
| **12.4. Complications of type 2 diabetes - diabetic foot syndrome:** | | | | | | | | | | | | |
| Yes | 303 | 73.4 | 169 | 73.5 | 167 | 73.6 | 168 | 74.0 | 137 | 72.5 | 472 | 73.4 |
| No | 110 | 26.6 | 61 | 26.5 | 60 | 26.4 | 59 | 26.0 | 52 | 27.5 | 171 | 26.6 |
| **12.5. Complications of type 2 diabetes - kidney disease:** | | | | | | | | | | | | |
| Yes | 136 | 32.9 | 105 | 45.7 | 81 | 35.7 | 73 | 32.2 | 87 | 46.0 | 241 | 37.5 |
| No | 277 | 67.1 | 125 | 54.3 | 146 | 64.3 | 154 | 67.8 | 102 | 54.0 | 402 | 62.5 |
| **12.6. Complications of type 2 diabetes - depression:** | | | | | | | | | | | | |
| Yes | 75 | 18.2 | 49 | 21.3 | 38 | 16.7 | 43 | 18.9 | 43 | 22.8 | 124 | 19.3 |
| No | 338 | 81.8 | 18.1 | 78.7 | 189 | 83.3 | 184 | 81.1 | 146 | 77.2 | 519 | 80.7 |
| **12.7. Complications of type 2 diabetes - eye diseases:** | | | | | | | | | | | | |
| Yes | 68 | 16.5 | 44 | 19.1 | 33 | 14.5 | 46 | 20.3 | 33 | 17.5 | 112 | 17.4 |
| No | 345 | 83.5 | 186 | 80.9 | 194 | 85.5 | 181 | 79.7 | 156 | 82.5 | 531 | 82.6 |
| **12.8. Complications of type 2 diabetes - diseases of the cardiovascular system:** | | | | | | | | | | | | |
| Yes | 224 | 59.1 | 146 | 63.5 | 134 | 59.0 | 141 | 62.1 | 115 | 60.8 | 390 | 60.7 |
| No | 169 | 40.9 | 84 | 36.5 | 93 | 41.0 | 86 | 37.9 | 74 | 39.2 | 253 | 39.3 |
| **12.9. Complications of type 2 diabetes - occurrence of recurrent infections:** | | | | | | | | | | | | |
| Yes | 97 | 23.5 | 40 | 17.4 | 56 | 24.7 | 48 | 21.1 | 33 | 17.5 | 137 | 21.3 |
| No | 316 | 76.5 | 190 | 82.6 | 171 | 75.3 | 179 | 78.9 | 156 | 82.5 | 506 | 78.7 |

The *Shapiro-Wilk* W test and normality diagrams showed that the percentage of correct answers did not meet the normality distribution assumption. There were statistically significant differences between the percentage of correct answers provided by first-, second- and third-grade students. There were no statistically significant differences between the percentage of correct answers provided by girls and boys (Table 6).

A two-sided post hoc test with Bonferroni correction revealed statistically significant differences between the percentage of correct responses provided by first- and third-grade students ($p<0.02$).

The knowledge of the respondents was classified to three levels. Average knowledge was noted for 89.6% of the students, including 89.3% of girls and 90% of boys, as well as 89.9% of first-, second- and third-graders each (Figure 1).

Forty-seven per cent of the respondents assessed their knowledge as insufficient. This included 46.7% of females and 47.4% of males as well as 41.4% of first-graders, 52.9% of second-graders and 46.6% of third-graders (Figure 2).

Table 6. The percentage of correct answers provided by the respondents to questions checking their knowledge

| Feature | | Median | Lower – upper quartile | Name and test result |
|---|---|---|---|---|
| Gender | Women | 54.17 | 47.22-61.11 | *Mann-Whitney* U test; p=0.890 |
| | Men | 52.78 | 47.22-61.11 | |
| Class | I | 52.78 | 47.22-61.11 | *Kruskal-Wallis* ANOVA; p=0.028 |
| | II | 52.78 | 47.22-61.11 | |
| | III | 55.56 | 50.00-61.11 | |
| Total | | 52.78 | 47.22-61.11 | |

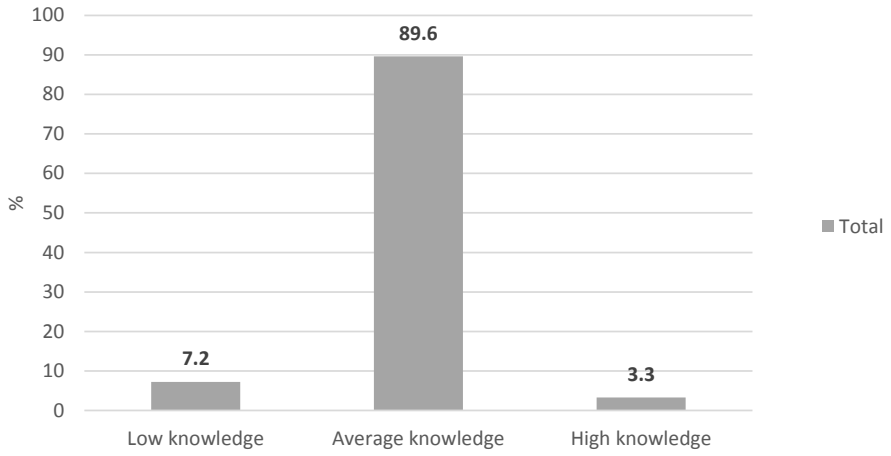


Figure 1. Knowledge on type 2 diabetes of the respondents

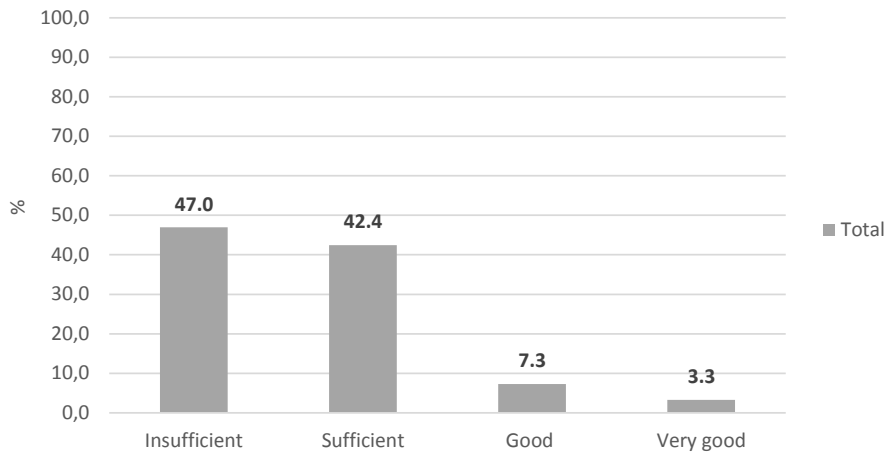


Figure 2. Self-assessment of the respondents' knowledge on type 2 diabetes

## DISCUSSION

Over the past years, prevention of type 2 diabetes mellitus has become one of the key challenges of contemporary medicine. The available research mostly focuses on the assessments of knowledge among diabetes patients rather than of risk factors for the disease, particularly in young people [40]. In this questionnaire, the correct definition of diabetes was recognised by 63.9% of the students. Similar results were obtained by *Rybarczyk-Szwajkowska,* who evaluated the knowledge of threats associated with lifestyle diseases among 475 students of higher schools in Polish city Łódź, University of Vienna and National Medical University in Kiev. The correct definition of type 2 diabetes was indicated by 66.67% of the respondents from Kiev, 51.35% of the respondents from Lodz and 40.6% of the students from Vienna [32]. In this study, 62.5% of the students indicated a relationship between age and increased risk of type 2 diabetes. This relationship is confirmed by the NHANES report which presented the prevalence of diabetes in given age groups: 3.7% for the group of 20 - 44 year-olds, 13.7% for the group of 45 - 64 year-olds and 26.9% for the group of ≥65 year-olds. These data are reflected in recommendations of the Polish Diabetes Association where the need for screening for diabetes mellitus every 3 years is underlined, particularly in individuals over 45 years of age [29]. In the present study, 40.9% of the respondents selected the age of 45 years as the age after which screening should begin. *Janeczek* et al. [16] obtained different results in their study regarding the knowledge about type 2 diabetes among nursing students. Only 3% of the respondents indicated the need for screening every 3 years after the age of 45 years, while 94% of the students selected annual screening.

Overweight and obesity more and more frequently contribute to the increased prevalence of type 2 diabetes. This is caused by long-term exposure of the liver to high concentrations of free fatty acids that cause progressive hyperinsulinaemia and tissue insulin resistance [11]. This mechanism is also described by *Szczeklik-Kumala* in a review on the treatment of diabetes among obese patients. Moreover, attention is paid to higher risk of type 2 diabetes among individuals with android obesity compared to those with gynoid obesity [38]. The present study revealed that 92.9% of the students thought that body weight was indeed a risk factor for the disease. A relationship between android obesity and increased risk of diabetes was indicated only by 18.5% of the examined secondary school students.

According to the recommendations of the Polish Diabetes Association, diabetes patients should undergo screening examinations for ischaemic heart disease (IHD). The guidelines of the European Society of Cardiology indicate that each patients with diabetes should be suspected of having IHD and the other way around: each patient with cardiovascular diseases should be suspected of having diabetes [41]. Cardiovascular diseases may therefore be classified both as a risk factor and a complication of diabetes. The present study shows that 53.2% of the students stated that cardiovascular diseases were risk factors and 60.7% believed them to be consequences of diabetes. Different outcomes were presented by *Ślusarska* et al., where 93.27% of the respondents indicated cardiovascular diseases as complications of type 2 diabetes [37]. In the meta-analysis on insulin resistance in the context of concomitant hypertension (HT), *Jasik* et al. demonstrated that, in most cases, HT precedes type 2 diabetes. The authors elucidate a relationship between primary HT and later development of diabetes with the impaired receptor signalling pathway for insulin, reduced blood flow and, in consequence, abnormal flow of glucose and insulin to peripheral tissues [17]. In the present study, 56% of the students indicated HT as a risk factor for type 2 diabetes. Another disease entity that is linked with type 2 diabetes is PCOS. Diabetes develops in 4 - 10% of women with this condition. *Janeczek* et al. demonstrated that 12.81% of the students indicated PCOS as a risk factor for type 2 diabetes [16]. The present study yielded different results as only 4.8% of the secondary school students decided that this answer was correct.

Glucocorticosteroids (GCS) are the most common drugs in the treatment of autoimmune diseases. Long-term use of these medications may lead to carbohydrate metabolism disorders, including type 2 diabetes. However, the risk mainly depends on therapy duration and dose of these drugs [25, 28]. In the present study, 74,0% of the students indicated long-term GCS treatment as a risk factor for type 2 diabetes. This results are confirmed by *Dąbrowski* and *Majdan*, who found a 1.4 - 1.5-fold greater risk of diabetes in patients treated with GCS compared with the healthy population [4].

According to the recommendations of the Polish Gynaecological Society, women with a history of gestational diabetes with normal blood sugar levels in the puerperium should be tested for glucose tolerance after 2 months. If the results are normal, tests should be repeated once every three years as part of type 2 diabetes prophylaxis [42]. The present study indicates that 60% of the students believe gestational diabetes to be a risk factor for type 2 diabetes. The study on genetic and clinical risk factors of diabetes mellitus, conducted by Kwak et al., reveals that the majority of women with a history of gestational diabetes are also diagnosed with type 2 diabetes in early postpartum

period and later in life [24]. Neonatal birth weight is also significant in the context of an increased risk of developing the disease. In the study of Mazur et al., it was demonstrated that the relationship between birth weight over 4 kg and later development of diabetes was significant [26]. In the present study, 26.3% of secondary school students indicated this relationship.

Eating habits are crucial factors involved in the pathogenesis of type 2 diabetes. The present study demonstrates that 92.4% of the students concur with this statement. Different results have been presented by Seń et al. They evaluated behaviours and knowledge about nutrition among university students in Wroclaw, Poland. The authors showed that 74% of the students of the Academy of Medicine, 58% of the students of Wroclaw University of Environmental and Life Sciences and 57% of the students of Wrocław University of Science and Technology stated that diabetes mellitus was a consequence of wrong eating habits [36]. In the present study, 27.6% of the students indicated that excessive energy intake was a cause of increased risk of diabetes. *Przybylska* et al. demonstrated a relationship between positive energy balance that leads to overweight and obesity and, in consequence, to diabetes [30]. In the present study, 27.6% of the students indicated that intake of excessively calorific foods was one of the risk factors. Another factor conductive to the disease is excessive share of simple sugars in daily diet [20]. The present study shows that 92.6% of the students indicated excessive sugar intake as a significant factor that might speed up the development of diabetes. Low physical activity is another modifiable factor affecting the development of type 2 diabetes. In this study, 85.7% of the respondents agreed with this statement. Noczyńska et al. report different results: 55.7% of the respondents indicated sports as a factor that may lower the risk of the disease [27].

In the study of *Dąbska* and *Żołnierczuk-Kieliszek*, 84.0% of the respondents stated that neuropathies manifesting with numbness and tingling were complications of type 2 diabetes [6]. The present study yielded different results. Only 12.2% of the students responded that neuropathies were a complication of diabetes, while 57.9% indicated diabetic foot syndrome as a complication of the disease. It was also found that 37.5% of the students indicated renal diseases as a possible complication of type 2 diabetes. Different results were obtained by *Roomizadeh* et al. who evaluated the knowledge about risk factors of kidney diseases. Only 12.7% of the respondents indicated diabetes mellitus as a risk factor [31]. Depression, as a real complication of diabetes, was indicated by 19.3% of the students, while *Dąbska* et al. observed 55% and 61% of responses that diabetes carried emotional complications and required support of the family and friends [5].

The analysis of the present study demonstrated that 60.7% of the students indicated cardiovascular diseases as a serious complication of diabetes mellitus. Similar outcomes have been presented by *Ying Xu* et al., who evaluated the knowledge of Chinese students about diabetes [43]. The present study shows that 21.3% of the students indicated recurrent infections as possible complications of diabetes. Khan et al. reported similar results from a study on the knowledge of students about diabetes: 29% of the respondents pointed to these complications [19]. The present study shows that the most numerous group of the respondents were those with an average level of knowledge, i.e. those who provided 40 - 70% of correct answers (89.6%). *Kocka* and *Dziedzic* [21] obtained different results: the average level of knowledge was noted in only 22.4% of the students, who provided 50 - 75% of correct answers, whilst most of the respondents were characterised by a low level of knowledge (74.3%) and provided less than 50% of correct answers.

The limitation of the study is the regional nature of the study. Therefore, the authors recommend caution in interpreting the results in relation to the population.

## CONCLUSIONS

1. The knowledge on risk factors for type 2 diabetes mellitus among secondary school students was varied. The most numerous group was characterized by an average level of knowledge.
2. There were no statistically significant differences between the percentage of correct answers provided by girls and boys.
3. There were statistically significant differences between the percentage of correct answers provided by first-, second- and third-grade students.
4. Our research shows that educational activities should be undertaken, especially about modifiable risk factors for type 2 diabetes.

**Conflict of interest**

*The authors declare no conflict of interest*

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ORIGINAL ARTICLE

# SURVIVAL IN MEN DIAGNOSED WITH PROSTATE CANCER IN POLAND IN YEARS 2000 – 2014 COMPARED TO EUROPEAN COUNTRIES BASED ON CONCORD-3

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## ABSTRACT

**Background.** Wealthy countries have observed in recent decades a fast-growing number of prostate patients, who require treatment and long-term cancer care. This trend seems to be connected with some demographic changes such as aging societies, better access to diagnostic methods with high sensitivity as well as large-scale secondary prevention (prostate cancer screening at early stage before clinical manifestation). Secondary prevention is becoming more accessible and widely applied. The expected effect of prevention is to improve overall survival while the mortality trend is decreasing. The prevention success requires highly effective healthcare system that must manage additional burden which is a consequence of the need to provide optimal treatment and healthcare in a big group of cancer patients diagnosed in effective prevention programms. According to the National Cancer Registry (NCR) the number of incidence from year 1980 – 1731 cases rose in year 2013 to 12 162 cases. Apart from incidence and mortality rates, the 5-year survival is a significant factor for the assessment of a population healthcare and healthcare system efficiency. The prognosis related to prostate incidence is 22 344 men in year 2025 in comparison to 12 162 in year 2013 – that would be a double rise in incidence. CONCORD-2 results (years 1995-2009) showed, among the others, that cancer curability for some cancers, including prostate cancer improved. In year 2018 the results of CONCORD-3 were published (years 2000-2014) showing a rising trend in improvement in prostate cancer curability in Poland

**Objective.** The objective was to analyse the 5-year survival in prostate cancer patients in Poland, and in each of 16 voivodships, with the focus on changes in years 2000 – 2014 in comparison to European trends.

**Material and Methods.** The analysis was based on the 5-year net survival (estimated in CONCORD-3) in prostate cancer patients diagnosed in Poland (NCR national data) and in all Polish voivodships.

The 5-year survival of prostate cancer patients and its changes in years 2000 – 2014 compared between 16 voivodships, Poland in total and 28 European countries.

**Results.** In Poland in years 2010 – 2014 the 5-year survival in prostate cancer patients was 78.1%, and compared to years 2000 – 2004 rose by 9.3 percentage points. Despite a systematic improvement in survival the differences between individual voivodships in Poland remained. In 6 voivodships the survival was higher than average for Poland and ranged from 80 to 82%. The lowest survival was in Opolskie voivodship – 72.3%. On a European scale, the curability of prostate cancer at that time was over 90% (9 countries), while Poland was among 5 countries whose total survival rate was less than 80% (from 72.3% - Opolskie voivodship to 83.6% –- Pomeranian voivodship).

**Conclusions.** The 5-year survival in prostate cancer patients in years 2010 – 2014 in Poland was significantly lower in comparison to Western Europe countries, and favourable trends on a regional level in Poland were too slow to overcome high differentiation in Europe. It is expected that changing the structure and organisation of cancer care in Poland into a modern National Oncology Network Comprehensive Cancer Care Network, together with the use of the experiences from European projects, including iPAAC and better financing will contribute to improvement in prostate cancer treatment in Poland.

**Key words:** *prostate cancer, curability, mortality trend, cancer care, CONCORD-3*

## STRESZCZENIE

**Wprowadzenie.** Wskutek starzenia się społeczeństwa, a także w wyniku postępu medycyny i wprowadzenia na szeroką skalę programów profilaktycznych liczba chorych na choroby nowotworowe wymagających leczenia i opieki w ostatnich latach szybko wzrasta – wykrywane jest więcej zmian nowotworowych o wczesnym stopniu zaawansowania wymagających dalszej diagnostyki. Profilaktyka wtórna staje się coraz łatwiej dostępna i szeroko stosowana. Oczekiwanym efektem profilaktyki jest poprawa przeżyć ogółem przy równoczesnym obniżającym się trendzie umieralności. Niezbędnym warunkiem sukcesu profilaktyki jest wysoka sprawność systemu lecznictwa, który musi podołać dodatkowemu

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obciążeniu wynikającemu z potrzeby zapewnienia optymalnego leczenia i opieki dużej grupie chorych z rakiem wykrytym w skutecznych działaniach profilaktycznych. Prognozy Krajowego Rejestru Nowotworów (KRN) dotyczące zachorowań na raka prostaty przewidują, że w roku 2025 roku zachoruje 22 344 mężczyzn ; w porównaniu do 12 162 w roku 2013 – byłby to prawie dwukrotny wzrost zachorowań. Oprócz zachorowalności i umieralności istotnym elementem oceny stanu zdrowia społeczeństwa oraz skuteczności systemu opieki zdrowotnej jest wskaźnik 5-letnich przeżyć. Wyniki CONCORD-2 (obejmujące lata 1995 – 2009) wykazały m.in., że w Polsce wyleczalność na niektóre nowotwory, w tym i na raka gruczołu krokowego poprawiła się. W 2018 roku zostały opublikowane wyniki trzeciej edycji projektu, obejmujące lata 2000 – 2014, które wskazują na utrzymywanie się trendu poprawy wyleczalności nowotworu gruczołu krokowego w Polsce.

**Cel.** Analiza wskaźnika 5-letnich przeżyć chorych na raka gruczołu krokowego w latach 2000 – 2014 w Polsce, w tym w 16 województwach, ze szczególnym uwzględnieniem zmian na tle trendów w krajach europejskich.

**Materiał i metody.** Badania oparto o wartości wskaźnika 5-letnich przeżyć (net survival) obliczone w projekcie CONCORD -3 oraz dane krajowe z Krajowego Rejestru Nowotworów (KRN). Wskaźnik 5-letnich przeżyć chorych na raka gruczołu krokowego a także jego zmiany, w latach 2000-2014, porównano między 16 województwami oraz w Polsce ogółem ze wskaźnikami 5-letnich przeżyć z 28 krajów europejskich.

**Wyniki.** W Polsce ogółem w latach 2010 – 2014 wskaźnik 5-letnich przeżyć chorych na raka prostaty wynosił 78.1% i w porównaniu do lat 2000 – 2004 jego wartość wzrosła o 9.3 pkt%. Pomimo systematycznej poprawy przeżyć utrzymywało się zróżnicowanie pomiędzy województwami w Polsce. W sześciu województwach wartość wskaźnika była wyższa niż w Polsce ogółem i wynosiła od 80 do 82%. Najniższe przeżycia były w woj. opolskim: 72.3%. W skali Europy wyleczalność raka gruczołu krokowego w tym okresie sięgała ponad 90% (9 krajów) natomiast Polska była wśród 5 krajów, których przeżycia ogółem były niższe niż 80% (od 72.3% - woj. opolskie do 83.6% - woj. pomorskie).

**Wnioski.** W Polsce wskaźnik 5-letnich przeżyć chorych na raka gruczołu krokowego w latach 2010 – 2014 był znacząco niższy w porównaniu z krajami Europy Zachodniej, a korzystne trendy na poziomie regionalnym w Polsce były zbyt wolne aby zniwelować znaczące zróżnicowanie w Europie. Oczekuje się, że przekształcenie struktury i organizacji lecznictwa onkologicznego w Polsce w nowoczesną Krajową Sieć Onkologiczną Szpitali, z wykorzystaniem doświadczeń z projektów europejskich, w tym iPAAC, wraz z wyższym poziomem finansowania przyczynią się do poprawy wyleczalności raka prostaty w Polsce.

**Słowa kluczowe:** *rak prostaty, wyleczalność, trend umieralności, oncological treatment,CONCORD-3*

## INTRODUCTION

Wealthy countries have observed in recent decades a fast-growing number of prostate patients, who require treatment and long-term cancer care. This trend seems to be connected with some demographic changes such as aging societies, better access to diagnostic methods with high sensitivity as well as large-scale secondary prevention programmes (prostate cancer screening at early stage before clinical manifestation).

The prevention success requires proper healthcare financing and highly effective healthcare system that must manage additional burden which is a consequence of the need to provide optimal treatment and healthcare in a big group of cancer patients diagnosed in effective prevention programmes.

Since the late 90's the analysis of incidence and mortality trends have been conducted in Poland, and their results are systematically published in modern forms by the National Cancer Registry. According to the National Cancer Registry the number of incidence from year 1980 – 1731 cases rose in year 2013 to 12 162 cases [16].

Since the modern assessment of cancer control in Organisation for Economic Cooperation and Development (OECD) countries includes the 5-year net survival together with incidence and mortality rates, availability of data on cancer survival and the 5-year survival is particularly important [17]. Apart from incidence and mortality rates, the 5-year survival is a significant factor for the assessment of a population health and healthcare system efficiency. Data from National Registries must follow very strict CONCORD standards. Standardised methods of data collection and analysis in the CONCORD-study [4, 5 ] allows for comparison between the voivodships and monitoring of the survival rate changes over time.

The 5-year net survival and survival trends for patients worldwide were estimated and published in CONCORD-3 based on data on 37 513 025 patients from 5 continents [5].

CONCORD-3 obtained the population data from 16 voivodships in Poland from the National Cancer Registry. All data was processed in a systematic quality control within the CONCORD procedures, which allowed for correct conclusions based on time trends' analysis and comparisons between countries and regions.

CONCORD-2 results (years 1995-2009) showed, among the others, that cancer curability for some cancers, including prostate cancer improved [4]. In year 2018 the results of CONCORD-3 were published (years 2000-2014) [5] showing a rising trend in improvement in prostate cancer curability in Poland.

## Objective

The objective was to analyse the 5-year survival in prostate cancer patients in Poland, and in each of 16 voivodships, with the focus on changes in years 2000 – 2014 in comparison to European trends.

## MATERIAL AND METHODS

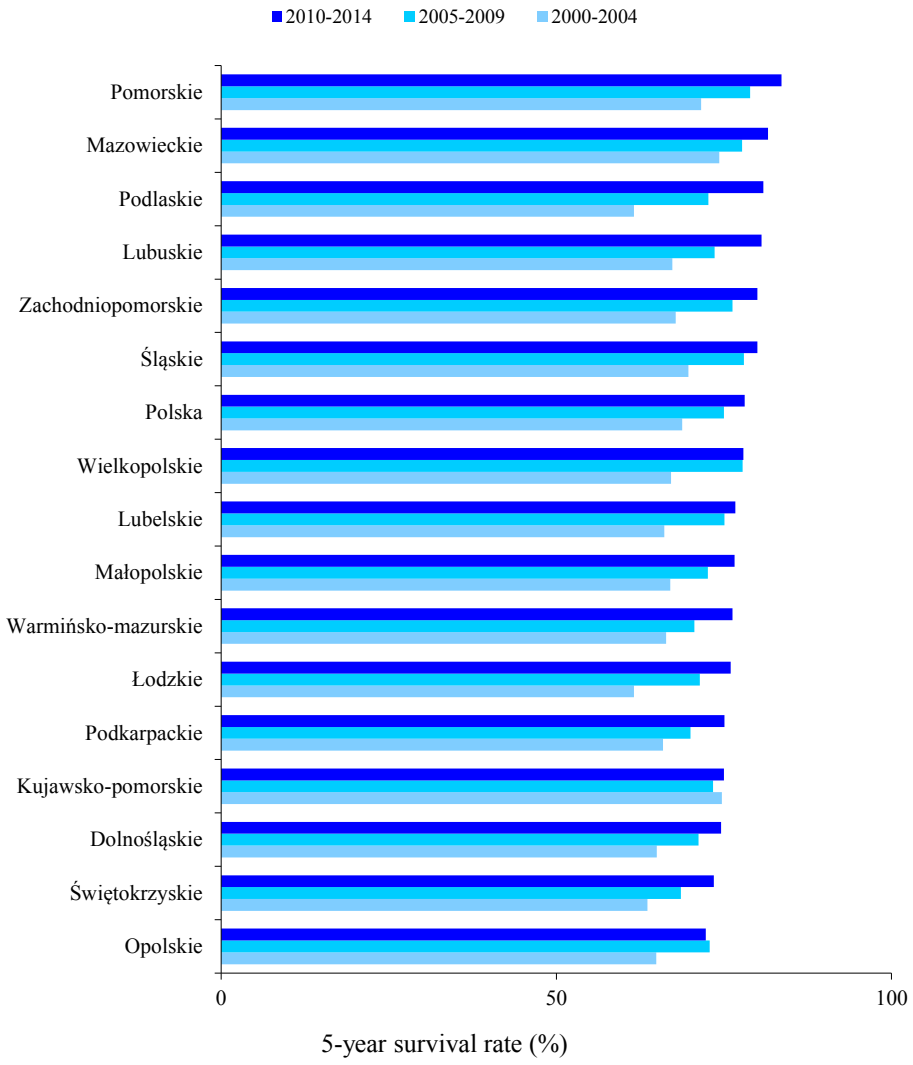
The study compares the 5-year survival in male prostate cancer patients and its changes in years 2000 – 2014 in 16 voivodships in Poland. The results are also discussed in comparison to other European countries.

The analysis was based on the 5-year net survival (estimated in CONCORD-3) in prostate cancer patients diagnosed in Poland (national data) and in all Polish voivodships. Incidence and quality data are presented in Table 1. Moreover, the 5-year survival for Poland, including individual voivodships was compared with the results from 28 European countries (Figure 2, Table 2).

Within CONCORD-3 study the 5-year survival was estimated based on data from national or regional registries in 322 administrative regions worldwide which met the criteria described by International Agency for Research on Cancer (IARC) [18], mainly in the scope of cancer completeness and detection.

Further systematic data quality control within CONCORD-3 covered the cancer follow-up and death time information if patients died during follow-up (till 31 December, 2014). Missing data was completed in the cooperation with cancer registries.

The survival analysis does not cover the cases lost from observation or with unconfirmed diagnosis of malignancy, unspecified morphological changes and follow-up shorter than 24 hours. The estimates and analysis of results were performed and published by one research centre – The London School of Hygiene




*Net survival

Figure1. Differentiation and changes in the 5-year survival rate* in patients diagnosed with prostate cancer in Poland and in 16 Polish voivodships in years 2000 - 2014

Table 1. Number of cases, data quality and 5-year survival rate*) of patients diagnosed in years 2000-2014 for prostate cancer and changes in survival rate in years 2000-2014 in Poland

| | No of cases included into survival analysis | Excluded (%) | Verified microscopically (%) | 5-year survival rate (%) | | Absolute difference (pkt%) |
|---|---|---|---|---|---|---|
| | 2000 - 2014 | | | 2000-2004 a | 2010-14 b | 2000-14 b-a |
| Polska | 131099 | 2.7 | 94.3 | 68.8 | 78.1 | 9.3 |
| Dolnośląskie | 9248 | 0.6 | 84.8 | 65.8 | 73.4 | 7.6 |
| ujawsko-pomorskie | 6951 | 1.1 | 98.3 | 74.7 | 75.0 | 0.3 |
| Lubelskie | 7628 | 5.2 | 92.4 | 66.1 | 76.7 | 10.6 |
| Lubuskie | 3056 | 1.9 | 97.3 | 57.3 | 80.6 | 23.3 |
| Łódzkie | 7446 | 2.7 | 88.0 | 61.6 | 76.0 | 14.4 |
| Małopolskie | 11487 | 3.4 | 95.3 | 67.0 | 76.6 | 9.6 |
| Mazowieckie | 18407 | 0.1 | 94.6 | 74.3 | 81.6 | 7.3 |
| Opolskie | 3061 | 0.3 | 98.6 | 64.9 | 72.3 | 7.4 |
| Podkarpackie | 7572 | 3.8 | 98.6 | 65.9 | 75.1 | 9.2 |
| Podlaskie | 3981 | 7.3 | 93.9 | 61.6 | 80.9 | 19.3 |
| Pomorskie | 9379 | 6.0 | 98.5 | 71.6 | 83.6 | 12.0 |
| Śląskie | 17032 | 0.8 | 93.8 | 69.7 | 80.0 | 10.3 |
| Świętokrzyskie | 5200 | 2.3 | 94.2 | 63.6 | 73.5 | 9.9 |
| Warmińsko-mazurskie | 4035 | 0.6 | 98.3 | 66.4 | 76.3 | 9.9 |
| Wielkopolskie | 12004 | 5.0 | 97.5 | 67.1 | 77.9 | 10.8 |
| Zachodniopomorskie | 4612 | 5.2 | 87.9 | 67.8 | 80.0 | 12.2 |

*) Net survival

and Tropical Medicine, which guarantees uniformity of processes and results' interpretation.

Polish data was analysed and provided by the National Cancer Registry in the cooperation with Voivodship Cancer Registries which covered the registration of all 16 administrative regions in Poland.

The analysis for cancer curability and its changes in Poland and 16 Polish voivodships in comparison to selected European countries was evaluated based on the survival difference in years 2000 – 2004 and 2010 – 2014. Mortality trends from the National Cancer Registry and the overview of Polish healthcare condition were used to discuss the cancer burden in Poland.

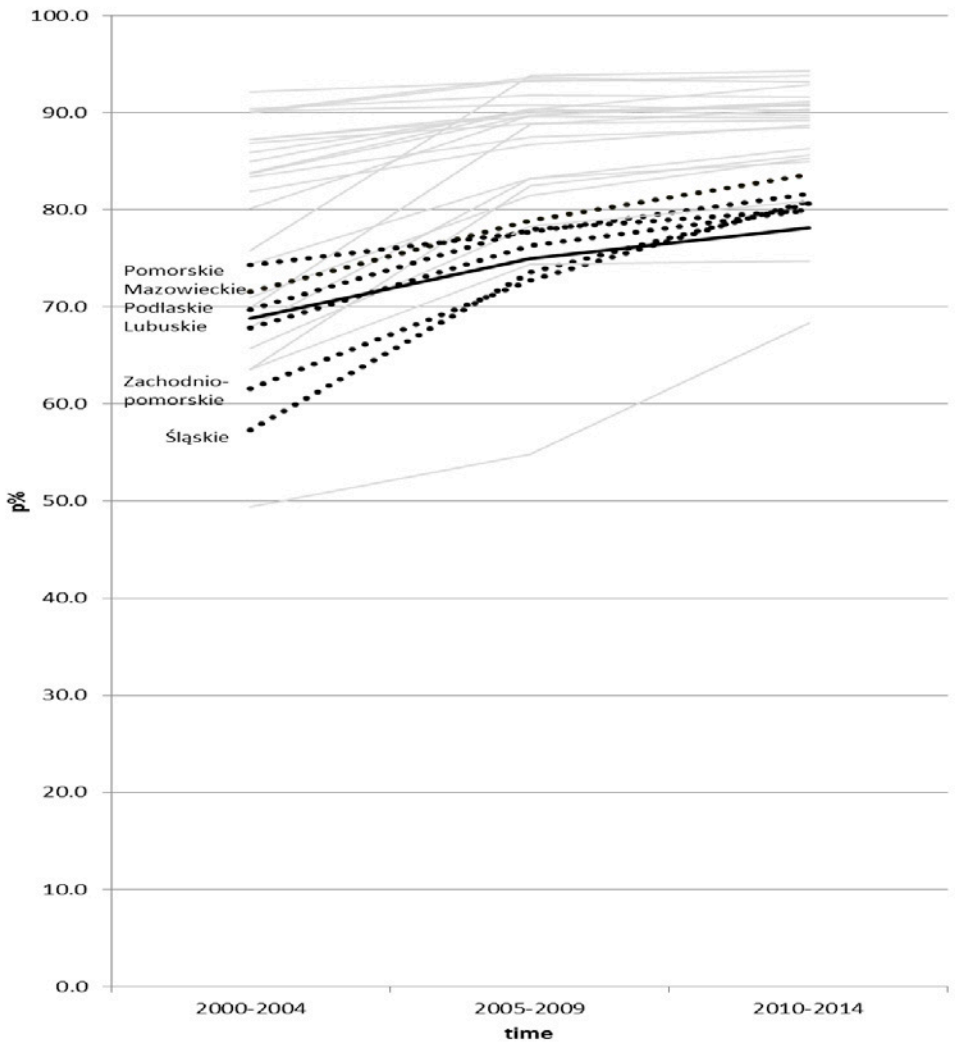
## RESULTS

Figure 1 shows the 5-year survivals in men diagnosed with prostate cancer in years 2000 – 2004 and 2010 – 2014. In Poland in years 2000 – 2004 the 5-year survival in prostate cancer patients was 68.8% (Figure 1, Table 1). The highest was in patients in Kujawsko-Pomorskie voivodship (74.7%), Mazowieckie voivodship (74.3%), Pomorskie voivodship (71.6%) and Śląskie voivodship (69.7%). In remaining 12 voivodships the 5-year survival was lower than the average survival for Poland (Figure 1, Table 1). The lowest survival was in Łódzkie and Podlaskie voivodships – 61.6%.

In Poland in years 2010 – 2014 the 5-year survival in prostate cancer patients was 78.1%, and compared to years 2000 – 2004 rose by 9.3 percentage points. Despite a systematic improvement in survival the differences between individual voivodships in Poland remained. In 6 voivodships the survival was higher than average for Poland and ranged from 80 to 82%. The lowest survival was in Opolskie voivodship – 72.3%.

Despite a systematic improvement in survival in Poland in years 2010 – 2014 compared to years 2000 – 2004 the prostate cancer curability was lower than in the majority of European countries. In 9 countries the survival was above 90%, and only in 5 countries, including Poland, the survival was lower than 80% (Figure 2, Table 2).

As presented in Figure 2, differentiation in survival in years 2000 – 2004 in Europe was significant, and the 5-year survival rate ranged from 92.1% in Belgium to 49.4% in Bulgaria. In that period the 5-year survival between Polish voivodships ranged from 61.6 percentage points (Łódzkie and Podlaskie voivodships) to 74.7 percentage points (Kujawsko-Pomorskie voivodship) – Figure 1.




*Net survival,
** Dotted lines indicate voivodships with the survival rate above the country's average: Pomorskie, Mazowieckie, Podlaskie, Lubuskie, Zachodniopomorskie, Śląskie; black line – Poland (total); grey lines – European countries
Figure 2. The 5-year survival rate* in patients diagnosed with prostate cancer in Poland compared to European countries in years 2000-2014**

Table 2. Number of cases, data quality and 5-year survival rate*) of patients diagnosed for prostate cancer in years 2000-2014 and changes in survival rate in European countries and several Polish voivodships in years 2000-2014. (Number of cases. Data quality).

| Country | No. of cases included into survival analysis | Excluded (%) | Verified microscopically (%) | 5-year survival rate (%) | | Absolute difference (pkt%) |
|---|---|---|---|---|---|---|
| | 2000-2014 | | | 2000-2004 a | 2010-2014 b | 2014-2000 b-a |
| Austria | 78 087 | 3.3 | 98.9 | 90.1 | 90. 8 | 0. 7 |
| Belgium | 100 855 | 0 | 99.7 | 92.1 | 93.2 | 1. 1 |
| Bułgaria | 27 814 | 5.8 | 92.5 | 49.4 | 54. 8 | 5. 4 |
| Croatia | 23 908 | 6.9 | 85.7 | 65.7 | 78.3 | 12.6 |
| Czech R. | 22 066 | 0.9 | 96.4 | 71.0 | 81.5 | 10.5 |
| Denmark | 55 055 | 0 | 98.3 | 63.6 | 82.5 | 18.9 |
| Estonia [1)] | 10 139 | 4 | 94.4 | 67.9 | 83.2 | 15.3 |
| Finland | 67.538 | 0 | 99.5 | 90.0 | 93.4 | 3.4 |
| France | 92.614 | 0.6 | 99.6 | 90.1 | 93.6 | 3.5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Spain [2)] | 65 866 | 1.9 | 92.0 | 85 | 90.4 | 5.4 |
| Netherlands | 144 281 | 0.6 | 97.5 | 83.4 | 87.5 | 4.1 |
| Ireland [3)] | 38 329 | 1.1 | 93.3 | 83.7 | 89.7 | 6 |
| Lithuania [4)] | 30.954 | 2.5 | 94.6 | 75.8 | 93.8 | 18 |
| Latvia | 13 151 | 0.6 | 100.0 | 69.9 | 88.8 | 18.9 |
| Malta [5)] | 2 130 | 2.6 | 94.3 | 81.9 | 86.4 | 4.5 |
| Germany | 309 196 | 7.4 | 98.9 | 90.4 | 91.8 | 1.4 |
| Poland | 134 755 | 2.7 | 94.3 | 68.8 | 75.0 | 6.2 |
| Portugal | 66 072 | 0.2 | 95.8 | 87.2 | 90.0 | 2.8 |
| Romania [6)] | 1 512 | 13.7 | 96.0 | 78.2 | 77.1 | -1.1 |
| Slovakia [7)] | 15 378 | 6.2 | 98.1 | 63.6 | 74.4 | 10.8 |
| Slovenia [8)] | 15 270 | 2.2 | 93.5 | 74.4 | 83.2 | 8.8 |

*)Net survival

[1)] Estonia 2000-2012, [2)] Spain 2000-2013, [3)] Ireland 2000-2013, [4)] Lithuania 2000-2012, [5)] Malta 2000-2013, [6)]Romania 2006-2012, [7)] Slovakia 2000-2010, [8)]Slovenia 2000-2013

In years 2010 – 2014 the survival rose in every country and region across Europe, however, the changes were insufficient to level the differences in Europe; the survival was 93.6% in France and 54.8% in Bulgaria. In Poland the survival in that period ranged from 72.3% (Opolskie voivodship) to 83.6% in Pomorskie voivodship. In Europe the lowest survival was in Bulgaria and some voivodships in Poland. However, in Pomorskie, Mazowieckie, Podlaskie, Lubuskie, Zachodniopomorskie, Śląskie voivodships the survival was within the European range (Figure 2).

## DISCUSSION

In years 2000 – 2014 favourable changes in Poland resulted in a higher 5-year survival in prostate cancer patients. However, the changes varied to some extent, and consequently, the differentiation between voivodships remained. The greatest changes were in Lubuskie and Podlaskie voivodships (19 and 23 percentage points respectively), the lowest changes in Kujawsko-Pomorskie and Mazowieckie voivodships (Table 1).

Based on the World Health Organisation data, *Wong* et al. [24] and *Bray* et al. [6] performed the analysis of prostate cancer incidence rate and mortality rate trends in more than 30 countries worldwide in years 1998 – 2012. It showed that in the majority of countries, including Poland, incidence rose and mortality decreases in that period.

In years 2012 and 2013 the mortality trend in Poland changed and became a rising one, with mortality incidence growing. In that period the 5-year survival also rose [10, 11, 19].

According to *Wojtyniak* et al. [23] there was a rise in mortality in 13 voivodships in Poland in years 2015 – 2016 in comparison to years 2000 – 2001, whereas in 3 voivodships: Wielkopolskie, Kujawsko-Pomorskie and Pomorskie the trend was opposite – mortality decreased. The rising mortality trend is connected with demographic changes in Europe and Poland. Due to the aging society the number of men above the age of 45 was higher in years 2010 – 2014 than in years 2000 – 2004 [16]. Moreover, early prostate cancer detection with the PSA test and prostate ultrasound became more available resulting in more prostate cancer patients referred to follow-up care and treatment.

Effective treatment depends on medical staff employment, adequate healthcare financing and effective organisation.

That epidemiological trend in Poland overlapped with unfavourable conditions for patients beginning cancer treatment. According to OECD) [17] the number of medicine doctors in Poland in year 2016 was the lowest in comparison to other European countries – 2.4 per 1000 inhabitants. The European average was 3.6 per 1000 inhabitants, whereas in Poland that number had not changed since year 2000, while the number of doctors in other European countries systematically rose [17]. Nurse employment in Poland was one of the lowest in Europe – 5.2 per 1000 inhabitants while the European average was 8.4 per 1000 inhabitants, reaching 16.2 in Denmark and 14.3 in Finland.

The data presented in Surveillance, Epidemiology and End Results Program, USA (SEER) [12] shows that among 332 075 prostate cases diagnosed in years 2010 – 2016 in the United States 76% was local stage prostate cancer. The 5-year survival for those patients was 100%. In France in years 2010 – 2014 the 5-year survival was also very high – 93.6 percentage points (Table 2). It suggests favourable diagnostic procedures in both countries, while an increased number of patients referred to further treatment after early diagnosis did not contribute to healthcare system burden.

B*ulliard* and *Chiolero* [7] suggest that large-scale prevention, e.g. intensive early diagnosis, including prostate cancer, or population screenings lead to overdiagnosis, and consequently, the fast rise in patients referred to further diagnosis may lead to overtreatment. That may result in healthcare system burden and unfavourably influence the healthcare system quality – the impact is put on detection of no or little prostate cancer progression cases. The more serious cases may not be sufficiently diagnosed [7]. There has been a rise in the 5-year survival in Poland, which is the result of cancer prevention. At the same time, however, mortality rises, which may result from an insufficient healthcare system, for example longer waiting time for critically ill patients, lower treatment quality, complications and inadequately treated accompanying diseases.

The Polish Supreme Audit Office (NIK) data [22] shows that cancer care treatment in Poland faces a great number of obstacles, including the healthcare system ones. The most crucial problems in years 2000 – 2014 were:

1. low cancer care financing (42 EUR per person in year 2014, whereas 85 EUR in the Czech Republic and 156 EUR in France [3],
2. improper cancer care network (in year 2012 oncological procedures were performed by 806 hospitals). However, the number of patients differed between hospitals – 80% of cancer patients was treated in about 10% out of 806 hospitals [9],
3. understaffing, particularly of pathomorphologists and nurses.

Moreover, according to NIK report 2018, in comparison to Western Europe Polish patients were provided with less access to modern technology, including innovative medicines (53% out of 94 new cancer care medicines registered in the EU were unavailable in Poland). It may have been the consequence of excessively long registration process of new technologies in guaranteed medical services, which was confirmed by the Supreme Audit Office report [22].

The National Cancer Registry prognoses in Poland a rise in cancer incidence in men by 13.9% (up to 91 999 cases) and by 25.1% in women (up to 84 200 cases) until year 2025 in comparison to year 2014 [8]. The prognosis related to prostate cancer incidence is 22 344 men in year 2025 in comparison to 12 162 in year 2013 – that would be a double rise in incidence [8].

For years 2016 – 2024 was passed by the Polish Parliament in year 2015 a next National Cancer Programme (NCP) [13,14 ] . Its main objective was to decrease the distance to European indicators in the 5-year survival in cancer patients diagnosed with cancers responsible for the most deaths in Poland. The specific objectives included, among others, reducing the rise in cancer incidence (primary prevention), improving early detection (secondary prevention), providing access to effective treatment methods.

In year 2015 to facilitate cancer treatment by making diagnostics faster and waiting time shorter so called 'Oncological Package' with DiLO card (*the Diagnosis and Oncological Treatment card*) was introduced [14, 21]. The Package also regulated the cancer patient follow-up and the procedures of coming back to the primary healthcare after cancer treatment.

In order to improve cancer care in Poland much more, the National Oncology Network (NON) has been introduced. Its pilot programme for cancer care beneficiaries was launched by the regulation of the Ministry of Health of 13 December, 2018 in Dolnośląskie and Kieleckie voivodships and started a reorganisation process of cancer care into a modern structure [20]. The pilot programme includes breast, colon, lungs, prostate and ovarian cancers, and is gradually including the remaining voivodships.

Polish NON concept is complementary to the European concept of Comprehensive Cancer Care Network (CCCN). Organising CCCN is an answer to a more and more frequent need by cancer service providers for a comprehensive cooperation between cancer care centers based on reference guidelines outlined according to the competences of each centre and in agreement with the nowadays experts' opinions. A multidisciplinary comprehensive cooperation between cancer centres in the frame of the CCCN and evidence-based public health would greatly facilitate diagnosis and treatment and would reduce disparities in the access to high quality cancer services in a way required by experts. The definition of tumor specific CCCN and its crucial elements has been developed within the European project CanCon [2], and as a next step, implemented during JA iPAAC (*innovative Partnership in Action Against Cancer Joint Action*) [15]

A modern model of multidisciplinary cancer care organised in a cancer care network on different levels of reference allows for implementation of optimal cancer care pathway, from diagnosis to rehabilitation and palliative care. The cancer care quality is monitored with the use of indicators set for the need of standardised and comparable indicators in order to evaluate the key stages of cancer care performed within the Polish NON .

Currently, health expenditure on cancer care amounts to less than 6% of all expenditures on healthcare in Poland. Thus, it is necessary to increase health expenditure on cancer care in Poland, and consequently arrive, at least, at the European Union average. As a result, the National Cancer Plan for Poland was proposed in order to increase changes to

enhance cancer care. The Strategy is included in the Act of Parliament of 24 April 2019 [1].

The ultimate goal for health care system financing is to increase health expenditure on cancer care to 7%. The National Cancer Plan plans to increase expenditure for implementation of the actions as follows:

- in year 2020 not less than 250.3 million PLN;
- in 2011 – 2023 not less than 451.2 million PLN per year;
- in 2024 – 2030 not less than 501.5 million PLN per year.

The expenditure would cover the following: – investment in medical staff; – investment in education – primary prevention (lifestyle); investment in patients – secondary prevention; investment in science and innovations; investment in cancer care system.

Actions which will be taken within the National Cancer Plan aim at reversing unfavourable epidemiological trends, including rising mortality in prostate cancer. That should contribute to an increase of the 5-year population survival, which in case of many cancers in Poland significantly differs from the majority of European countries.

## CONCLUSIONS

1. The 5-year survival in prostate cancer patients in years 2010 – 2014 in Poland was significantly lower in comparison to Western Europe countries, and favourable trends on a regional level in Poland were too slow to overcome high differentiation in Europe.
2. It is expected that changing the structure and organisation of cancer care in Poland into a modern National Oncology Network, together with the use of the experiences from European projects, including iPAAC and better financing will contribute to improvement in prostate cancer treatment in Poland.

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**Conflict of interest**

*The authors declare no conflict of interest.*

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ORIGINAL ARTICLE

# THE RELATIONSHIPS BETWEEN FOOD ATTITUDES AND SOCIODEMOGRAPHIC DETERMINANTS AMONG STUDENTS OF THE THIRD AGE UNIVERSITY IN NORTHERN POLAND

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## ABSTRACT

**Background.** A thorough understanding of nutritional needs, food attitudes, and preferences are necessary for aging societies. So far the detailed studies on food attitudes and their determinants among elderly people were relatively scarce.
**Objective.** This research was aimed at the determination of relationships between food attitudes and some sociodemographic features among elderly people, students of the Third Age University in Poland.
**Material and methods.** The study was conducted among 607 students of the Third Age University based on the authors` questionnaire. The survey was anonymous. The attitudes towards health benefits of foods, novel foods, light and organic foods, food as a reward and pleasure, restriction of food intake, and the packaging and composition of food were investigated.
**Results.** The relationships between attitudes and gender, age, education level, professional activity, BMI index, and economic status were differentiated. The positive attitudes over 50% were noticed only for the health benefits of foods and the packaging and composition of the food. For the other attitudes, the neutral attitudes were dominant. The three significant relations between attitudes and sociodemographic determinants were notices only for gender, two such relations were found for professional activity, the economic status and BMI index, and relations between age or education level – only for a single attitude.
**Conclusions.** The obtained results may be explained as a complex effect of specifics of this group and the overall tendency for conservative attitudes observed among elderly people. The food attitudes are significantly related to gender and other determinants become much less important for the surveyed group of the participants of the Third Age University.

**Key words:** *food attitudes, elderly people, determinants of food choice*

## STRESZCZENIE

**Wprowadzenie.** Dokładne zrozumienie potrzeb żywieniowych, percepcji i preferencji żywieniowych najstarszego pokolenia jest niezbędne dla starzejących się społeczeństw. Dotychczas nieliczne są szczegółowe badania dotyczące postaw żywieniowych i ich uwarunkowań wśród ludzi starszych.
**Cel.** Celem badania było określenie zależności między postawami wobec wybranych rodzajów żywności i cechami socjodemograficznymi w grupie ludzi starszych, słuchaczy Uniwersytetu Trzeciego Wieku w Polsce.
**Materiał i metody.** Badania przeprowadzono wśród 607 słuchaczy Uniwersytetu Trzeciego Wieku z wykorzystaniem autorskiego kwestionariusza ankiety. Badanie było anonimowe. Określono postawy wobec walorów zdrowotnych żywności, żywności typu light i organicznej, nowej żywności, żywności jako nagrody i przyjemności, opakowania i składu produktu, jak też wobec ograniczeń w spożyciu żywności.
**Wyniki.** Zależności między postawami, a płcią, wiekiem, poziomem wykształcenia, aktywnością zawodową, wartością wskaźnika BMI i sytuacją ekonomiczną respondentów okazały się zróżnicowane. Pozytywne postawy (w ponad 50%) odnotowano jedynie w odniesieniu do walorów zdrowotnych żywności oraz informacji na opakowaniu, a w przypadku pozostałych determinant dominowały postawy neutralne. Istotne zależności trzech postaw i cechy socjodemograficznej stwierdzono jedynie dla płci, zależności dwóch postaw od takiej cechy - dla aktywności zawodowej oraz statusu ekonomicznego, a zależność tylko jednej z postaw - jedynie dla wieku i wykształcenia.
**Wnioski.** Uzyskane wyniki można tłumaczyć złożonym efektem specyfiki badanej grupy i ogólnej tendencji do bardziej konserwatywnych postaw w starszym wieku. Wpływ płci na postawy jest najbardziej istotny, natomiast zależności między postawami względem żywności i pozostałymi cechami socjodemograficznymi nie są tak znaczące w badanej grupie słuchaczy Uniwersytetu Trzeciego Wieku.

**Słowa kluczowe:** *postawy żywieniowe, osoby starsze, determinanty wyboru żywności, cechy socjodemograficzne*

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## INTRODUCTION

In all developed countries, because of quickly increasing average age and decreasing the number of children, the fractions of elderly people become greater. In the whole of Europe, the number of citizens aged 65+ is expected to account for over 30% of the population by 2050 [17].

A thorough understanding of the elderly people as food consumers, their nutritional needs, food perception, and preferences are necessary, for the aging societies, to increase or at least maintain the quality of life (QoL). The QoL is nowadays an essential term considered as subjective well-being, life satisfaction, or happiness [6]. For example, the relative (emotional) well-being results from an assessment of the environment, in which a person lives, his/her needs and desires, comparisons with other persons, and personal features influencing feelings of satisfaction and happiness [8].

The QoL perception is relatively stable during the whole mature life, but it decreases among elderly persons [6]. The QoL is influenced by a variety of determinants. Among them, the economic security and education level were assumed to affect life satisfaction [28]. In the research made on the subjects aged 18-65 yrs. [15] the most critical determinants of the QoL were good health, self-independence, good incomes, proper relations with family and friends, possessing a comfortable apartment or house, life satisfaction, pleasant neighborhood, the possibility of education. The elderly males declared better QoL than the females, and such people living with their families felt better than the lonely elderlies [2, 42].

The critical determinant of the QoL is the eating behavior and its anticipated relation with health. The health-related QoL was considered as the primary goal for health promotion [9]. The excellent nutrition would stimulate the health-related QoL by averting malnutrition, preventing dietary deficiency disease, and promoting optimal functioning [3]. When investigating the residents of long-term care facilities, their QoL related to eating was found positive, but issues related to autonomy such as food choice and snack availability were less favorable [33]. The proper nutritional status, diet quality, and sufficient protein and micronutrient intakes were essential for the health and well-being of elderly people [25].

An appearance of a relationship between nutritional status and QoL was noticed among people in malnutritional status [34]. Some of the food restrictions, such as avoiding fatty meat and dairy products, animal fats, sugar and sweets, salt and salted foods, were in line with recommendations to elderly people and could have beneficial effects on fat, salt, and sugar intake [54]. In Poland, such restrictions resulting in the improper eating behavior of elderly people were found [27, 66, 67]. In particular, the shortage of fruit, raw vegetables, and milk, and excess intake of animal fat were frequent [26, 62, 66]. With increasing age, the feeling of hunger and thirst decreases, the feeling of taste and smell also decreases, and thus the meal consumption does not provide such pleasure as in younger and middle-aged resulting in unbalanced eating [38]. The reduction in food intake and the amount of liquid consumed occurs as a result of reduced appetite and thirst or inadequate consistency of the food that causes problems with chewing food [31]. The experience affects the views on foods and meals [13]. Even the frequency of feeding of many elderly people does not meet the needs of their organisms [18].

The studies of determinants of food attitudes in this group of persons were not frequent. The pro-health attitudes of some elderly people likely followed the advice of friends and the reading of popular science guides [5]. On the other hand, adherence to a healthy Baltic Sea diet (BSD) among Finnish elderly women was not related to their perception of QoL [49]. The neophobia, a less investigated phenomenon, was mostly influenced by the material situation and professional activity of elderly people [63]. Therefore, in this investigation, a specific group of elderly people, the students of the Third Age University (TAU), was surveyed. Such a group has been selected based on an assumption that it is composed of people relatively well-educated, ambitious, and active that may affect their food attitudes. The main determinants of the research were some socio-economic features.

## MATERIAL AND METHODS

The survey was done in 2014 among 607 participants of the Third Age University in Pomerania and Western Pomerania voivodships in Poland based on the author's questionnaire. The survey was anonymous. The detailed characteristics of the sample are shown in Table 1.

The main study was followed by a pilot study to verify the correctness of the prepared questionnaire and to introduce some necessary changes. Here described study was composed of a collection of data on some sociodemographic determinants (gender, age, education level, professional activity, BMI index, and economic status of subjects) and assessed food attitudes.

The attitudes towards six different features of foods such as health benefits of foods, light and organic foods, novel foods, the food as a reward or as a pleasure, packaging together with the composition of food, and restrictions of food intake, were investigated. The relations of food attitudes on the above-mentioned determinants were assessed. The determinants were divided into two, three, or four levels.

The attitudes were determined by the appropriate following survey tests, already used or here developed:

Table 1. Characteristics of the sample in the study

| Socio-demographic determinants | Description | Percentage |
|---|---|---|
| Gender | Males | 82.4 |
| | Females | 17.6 |
| Age (years) | <60 | 16.0 |
| | 61-70 | 51.7 |
| | 70+ | 32.3 |
| Education level | Primary | 11.5 |
| | Secondary | 52.4 |
| | Higher | 36.1 |
| Professional activity | Active | 23.4 |
| | Inactive | 76.6 |
| BMI index value ($kg/m^2$) | < 20 | 0.5 |
| | 20-25 | 38.2 |
| | 25-30 | 43.7 |
| | > 30 | 17.6 |
| Economic status | Very good | 9.6 |
| | Moderate | 81.4 |
| | Bad | 7.4 |
| | Very bad | 1.6 |

- Health Attitude Scale [47] for an assessment of attitudes towards the health benefits of foods (8 statements)
- Natural Food Product Attitude Scale [47] for an assessment of attitudes towards the light and organic foods (6 statements)
- Food Neophobia Scale [46] for an assessment of attitudes towards novel foods (6 statements selected by the authors)
- Using Food as a Reward and Pleasure Scale [48] for an assessment of attitudes towards the food as a prize or as a pleasure (6 statements)
- Attitude Scale for an assessment of attitudes towards the information on the packaging (4 statements; developed by the authors)
- Restricted Eating Scale [65] for an assessment of attitudes towards the restriction of food intake (6 statements )

The Likert Scale was applied to measure attitudes. The test results were analyzed using the Microsoft Office Excel 97-2003 for Windows spreadsheet function and Statistica version 7. Evaluation of attitudes containing analyzed statements was carried out using the 5-point scale, beginning from 1 (disagree), 2 (rather disagree), 3 (neither agree nor disagree), 4 (rather agree), and 5 (agree). The attitude was assumed as positive if the received value was 5 or 4, negative for 1 and 2, and neutral for value 3.

A *Chi*-square test was used to test the significance of relations between determinants and attitudes. The probability levels show the values at which the statement about no appearance of a significant relationship between a determinant and attitude (positive, negative, or neutral) is true.

## RESULTS

The results of investigations are shown in Figure 1 for the whole sample and in Tables 2-7 as relations between different determinants and attitudes. The positive attitudes over 50% were noticed only for two attitudes, on the health benefits of foods, and the

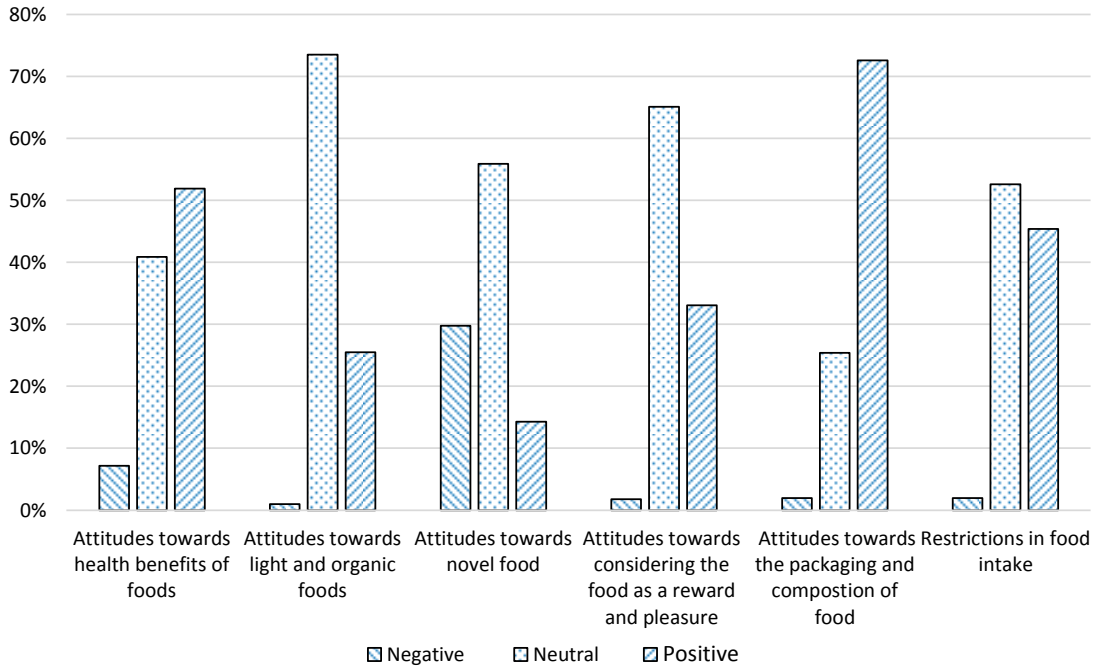


Figure1. Percentage of subjects expressing their negative, positive or neutral attitudes towards some foods

packaging and composition of the food. For other attitudes the neutral attitudes were dominant.

As considering gender (Table 2), there was a significant relation of three attitudes on this determinant, namely towards the health benefits, foods as a reward or pleasure, and the packaging and composition of the food. Females more often than males indicated the importance of the health benefits, the food offered as a reward or as pleasure, and the packaging and composition of the food.

Age was an important determinant of food attitudes only as regards the packaging and composition of food (Table 3). The appearance of this positive attitude was negatively correlated with age.

The significant relations were also observed for education level as a determinant (Table 4). However, the relations between education level and different attitudes were relatively inconsistent.

Table 2. Attitudes of participants as related to gender (in pct. of the sample)

| Attitude | Gender | Attitude | | |
|---|---|---|---|---|
| | | Negative | Neutral | Positive |
| Attitude towards health benefits of foods p=0.0010* | Females | 1.6 | 26.6 | 71.8 |
| | Males | 8.4 | 43.9 | 47.7 |
| Attitude towards light and organic foods p=0.2100 | Females | 1.2 | 71.8 | 27.0 |
| | Males | 0.9 | 73.8 | 25.2 |
| Attitude towards novel food p=0.2100 | Females | 33.2 | 55.4 | 11.4 |
| | Males | 29.0 | 56.1 | 15.0 |
| Attitude towards the food as a reward and pleasure p=0.0002* | Females | 0.4 | 59.6 | 40.0 |
| | Males | 1.9 | 66.4 | 31.8 |
| Attitude towards packaging and composition of the food p=0.0070* | Females | 1.4 | 13.2 | 85.4 |
| | Males | 1.9 | 28.0 | 70.1 |
| Attitude towards restrictions in food intake p=0.8900 | Females | 1.4 | 49.4 | 49.2 |
| | Males | 1.8 | 53.3 | 44.9 |

Table 3. Attitudes of participants as related to age (in pct. of the sample)

| Attitude | Age (years) | Negative | Neutral | Positive |
|---|---|---|---|---|
| Attitude towards health benefits of foods p=0.4800 | 51-60 | 2.3 | 32.6 | 65.1 |
| | 61-70 | 3.2 | 24.5 | 72.3 |
| | 70+ | 2.6 | 35.2 | 62.2 |
| Attitude towards light and organic foods p=0.1100 | 51-60 | 0.0 | 66.3 | 33.7 |
| | 61-70 | 1.0 | 74.8 | 24.2 |
| | 70+ | 2.0 | 69.9 | 28.1 |
| Attitude towards novel food p=0.1040 | 51-60 | 22.1 | 69.8 | 8.1 |
| | 61-70 | 30.3 | 55.4 | 14.3 |
| | 70+ | 42.3 | 49.0 | 8.7 |
| Attitude towards considering the food as a reward and pleasure p=0.0700 | 51-60 | 0.0 | 58.1 | 41.9 |
| | 61-70 | 1.0 | 59.9 | 39.2 |
| | 70+ | 0.5 | 61.2 | 38.3 |
| Attitude towards the packaging and composition of the food p=0.0000* | 51-60 | 0.0 | 14.0 | 86.0 |
| | 61-70 | 0.6 | 13.4 | 86.0 |
| | 70+ | 3.6 | 21.4 | 75.0 |
| Restrictions in food intake p=0.4200 | 51-60 | 0.0 | 46.5 | 53.5 |
| | 61-70 | 1.6 | 48.4 | 50.0 |
| | 70+ | 2.0 | 54.1 | 43.9 |

The professional activity (Table 5) was a significant determinant of the attitudes towards the novel food and the packaging and composition of the food. On the other side, these relations were relatively weak.

The BMI value was a significant determinant also for two attitudes (Table 6), towards the health benefits and the novel foods. The positive attitudes followed the increasing BMI value.

For the last determinant, the economic status (Table 7), it became important for three attitudes, namely towards the novel food, the food as a reward and pleasure, and the packaging and food composition. However, the relations of these attitudes on economic status were complex.

Table 4. Attitudes of participants as related to education level (in pct. of the sample)

| Attitude | Education level | Negative | Neutral | Positive |
|---|---|---|---|---|
| Attitude towards health benefits of foods p=0.1300 | Primary | 0.0 | 39.1 | 60.9 |
| | Secondary | 2.8 | 23.0 | 74.2 |
| | Higher | 3.7 | 36.1 | 60.3 |
| Attitude towards light and organic foods p=0.6600 | Primary | 0.0 | 68.9 | 31.1 |
| | Secondary | 1.9 | 69.8 | 28.3 |
| | Higher | 0.5 | 76.3 | 23.3 |
| Attitude towards novel food p=0.2900 | Primary | 43.5 | 44.3 | 12.2 |
| | Secondary | 32.1 | 57.9 | 10.1 |
| | Higher | 30.1 | 55.3 | 14.6 |
| Attitude towards considering the food as a reward and pleasure p=0.1500 | Primary | 0.0 | 67.8 | 32.2 |
| | Secondary | 1.3 | 59.4 | 39.3 |
| | Higher | 0.0 | 60.7 | 39.3 |
| Attitude towards the packaging and composition of the food p=0.0100* | Primary | 2.6 | 15.4 | 82.0 |
| | Secondary | 1.6 | 14.8 | 83.6 |
| | Higher | 0.9 | 17.4 | 81.7 |
| Restrictions in food intake p=0.0600 | Primary | 0.2 | 75.9 | 23.9 |
| | Secondary | 3.0 | 44.9 | 52.1 |
| | Higher | 0.0 | 57.9 | 42.1 |

Table 5. Attitudes of participants as related to professional activity (in pct. of the sample)

| Attitude | Professional activity | Negative | Neutral | Positive |
|---|---|---|---|---|
| Attitude towards health benefits of foods p=0.2800 | Active | 4.9 | 35.2 | 59.9 |
| | Inactive | 2.2 | 28.0 | 69.9 |
| Attitude towards the light and organic foods p=0.7200 | Active | 0.7 | 69.7 | 29.6 |
| | Inactive | 1.3 | 72.9 | 25.8 |
| Attitude towards novel food p=0.0130* | Active | 23.2 | 64.1 | 12.7 |
| | Inactive | 35.3 | 52.9 | 11.8 |
| Attitude towards considering food as a reward & pleasure p=0.0900 | Active | 0.7 | 61.3 | 38.0 |
| | Inactive | 0.6 | 60.6 | 38.7 |
| Attitude towards packaging and composition of the food p=0.0370* | Active | 0.7 | 14.1 | 85.2 |
| | Inactive | 1.7 | 16.3 | 81.9 |
| Restrictions in food intake p=0.3200 | Active | 2.1 | 50.7 | 47.2 |
| | Inactive | 1.3 | 49.9 | 48.8 |

Table 6. Attitudes of participants as related to the BMI value (in pct. of the sample)

| Attitude | BMI (kg/m$^{2)}$ | Negative | Neutral | Positive |
|---|---|---|---|---|
| Attitude towards health benefits of foods p=0.0060* | < 20 | 0.0 | 66.7 | 33.3 |
| | 20-25 | 1.3 | 30.2 | 68.5 |
| | 25-30 | 3.4 | 29.4 | 67.2 |
| | > 30 | 4.7 | 28.0 | 67.3 |
| Attitude towards light and organic foods p=0.3900 | < 20 | 0.0 | 100.0 | 0.0 |
| | 20-25 | 0.9 | 73.7 | 25.4 |
| | 25-30 | 0.8 | 74.3 | 24.9 |
| | > 30 | 2.8 | 62.6 | 34.6 |
| Attitude towards novel food p=0.0050* | < 20 | 33.3 | 66.7 | 0.0 |
| | 20-25 | 33.6 | 56.9 | 9.5 |
| | 25-30 | 32.8 | 58.1 | 9.1 |
| | > 30 | 29.0 | 45.8 | 25.2 |
| Attitude towards considering the food as a reward and pleasure p=0.8000 | < 20 | 0.0 | 100.0 | 0.0 |
| | 20-25 | 0.4 | 57.3 | 42.2 |
| | 25-30 | 0.4 | 62.3 | 37.4 |
| | > 30 | 1.9 | 63.6 | 34.6 |
| Attitude towards the packaging and composition of the food p=0.5900 | < 20 | 0.0 | 0.0 | 100.0 |
| | 20-25 | 2.6 | 18.5 | 78.9 |
| | 25-30 | 0.4 | 14.0 | 85.7 |
| | > 30 | 1.9 | 15.0 | 83.2 |
| Restrictions in food intake p=0.0600 | < 20 | 0.0 | 100.0 | 0.0 |
| | 20-25 | 0.4 | 51.7 | 47.8 |
| | 25-30 | 3.0 | 44.9 | 52.1 |
| | > 30 | 0.0 | 57.9 | 42.1 |

Table 7. Attitudes of participants as related to economic status (in pct. of the sample)

| Attitude | Economic status | Negative | Neutral | Positive |
|---|---|---|---|---|
| Attitude towards health benefits of foods p=0.5900 | Very good | 0.0 | 22.4 | 77.6 |
| | Moderate | 3.2 | 30.0 | 66.8 |
| | Bad | 0.0 | 35.6 | 64.4 |
| | Very bad | 10.0 | 30.0 | 60.0 |
| Attitude towards light and organic foods p=0.4900 | Very good | 6.9 | 69.0 | 24.1 |
| | Moderate | 0.4 | 72.9 | 26.7 |
| | Bad | 2.2 | 73.3 | 24.4 |
| | Very bad | 0.0 | 50.0 | 50.0 |
| Attitude towards novel food p=0.0010* | Very good | 32.8 | 48.3 | 19.0 |
| | Moderate | 32.2 | 56.1 | 11.7 |
| | Bad | 42.2 | 57.8 | 0.0 |
| | Very bad | 0.0 | 60.0 | 40.0 |
| Attitudes towards considering the food as a reward and pleasure p=0.0300* | Very good | 0.0 | 60.3 | 39.7 |
| | Moderate | 0.8 | 60.7 | 38.5 |
| | Bad | 0.0 | 68.9 | 31.1 |
| | Very bad | 0.0 | 30.0 | 70.0 |
| Attitude towards the packaging and composition of the food p=0.0000* | Very good | 1.7 | 10.3 | 87.9 |
| | Moderate | 0.8 | 15.6 | 83.6 |
| | Bad | 8.9 | 20.0 | 71.1 |
| | Very bad | 0.0 | 40.0 | 60.0 |
| Restrictions in food intake p=0.0600 | Very good | 0.0 | 43.1 | 56.9 |
| | Moderate | 1.8 | 49.8 | 48.4 |
| | Bad | 0.0 | 64.4 | 35.6 |
| | Very bad | 0.0 | 40.0 | 60.0 |

## DISCUSSION

***The attitudes towards health importance***

The attitudes measured in the sample composed of participants of the TAU, a particular social group, towards various aspects of eating behavior, ranged between negative through neutral up to positive ones, depending on the specific attitude and determinant. The positive attitudes were expressed by over 50% of subjects only towards the health benefits of food. This result is in perfect accordance with several previous reports in which good health was considered essential for the Polish people [21, 22, 29, 32, 35, 55, 58]. It may be assumed that the positive attitudes of the elderly people towards the health-related diet can result from the willingness to consume products that positively affect the health of seniors. Such supposition is confirmed by the frequent occurrence of many illnesses and an appearance of beliefs in pro-health diets, like cholesterol-lowering products, often consumed by people aged 50+ [10, 24, 61, 66]. The coronary diseases are typical for elderly persons and are associated often with their eating [11, 12]. Diseases of the gastrointestinal tract occur frequently among people aged 65+ in many European countries [23] and include the gastro-oesophageal reflux disease for 53-66% of respondents, cholelithiasis for about 30% of females, and 16- 20% of males, and the diseases of the large intestine constitute about 25% of all diseases typical for the elderly people. Numerous diseases and drug intake increase the risk of adverse interactions and enforce modifications in the nutrition of the elderly persons, and limit the free choice of food [16]. Every third inhabitant of Poland complained about long-term health problems or chronic diseases lasting at least six months, almost 60% of people aged 50+ and 73% of those aged 60+ [57]. On the other hand, expected increased mental or physical activity of any type [14] can be a reason for coming people to the TAU. The health consciousness was a stimulus that positively affects the eating facilitators (natural content, nutritional content, and ecological welfare) as well as inhibitors (usage, risk, and value barriers) [59]. Such behavior can be even unconscious; in previous research, only a few participants met the recommendations for the different food [19].

***The attitudes towards light and organic food***

There are not too many studies on the relationships between the elderlies` attitudes towards light products and organic food. Participation in cultural activities had a positive impact on the inclination to purchase organic products, to an extent dependent on the social orientation of each cultural activity [1]. Moreover, higher organic budget shares were found among well-educated consumers in urban areas and linked to the belief that organic products are healthier. On the other hand, no significant relations were determined between the consumption of organic food and the perceptions that organic products were more animal or environmentally friendly [7]. On the other hand, the perception of foods suitable for weight management like light foods rested not only on simple measures such as energy, fat, and sugar but also on a complex set of generalized food ideals [41].

***The attitudes towards the novel food***

Even if neutral attitudes are characteristic of many foods, the most diversified become attitudes towards the novel food. The negative attitudes were expressed by about 30% of the sample and, simultaneously, the positive ones were prevalent. It means that elderly people do not remain neutral against novel foods. Attitudes towards novel foods can be significantly different, and their extreme forms are referred to as nutritional neophobia (negative attitude) and food neophilia (positive attitude). In an earlier study, 82% of subjects declared that they preferred already known food and only 23% chose the exotic dishes [63]. In other work by *Jeżewska-Zychowicz* et al. [24], the low nutritional neophobia was observed among professionally active people. Current research also showed that the negative attitude towards novel food was expressed mainly by people with only primary education. Along with the increase in education, a smaller percentage of people with high food neophobia and at the same time a higher percentage of people with low food neophobia were found. Similarly, the convenience food was also accepted by elderly people in other research [45]. The associations between food security, the most uncertain for novel foods, and health outcomes are characteristic in older adults [43]. The elderly may be more willing to accept novel foods than do younger adults because of olfaction [44]. The food history, sensory and oral motors can be important determinants in the food choice [51]. However, in *Song* et al. studies [53], the older consumers were shown to be the most determined to purchase and try healthy, but traditional meal component foods enriched with protein. On the other hand, *Jeżewska-Zychowicz* et al. [24] also proved that the elderly people declared the most frequently among all that they neither knew nor took the novel food.

***The attitudes towards the food as a reward or pleasure***

Nutritional behaviors are not always the answer to the feeling of hunger as the emotions and mood often condition them. The participants of the TAU scarcely expressed a negative attitude in this case. The high support for such attitude was observed among females, which may result from the greater emotionality of

women trying to improve their mood, for example by eating sweets often resulting in overweight [37]. The subjective hedonic experience of food is certainly encoded in the area of activity in the pleasure system [30]. For persons aged 65-101 yrs., the tendency to prefer sweet and solid food was already noticed and this specific desire disappeared at hospitalized patients or retirement houses` residents [64]. Another case is a long-term treatment of people with obesity who after at least 5 months stopped to consider the food as a reward [39]. The pleasure motivation was observed as a stronger predictor of eating than demographic factors people aged at 65+ in Australia [52].

***The attitudes towards the packaging and food composition***

The attitudes of the elderly people expressed towards the packaging and food composition of the product are often significant. The product label is essential information about the food and affects its acceptance and choice. The statistical significance between attaching attention to the information on the packaging (label) by the respondents was shown, and age, the level of education, and professional activity of seniors were important as the determinants. Similar results were already obtained by *Niewczas* [40], demonstrating the significant impact of specific information on the packaging on the perception to the extent related to food, age, gender, and education level. So far reports on a relationship between diet and food label indicated that reading the nutrition facts label was associated with healthier diets [4]. Front-of-pack labeling was a particularly efficient tool for increasing consumers' awareness of the nutritional quality of food products and promoting healthier food choices [50]. The importance of labeling and quality of information was noticed in several reports [60], particularly as concerns the contents of specific supplements. Moreover, some consumers are willing to pay a premium for redundant or superfluous food labels that carry no additional information for the informed consumer [68]. Finally, it is interesting that hungering for the past which may be frequent among elderlies together with nostalgic food labels may increase purchase intentions and actual consumption [69].

***The attitudes towards food restrictions***

The diet restrictions are well accepted and they are then in full accordance with previous studies. The investigations of elderly people, residents of the Warsaw neighborhood, showed that over 67% of subjects applied food restrictions and 33% introduced fresh vegetables and fruit, yogurts, wholemeal bread, low-fat meat and cold cuts, fruit and vegetable juices to their diets for health reasons. According to *Wierzbicka* and *Roszkowski* [67], only 10% of elderly people avoid fruit, vegetables, and milk. Such attitudes may be due to the real needs of elderlies who suffer from different illnesses or obesity. However, tooth loss and the lack of oral rehabilitation certainly results in the restriction of the consumption of fruits, vegetables, proteins, as shown in Brasil among people aged 65-74 [56].

***Summary***

Considering the possible relations between sociodemographic determinants and attitudes, the effect of gender was here the most prevalent as noticed in many past studies [24, 36]. Other determinants, like age, education level, professional activity, economic status, and BMI value affected only slightly some of the attitudes, and usually in a complex manner. However, the economic security and education level can influence the life satisfaction of the people [20, 28]. Such determinants did not seriously differentiate the eating attitudes observed in this study likely because the subjects were relatively well-educated and active in the TAU, imagined themselves as being in good or perfect economic situation. That confirming, *Jeżewska-Zychowicz* et al. [24] observed a similar lack of relationship between the level of education and professional activity and the consumption of pro-health food.

## CONCLUSIONS

Results of the studies showed a limited number of statistically significant correlations between the attitudes of the elderly people, participants of the TAU, and the examined sociodemographic features. Gender seems the essential determinant of food attitudes when compared to all other determinants. The reasons may be the different meanings of the quality of life and different experiences of surveyed elderlies, and various roles of elderly males and females in society.

The most positive attitude is expressed towards health benefits. Such behavior is entirely justified by a sample of elderly adults suffering from different illnesses.

A high fraction of neutral attitudes may result from different reasons for each attitude: lack of interest in light and organic foods or in considering the food as a reward or pleasure, typical of elderly people.

**Conflict of interest**

*The authors declare no conflict of interest.*

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**Discussion.** Emphasize the new and important aspects of the results and a comprehensive interpretation of the results obtained against the background of results obtained by other authors. Quotations should be restricted to those with immediate relevance to the author's findings.

**Conclusions.** They should be stated precisely in points or descriptively and should be logically connected with the aims stated in the introduction. Statements and conclusions not derived from own observations should be avoided. If a hypothesis is proposed it must be stated clearly.

**Acknowledgements.** These should be placed directly after the Conclusion section**.** One or more statements should specify: (1) persons who contributed substantially to the study but cannot be regarded as authorship, such as technical assistants, statisticians, data collectors etc. Their assistance should be acknowledged for the sake of transparency. It must be clear that they are not responsible for the final version of the article. You must ensure you have the consent of all the persons named in the acknowledgements; (2) all sources of financial and material support, which should specify the nature of the support. The recommended form is: "This work was supported by: (name of the organization, project number etc.)"; (3) relationships that may pose the conflict of interest.

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2. *Lopes M.C., Giudici K.V.*, *Marchioni D.M.*, *Fisberg R.M.*, *Martini L.A.*: Relationships between n-3 polyunsaturated fatty acid intake, serum 25 hydroxyvitamin D, food consumption, and nutritional status among adolescents. Nutr Res 2015;35(8):681-688.
3. *Shridhar G.*, *Rajendra N.*, *Murigendra H.*, *Shridevi P.*, *Prasad M.*, *Mujeeb M.A.*, *Arun S.*, *Neeraj D.*, *Vikas S.*, *Suneel D.*, *Vijay K.*: Modern diet and its impact on human health. J Nutr Food Sci 2015;5:6 doi:10.4172/2155-9600.1000430.
4. *Wu M.*, *Yu G.*, *Cao Z.*, *Wu D.*, *Liu K.*, *Deng S.*, *Huang J.*, *Wang B.*, *Wang Y.*: Characterization and human exposure assessment of organophosphate flame retardants in indoor dust from several microenvironments of Beijing, China. Chemosphere 2015, doi:10.1016/j.chemosphere.2015.12.111.

*Books and chapter in a book:*

5. *Riley D.M., Fishbeck P.S.*: History of methylene chloride in consumer products. In: *Salem H.*, *Olajos E.J.* (eds.). Toxicology in Risk Assessment. London, Taylor & Francis, 2000.

*Legislative acts:*

6. Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. Off J EU L 364, 20.12.2006.

*Internet source:*

7. The Rapid Alert System for Food and Feed (RASFF) Portal. Available
8. https://webgate.ec.europa.eu/rasff-window/portal (accessed 18.10.2010)

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**Abbreviations, symbols, units.** Generally known and used abbreviations may be left unexplained, others must be explained at the first use in the text. Metric SI units are recommended, however also other generally used units are accepted.

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The editor reserves the right for introducing the editorial corrections in the manuscript which will not influence the scientific contents of the article without prior informing the author.

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