Pol. J. Food Nutr. Sci., 2014, Vol. 64, No. 4, pp. 267–276
DOI: 10.2478/pjfns-2013-0026
http://journal.pan.olsztyn.pl

Original article
Section: Nutritional Research

Total Antioxidant Capacity and Its Dietary Sources and Seasonal Variability in Diets of Women with Different Physical Activity Levels

Magdalena Członka–Matyasik[1], Katarzyna Ast[2]*

[1]*Department of Human Nutrition and Hygiene, Poznan University of Life Sciences, ul. Wojska Polskiego 31, 60–624 Poznań, Poland*
[2]*Department of Morphological Biology and Health Science, Faculty of Physical Education in Gorzow Wlkp., Poland*

Key words: ORAC, seasonal dietary intake, physical activity level, women

Increased physical activity induces oxidative stress and utilization of dietary antioxidants. Information on dietary sources of antioxidants in diets are limited.

We aimed to analyse the antioxidant potential, seasonal variation and dietary sources in the diets of women exercising and not exercising regularly.

We studied 48 women: 25 regularly exercising (FIT) and 23 not exercising regularly (NFIT). 192 seasonal recalls were collected regarding the consumption of dietary sources of antioxidant compounds in spring, summer, autumn and winter. A food frequency questionnaire was used. For each season, the total density of the antioxidant diet (Q–ORAC in μmolTE/1000kcal) was calculated.

The main sources of antioxidants in women's diets (FIT+NFIT) were fruit (32.1% of total supply), vegetables (11.5%), tea (9.3%), dark chocolate (5.7%), and sweets in total (1.9%) and red wine (1.1%). The Q–ORAC of women's diets (FIT+NFIT) significantly depended on the season ($p<0.001$) and were highest in the summer (23444 μmolTE/1000 kcal) and lowest in the spring (13978 μmolTE/1000 kcal). Higher differences in the Q–ORAC between seasons were observed in FIT women (Q–ORAC quotients from 0.8 to 1.9) than NFIT women (from 0.9 to 1.2). The Q–ORAC of FIT and NFIT women diet did not differ significantly in any season or average per year (18078 *vs.* 18775 μmolTE/1000 kcal, respectively; $p>0.05$).

The total antioxidant density of women diets and consumption of dietary sources of antioxidants was not related to their physical activity. All of the women were characterised by seasonal variation in consumption, which was higher in active than inactive women.

INTRODUCTION

During exercise, oxygen consumption can increase by a factor of more than 10 [Davies *et al*., 1982; Dekkers *et al*., 1996]. This process might lead to increase of oxidants production and effects in damage that contributes to muscular fatigue while exercise. Beneficial effect of exercise is still worthwhile to underline but, what was discussed and suggested previously, those who exercise regularly or occasionally should ingest supplementation and foods rich in antioxidants [Clarkson, 1995; Kanter, 1998]. The level of physical activity, the nutritional value of the diet and their mutual relation have been discussed in various studies [Dutton *et al*., 2008; Przybyłowicz & Wądołowska, 2009]. Regular moderate physical effort has a modulating effect on the immune system and a favourable effect on health [Karolkiewicz *et al*., 2009]. High–intensity physical effort can cause increased production of reactive forms of oxygen and the emergence of oxidative stress in the body causing, among others, fatigue and damage to tissues [Vollaard *et al*., 2005].

A diet that is rich in compounds with an antioxidative effect reduces the risk of multiple diseases with aetiology related to oxidative stress [Kay *et al*., 2006]. It has been proven that proper diet composition affects the antioxidative status *in vivo*, among others through the type and content of biologically–active compounds, it improves functions of the immune system and increases ability of cells to defend against free radicals [Gałek & Targoński, 2003; Prior *et al.,* 2007]. For this reason, an optimally balanced diet, adjusted to the physical activity level, is of significant importance.

The research carried out among persons who practice sport shows irregularities in their dietary patterns [Gacek, 2009], which may result in a lower supply of antioxidants originating from the diet. The results of the studies suggest that an increase in the content of antioxidants in a diet by increasing the number of vegetable and fruit portions from five to eight a day improves the ability of the body to counteract free–radical processes [Cao *et al*., 1998]. This has been also confirmed by several short–term experiments using diet therapy [Watzl *et al*., 2005; Wood *et al*., 2012].

No studies exactly concerning dietary sources of antioxidant compounds in the diets of physically active persons and their seasonal fluctuations have been found in the Polish literature. The only data reporting on the antioxidant ca-

* Corresponding Author: Tel. +4861 848 73 35;
E–mail: magdalena.matyasik@up.poznan.pl (M. Członka–Matyasik)

pacity of daily diets were carried out previously by Ilow *et al.* [2012a, b], and focused on university students in summer period and 50–year–old residents of Wroclaw city.

Women are, as a rule, more interested in health than men, and their diets include more certain health–promoting components [Wądołowska, 2010]. For this reason, this study has focused on exercising and not exercising women. It was hypothesised that the antioxidant capacity of diets in women who were exercising is higher than in the diet of not exercising women. Moreover, the antioxidant capacity of physically active is less affected by seasonal fluctuations. The aim of this study was to compare diets of physically–active and non–active women regarding antioxidant capacity and their dietary sources as well as impact of season on the antioxidative capacity of diets.

MATERIALS AND METHODS

Subjects and groups

The study was performed in two groups of women who were separately selected. The first group were women regularly exercising (FIT) and the second group were women not exercising regularly (NFIT).

Inclusion criteria and physical activity classification

The FIT group was recruited from women attending to one of the biggest fitness clubs in Poznań, open 24h a day, where information about studies was announced. The group collection procedure is presented in Figure 1. Inclusion criteria for both groups are presented below:

- age 25–40 years,
- regularly attended (at least for last three years) fitness classes, lasting 90 min at once, on average twice a week (concern only FIT group),
- the absence of any modifications of usual diet, for example weight reduction diet, diet with diabetic or allergic or hypolipemic modifications,
- lack of (minimum one of them):
  - nutritional disorders,
  - professional sporting activity on an advanced level,
  - dietary antioxidant supplementation.

When recruiting for the NFIT group, we intended to minimize the impact of other factors. Participants qualified for the FIT group were asked to indicate or recommend colleague, who did not participate in fitness classes for the last three years, were in similar age and were characterised by a similar socioeconomic status and education level. What may suggest that nutritional behaviour of both FIT and NFIT were particularly conditioned by physical activity level.

In order to confirm the differences in physical activity level in both groups, an International Physical Activity Questionnaire (IPAQ) was performed and procedure described by Ainsworth *et al.* [2000] was used. The IPAQ was employed to calculate estimates of physical activity energy expenditure using standard metabolic equivalent (MET – Metabolic Energy Turnover values). A weighted sum of daily physical activity energy expenditure (MET–minutes/week) was calculated using the reported amount of time (min/day) spent in activity of each intensity. The following MET weights were used: walking = 3.3 METs, moderate physical activity = 4.0 METs and vigorous physical activity = 8.0 METs. Summary scores for each level of activity were calculated for weekdays. According to this criteria, a high physical activity level (>3000 MET–minutes/week) in all FIT women (n=25) was confirmed as well as a low or moderate physical activity level (<3000 MET–minutes/week) in 24 of FIT women.

Finally, the research involved 48 women aged from 25 to 35, who were divided into two groups: FIT (n=25) and NFIT

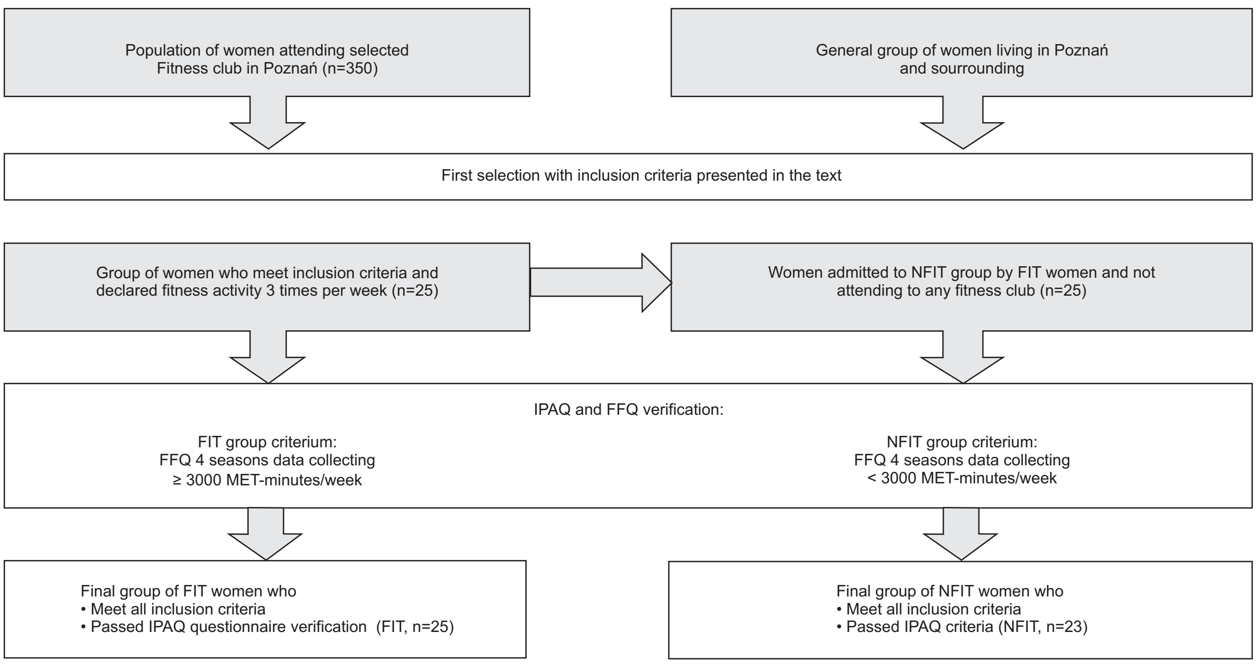

FIGURE 1. Data collection sequence included subjects and group classification. (Abbreviations: IPAQ – International Physical Activity Questionnaire; FFQ – Food Frequency Questionnaire; FIT – women regularly exercising; NFIT – women not exercising regularly).

(n=23) (Table 1). Two NFIT women were removed from studies because of incomplete questionnaire in one season (1 person) or not meeting the criteria of low physical activity (1 person).

Each woman was examined according to precisely specified procedures. In the first stage, anthropometric parameters and body composition were determined, and then information on the food intake was obtained through direct interview. Before starting the examination, respondents were not given any information concerning proper nutrition. The research was carried out in winter at the turn of 2010 and 2011.

The participation in the study required consent given by women. All information was collected by means of "face–to–face" contact. Well–trained qualified researchers conducted the investigations and measurements.

Evaluation of body weight and composition

Measurements of height, body weight and circumferences were performed according to principles established in anthropometry. Body height using a manual anthropometer was measured (accuracy of 1 mm), and body weight with the use of an electronic scale by Radwag with an accuracy of 100 g. Waist and hip measurements were taken using an anthropometric tape with an accuracy of 0.5 cm. Body Mass Index (BMI) and Waist–to–Height Ratio (WHtR) were calculated

Body composition was measured using the bioelectrical impedance analysis (BIA) method, with the use of a BIA–101s body composition analyser manufactured by Akern–RJL according to the recommended procedure [Lukaski *et al*., 1986]. Information obtained included fat mass content (FM in kg and % of body weight), fat free mass (FFM in kg), muscle mass (MM in kg and % of body weight) and total body water (TBW in litres and % of body weight).

Food intake assessment

Information on sources and the antioxidative capacity of diet of respondents was obtained with the use of a Food Frequency Questionnaire (FFQ). Use was made of a food list from the FFQ developed by Wądołowska and Niedźwiecka (the so–called FFQ–D10, unpublished materials). The food list in the FFQ–D10 questionnaire was verified in pilot research and validated in a version that included six food frequency categories (FFQ–6; unpublished materials). Validation studies for FFQ–6 proved the high reliability of the questionnaire (kappa statistics between 0.6 and 0.8) for 16% of the total number of food groups, moderate reliability (kappa between 0.4 and 0.6) was proven for 81% of the total number of food groups and low reliability (kappa below 0.4) was proven for 3% of the total number of food groups. The original FFQ–D10 questionnaire contained 75 food groups. For the needs of this research, FFQ–D10 was supplemented with a detailed food list (34 products), which constituted potential sources of compounds of antioxidative effect in the customary diet. In total, the questions were asked about the intake of 108 products or food groups, for four seasons separately. 192 seasonal food intake interviews were obtained (from 48 women).

The procedure based on another food frequency questionnaire developed by Wądołowska (the so–called FFQ) and validated [Wądołowska, 2005; Kowalkowska *et al*. 2013] that was applied for quantitative evaluation of the food intake. Respondents specified their food intake by: (i) freely indicating usual frequency of food and beverage intake during a day, week, month (open type questions) and (ii) indicating the amount of their typical portion of food and beverage, which they specified in grams or pieces (eggs) and on the basis of photos from the album of food and meal photos [Szponar *et al.,* 2000]. This was used as a basis to calculate the amount of consumed food or beverages (by multiplying the usual frequency and amount), which was then expressed as g/day.

Evaluation of antioxidative capacity of diets

The antioxidative potential of a diet was expressed using the ORAC ratio (Oxygen Radical Absorbance Capacity), which describes the total capacity of the mix of antioxidants contained in food to inhibit free oxygen radicals [U.S. Department…, 2010]. The ORAC unit of measure is "μmol TE/100g" determining antioxidative capacity equal to 1 micromole of trolox equivalent per 100 grams of the sample [Cao *et al*., 1998; Ou, 2001]. Trolox (TE: 6–hydroxy–2,5,7,8–tetramethylchroman–2–carboxylic acid) is water–soluble vitamin E used for reduction of stress or damage caused by oxidation. For example, 1 ORAC indicates the protection against free radicals provided by 1 micromole of trolox. Measurement of ORAC ratio for food products, based on the fluorometric method has been described in literature [Ou *et al*., 2001]. Its values were analytically determined for 326 food products, and published in the form of a database by American Department of Agriculture [U.S. Department…, 2010]. This database provided a starting point to calculate the antioxidative potential of diets in this study. Analytical evaluations were performed for food making up components of a typical diet of Poles that were not included in this database (34 products), using methods consistent with the American database.

The antioxidative potential of diets of the examined women was calculated by summing up the ORAC value of the food taken in by women in individual seasons of the year (spring, summer, autumn, winter) and in total during the entire year. The following values were calculated:

- the so–called total antioxidative density of diet (Q–ORAC), *i.e.* antioxidative potential per 1000 kcal of diet (in μmol TE/1000 kcal),
- share (%) of selected food groups in total antioxidative density, distinguishing 16 food groups:
- fruit (gooseberry, pineapple, watermelon, avocado, banana, peach, lemon, grapefruit, pear, apple, blackberry, kiwi, raspberry, tangerine, mango, melon, apricot, nectarine, orange, currant, plum, strawberry, grapes, cherry),
- dried fruit (date, fig, apricot, dried plums, raisin, cranberry),
- vegetables (eggplant, broccoli, beetroot, onion, garlic, pumpkin, cauliflower, white cabbage, red cabbage, maize, carrot, cucumber, pepper, parsley, tomato, leek, radish, lettuce, celery, chive, spinach),
- seasonings (basil, curry, cinnamon, nutmeg, clove, ginger, marjoram, oregano, pepper, parsley, sage, thyme),
- leguminous plants (white dry bean, string bean, green peas, lentil, soya bean),

TABLE 1. Demographic and anthropometrical characteristics of exercising (FIT) and non–exercising women (NFIT) (mean ± standard deviation).

Parameter	FIT+NFIT n=48	FIT n=25	NFIT n=23
MET–minutes/week*	3999±2494 (666–9647)	6227±1789 (3340–9647)	1973±460 (666–2826)
Age* (years)	31±4 (25–38)	30±4 (25–36)	32±4 (25–38)
Place of residence (%)			
City > 500000 inhabitants	90	85	95
Town > 30000 inhabitants	8	10	5
Village or town > 5000 inhabitants	2	5	0
Education (%)			
Higher	75	65	85
Secondary	19	25	15
Elementary	6	10	0
Height (cm)	168.4±6.5 (150.0–181.0)	168.6±6.9 (156.0–181.0)	168.1±6.2 (150.0–179.0)
Body weight (kg)	61.8±7.8 (49.0–84.0)	60.2±6.3 (51.0–71.0)	63.6±9.0 (49.0–84.0)
Waist circumference* (cm)	72.3±5.9 (61.0–86.0)	70.3±4.9 (61.0–79.0)	74.5±6.2 (65.0–86.0)
Hip circumference (cm)	97.1±6.7 (85.0–114,0)	95.9±5.3 (85.0–108.0)	98.4±7.8 (87.0–114.0)
BMI (kg/m^2)	21.8±2.4 (17.2–27.6)	21.1±1.5 (18.5–23.9)	22.5±2.9 (17.2–27.6)
WHtR*	0.42±3.6 (36.7–51.5)	0.42±2.6 (36.7–47.3)	0.44±3.9 (38.7–51.5)
TBW* (%)	53.0±4.6 (53.2–43,9)	54.7±3.6 (48.2–61.5)	52.2±5.2 (43.9–62.1)
FM* (%)	26.8±6.4 (15.1–40.0)	25.0±5.1 (16–34.1)	28.8±7.1 (15.1–40)
FFM* (%)	72.4±8.3 (36.1–84.9)	75.1±5.1 (65.9–84.0)	69.6±10.2 (36.1–84.9)
MM (%)	36.5±7,6 (20.2–53.8	38.5±6.3 (27.3–53.8)	34.3±8.4 (20.2–49.4)

Statistically significant differences in T test between FIT *vs.* NFIT at: *p<0.05; () minimum–maximum range provided in brackets.

- potatoes,
- nuts (almonds, pistachio nuts, walnuts, hazelnuts),
- tea (all types),
- fruit juices,
- total wine (all types),
- red wine,
- olive oil,
- total bread (all types),
- wholemeal bread,
- total sweets (all types, *e.g.* candy bars, leavened cake, various types of chocolate),
- bitter chocolate.

Statistical analysis

On the basis of previous authors' studies regarding an antioxidative capacity of a usual diet in four seasons (measured as a total antioxidative density in μmolTE/1000 kcal) in non–obese adults (578 dietary recalls, 144 subjects) and assuming in turn, 5%, 10% and 15% error of estimation of total antioxidative density, it was calculated that the minimum sample size in women subgroups equals 226, 57, 25, respectively. Therefore it was assumed to select 25 subjects in each FIT and NFIT group.

For the examined parameters, the correspondence of their distribution with the normal distribution was verified. Descriptive statistics were calculated for all parameters: arithmetic mean, median, standard deviation, minimum and maximum value or the range of 25–75 percentile. The following tests were used for verification of differences between the groups:

- T–test for independent samples, to compare demographic characteristics and anthropometric indicators of FIT and NFIT women (Table 1),
- Mann–Whitney U test, to compare parameters of distribution different than normal or of inhomogeneous variants, *i.e.* comparison of Q–ORAC of diets of FIT and NFIT women (Table 2),
- Friedman ANOVA by rank test for repeated measurements, to compare Q–ORAC of women's diets in 4 seasons (Table 2) and to compare the share (%) of selected food groups in the total Q–ORAC of women's diets in 4 seasons (Table 3),
- Wilcoxon matched pair test, to compare Q–ORAC of the diets of women in individual seasons (spring/summer, spring/winter *etc.*) (Table 2),

The analysis of the share of selected food groups in the total Q–ORAC of women's diets depending on the season was performed for six food groups for which the average median of share in the total antioxidative density of women's diet was more than 1% over the entire year.

TABLE 2. Total antioxidant density[1] (Q–ORAC in μmolTE/1000 kcal) in diets of exercising (FIT) and non–exercising women (NFIT) by season.

Season	FIT+NFIT n=48	FIT n=25	NFIT n=23	Ratio FIT/NFIT
Entire year[2]	18661 (13785–26 195)	18078 (13568–24 163)	18775 (14748–26245)	1.0
Spring[2]	13978 (11105–21 203)	12849 (10777–16 792)	17775 (11416–22452)	0.7
Summer[2]	23444 (15807–33769)	24823 (19079–33341)	21660 (15645–34198)	1.1
Autumn[2]	17567 (11 678–22 921)	16507 (11440–22600)	18748 (13968–23953)	0.9
Winter[2]	16745 (11542–21342)	15072 (10374–19971)	18534 (13968–23335)	0.8
4 season comparison[3]	***	***	***	–
Summer/spring ratio[4]	1.7***	1.9***	1.2***	–
Summer/winter ratio[4]	1.4***	1.6***	1.2***	–
Summer/autumn ratio[4]	1.3***	1.5***	1.2***	–
Spring/autumn ratio[4]	0.8*	0.8*	0.9	–
Spring/winter ratio[4]	0.8*	0.9	1.0	–
Autumn/winter ratio[4]	1.0***	1.1*	1.0*	–

[1]values expressed as median; () the range of 25–75 percentile presented in brackets; [2]FIT *vs.* NFIT comparison using the U Mann–Whitney test; [3]comparison in seasons using the Friedman ANOVA by ranks test; [4]comparison in seasons using Wilcoxon matched pair test; statistically significant differences at: *p<0.05, **p<0.01, ***p<0.001.

The correlations with a p level lower than 0.05 were considered significant. Statistical analyses were performed using Statistica 10.0 PL by StatSoft software.

RESULTS

FIT and NFIT women differed in their body composition (Table 1). FIT women, as compared to NFIT women, had significantly lower ($p<0.05$) mean waist circumference (by 4.2 cm), Waist–to–Height Ratio (by 0.02) and fat mass (by 3.8 % units), and higher mean total water content (by 2.5 % units) and fat–free mass (by 5.5 % units). FIT women had insignificantly lower mean body mass, hip circumference and BMI and insignificantly higher muscle mass than NFIT women.

The Q–ORAC median of diets of FIT and NFIT women did not significantly differ in any season, nor on average per year ($p>0.05$) (Table 2). The Q–ORAC median in the entire year was 18078 μmolTE/1000 kcal in FIT women and 18775 μmolTE/1000 kcal in NFIT women.

The antioxidative density of women's diet significantly depended on the season (Table 2). Seasonal differences in Q–ORAC were demonstrated in the total sample (FIT+NFIT; $p<0.001$) and independently in FIT ($p<0.001$) and NFIT ($p<0.001$) groups. In FIT+NFIT women's diets, Q–ORAC was the highest in summer (23444 μmolTE/1000 kcal), and the lowest in spring (13978 μmolTE/1000 kcal). Higher differences in Q–ORAC between seasons were recorded in FIT women (Q–ORAC ratios between seasons from 0.8 to 1.9) than in NFIT women (from 0.9 to 1.2). More significant ($p<0.05$) seasonal differences in Q–ORAC were revealed in FIT women (five differences between seasons per six) than in NFIT women (four differences per six). In FIT women, no significant differences in Q–ORAC were demonstrated between spring and winter (0.9 ratio). In NFIT women, no significant difference was demonstrated in Q–ORAC between spring and winter (1.0 ratio) or between spring and autumn (0.9 ratio).

The main sources of total antioxidative density in women's (FIT+NFIT) diets were fruit (share median of 32.1%), vegetables (11.5%), tea (9.3%), bitter chocolate (5.7%), total sweets (1.9%) and red wine (1.1%) (Figure 2). The median of share of other food groups in the total antioxidative density of women diets was small, amounting from 0.3% for nuts and dried fruit to 0 % for wholemeal bread and for total bread.

FIT and NFIT women did not significantly differ in dietary sources of antioxidative potential, or in the intake calculated for the entire year or in any of the seasons (Table 3). Median ratios for the share of individual food groups in Q–ORAC of FIT vs. NFIT women's diet were between 0.6 and 1.9 for the entire year, and between 0.4 and 2.2 in individual seasons (Table 3).

The share of food groups in Q–ORAC of FIT+NFIT women's diets, and independently in diets of FIT women and diets of NFIT women, significantly depended on the season, except for vegetables in FIT women (Table 3). For vegetables, the lowest seasonal variability in Q–ORAC was found during a year. For FIT+NFIT women, the median of the share of vegetables in Q–ORAC significantly varied from 9.5% in winter to 12.0% in summer ($p<0.05$), in FIT women the median of the share of vegetables in Q–ORAC changed insignificantly from 9.7% in winter to 12.8% in summer ($p>0.05$), and in NFIT women the median of the share of vegetables in Q–ORAC significantly changed from 9.3% in autumn and winter to 11.2% in spring ($p>0.05$).

The highest seasonal differences in the share of food groups in Q–ORAC were found for fruit (FIT+NFIT: between 18.4% in spring to 42.9% in summer $p<0.001$), tea (FIT+NFIT: from 18.2% in summer to 33.6% in spring;

p<0.001), bitter chocolate and total sweets (FIT+NFIT: from 7.2% in summer to 16.7% in spring; p<0.001). A corresponding seasonal variability was observed in subgroups of FIT and NFIT women.

DISCUSSION

The research did not reveal differences in the total antioxidative potential of diets between physically–active and non––active women on average. On the other hand, it proved significant seasonal variability in the intake of antioxidative components, as well as seasonal differences in the share of dietary sources of antioxidants in women's diets.

It is difficult to refer own results to literature data, since according to the best knowledge of the authors; there is a limited amount of information concerning the level of total antioxidative potential of diets, particularly of physically–active subjects. The available studies report an increased intake of selected food groups which increase the antioxidative potential of a diet and have a protective effect in the case of cardiovascular diseases [Franzini *et al*., 2012]. The meta–analysis published in 2014 revealed that an increase in the intake of flavo-

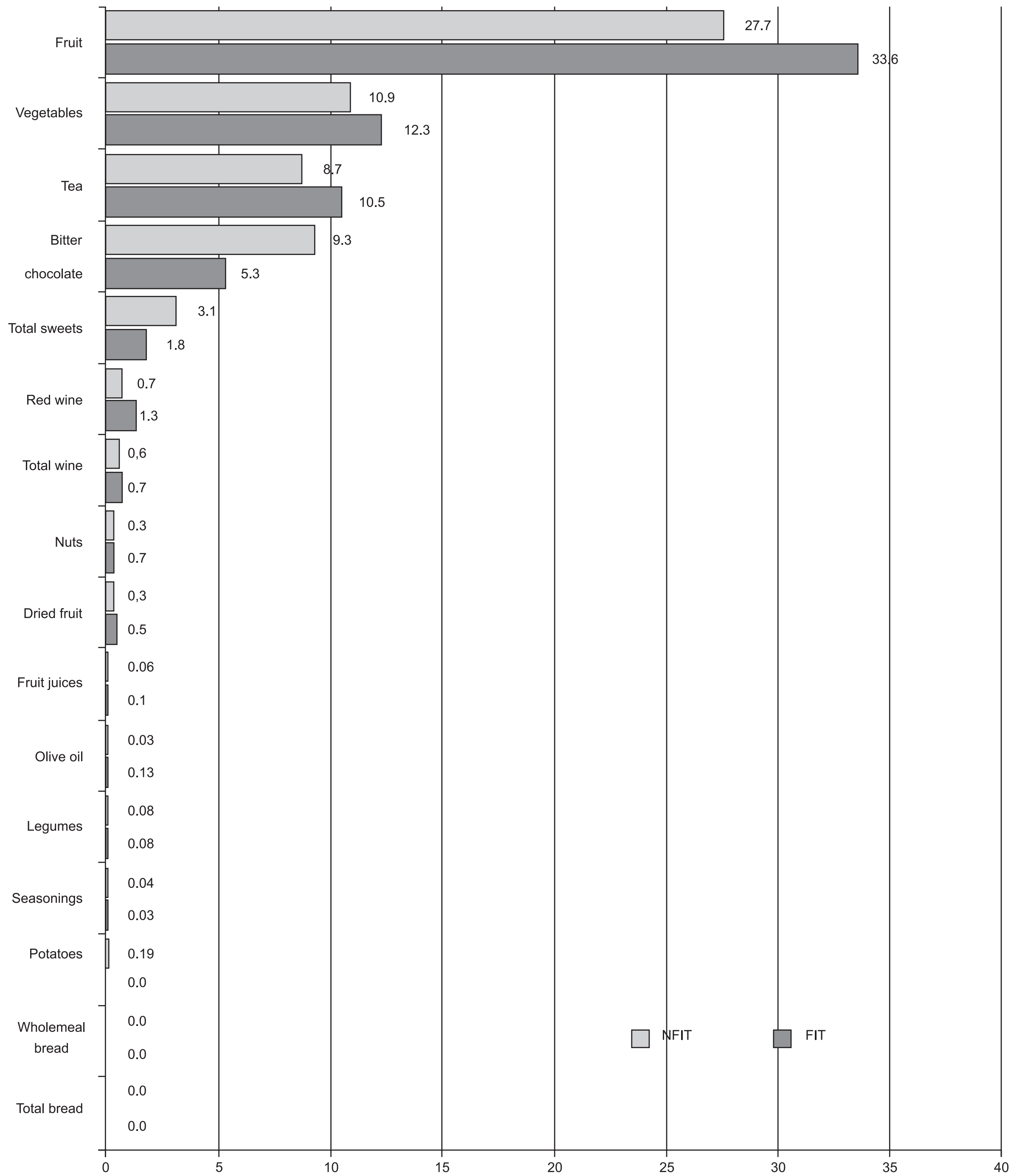

FIGURE 2. The share[1] (%) of selected food groups in the total antioxidant density (Q–ORAC) in women's diets (FIT+NFIT). ([1]the share is presented as median, therefore median calculated for all food groups is not the arithmetic mean of median calculated separately for each food group; FIT – exercising women; NFIT – non–exercising women).

TABLE 3. The contribution[1] (%) of selected food groups in total antioxidant density (Q–ORAC) in diets of exercising (FIT) and non–exercising women (NFIT) by season.

Food groups and season	FIT+NFIT n=48	FIT n=25	NFIT n=23	FIT/NFIT ratio
Fruit				
Entire year	32.1 (18.5–39.5)	33.6 (21.2–39.4)	27.7 (14.3–39.6)	1.2
Spring	18.4 (8.8–32.6)	19.0 (13.2–31.9)	17.4 (6.0–33.1)	1.1
Summer	42.9 (25.4–51.2)	46.3 (35.2–51.6)	39.9 (19.4–51.72)	1.2
Autumn	30.8 (12.4–42.4)	29.3 (16.1–42.1)	32.6 (11.2–47.1)	0.9
Winter	27.0 (16.2–39.1)	28.7 (19.7–39.1)	25.3 (9.1–41.1)	1.1
4 season comparison	***	***	***	
Vegetables				
Entire year	11.5 (7.8–15.4)	12.3 (7.9–15.9)	10.9 (7.7–14.3)	1.1
Spring	10.7 (7.3–17.1)	10.2 (7.3–17.8)	11.2 (7.3–13.9)	0.9
Summer	12.0 (8.4–16.9)	12.8 (8.5–16.6)	10.5 (8.0–17.6)	1.2
Autumn	10.1(7.6–15.0)	10.6 (8.4–16.2)	9.3 (5.8–13.7)	1.1
Winter	9.5 (6.5–13.8)	9.7 (7.0–13.0)	9.3 (5.3–14.1)	1.0
4 season comparison	*	NS	*	
Tea				
Entire year	9.3 (5.9–15.5)	10.5 (7.6–15.4)	8.7 (5.5–16.6)	1.2
Spring	33.6 (20.3–47.0)	33.1 (21.2–41.7)	37.8 (10.9–50.2)	0.9
Summer	18.2 (12.4–28.9)	15.1 (12.2–28.8)	22.4 (12.6–32.9)	0.7
Autumn	27.2 (15.3–40.6)	28.7 (18.8–41.8)	26.4 (10.0–39.4)	1.1
Winter	28.5 (16.8–42.4)	29.4 (22.7–41.6)	27.5 (9.6–46.9)	1.1
4 season comparison	***	***	***	
Bitter chocolate				
Entire year	5.7 (2.2–11.1)	5.3 (2.4–9.7)	9.3 (2.0–16.4)	0.6
Spring	16.7 (5.5–25.6	12.0 (5.7–21.4)	22.7 (4.6–37.6)	0.5
Summer	7.2 (3.1–17.6)	5.8 (3.3–13.2)	13.7 (0.8–31.7)	0.4
Autumn	11.1 (4.2–22.5)	9.8 (4.4–16.1)	12.0 (3.2–39.4)	0.8
Winter	11.6 (4.4–21.9)	11.2 (5.0–18.3)	12.2 (0.0–25.5)	0.9
4 season comparison	***	***	**	
Total sweets				
Entire year	1.9 (0.7–3.7)	1.8 (0.8–3.2)	3.1 (0.7–5.5)	0.6
Spring	16.7 (5.5–25.6)	12.0 (5.7–21.4)	22.7 (4.6–37.6)	0.5
Summer	7.2 (3.3–17.6)	5.8 (3.4–13.2)	13.7 (0.8–1.70)	0.4
Autumn	11.1 (4.2–22.5)	9.8 (4.4–16.1)	12.0 (3.2–39.4)	0.8
Winter	11.6 (4.4–21.9)	11.2 (5.0–18.3)	12.2 (0.0–25.5)	0.9
4 season comparison	***	***	**	
Red wine				
Entire year	1.1 (0.0–2.1)	1.3 (0.0–2.3)	0.7 (0.0–1.9)	1.9
Spring	1.1 (0.0–2.3)	1.3 (0.0–2.5)	0.0 (0.0–1.7)	–
Summer	0.5 (0.0–1.4)	0.8 (0.0–1.8)	0.0 (0.0–1.0)	–
Autumn	1.0 (0.0–2.1)	1.3 (0.0–2.1)	0.7 (0.0–2.1)	1.9
Winter	1.0 (0.0–2.0)	1.3 (0.0–2.3)	0.6 (0.0–1.2)	2.2
4 season comparison	***	***	***	

[1]The share is presented as a median, therefore the median calculated for whole year is not the arithmetic mean of median calculated for 4 seasons; [2]group of food products where the median of total antioxidant density in the group of women was lower than 1% in whole year were excluded from analysis; () The range of 25–75 percentile presented in brackets; Statistically significant difference for the comparisons FIT *vs.* NFIT between seasons or in the Friedman Rank ANOVA test: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, NS – not significant: $p > 0.05$.

noids by 500 mg/day was related to a 5% reduction of type 2 diabetes risk [Liu *et al*., 2014]. The total antioxidant potential of a diet has been evaluated in few studies. In Polish female and male students from Wrocław, the total antioxidative potential of the diet was 10031.9 μmolTE/day and 10050.1 μmolTE/day, respectively [Ilow *et al.,* 2012a]. Similar results were obtained in Greece (10796 μmolTE/day) [Dilis & Trichopoulou, 2010] and Spain [11139 μmolTE/day] [Agudo *et al.*, 2007]. Higher values were found in research on Swedish women (12127 μmolTE/day) [Rautiainen *et al*., 2008].

In our research, the total mean annual antioxidative potential of the women's diet was slightly higher than in the studies cited above. It amounted to about 18500 μmolTE/1000 kcal and did not depend on the level of the sport activity of women. Differences between our own research and quoted literature sources could result from the specificity of population groups under examination – age (students *vs.* adults), region of residence (Central *vs.* North Europe *vs*. the Mediterranean Basin) and cultural differences in composing daily food rations.

The main source of oxidative potential in women's diet was fruit. It provided about 1/3 of the total antioxidative density of the diet. The share of fruit in total antioxidative density was about three times higher than the share of vegetables or tea, and six times higher than of bitter chocolate. The significance of other food, *e.g.* seasonings, nuts, dried fruit, fruit juices and leguminous vegetables as sources of antioxidants in diets was marginal. Over the entire year, on average, they provided less than 1% of the total amount of antioxidants. Total sweets provided about 2% antioxidants and red wine – considered to be a rich source of natural compounds of the antioxidant effect – provided about 1% of those compounds in women's diets [Svilaas *et al*., 2004; Qureshi *et al.,* 2014]. The nutritional sources of antioxidant compounds and the seasonal differences in the intake of antioxidants in Polish diet have already been studied. These data were reported by Ilow *et al.* [2012a, 2012b] and supported our results regarding the main contribution of fruit and vegetables in the total antioxidant capacity of diet.

A significant seasonal variability in the intake of dietary antioxidants is an important observation of our study. Antioxidative density of women's diets was found to be the highest in summer, lower in autumn and winter season and the lowest in spring. Antioxidative density of women's diet in the summer season was 1.7 times higher than in spring. Seasonal differences in the content of antioxidants resulted from changes in the structure of food intake by women. In summer, the share of antioxidants derived from fruit increased, while the share of antioxidants from tea, bitter chocolate, total sweets and red wine decreased. Such differences in the consumption of fruit, tea, sweets and wine are expected. Many studies documented seasonal food intake changes in people living in various cultures and climatic conditions [Adamczyk, 2002; Cai *et al.,* 2004]. The seasonal character of the intake particularly concerned fruit and vegetables, as well as some milk products [Capita *et al.,* 2005].

Surprisingly, the research demonstrated little seasonal variability in the intake of antioxidants derived from vegetables. The share of vegetables in the total antioxidant density in women's diet ranged from 9.5% in winter to 12.0% in summer. This means that the ratio of seasonal variability between summer and winter in the intake of antioxidants derived from vegetables was 26%. This result suggests a relatively stable consumption of vegetables over the entire year, particularly in comparison to fruit. The ratio of seasonal variability between summer and spring in consumption of antioxidants derived from fruit was 133%. Apparently, seasonal variability in the intake of antioxidants partially depended on the amount of consumed fruit, as well as on their choice. As reported by Adamczyk [2002] and Kowrygo [2000], characteristic features of fruit consumption in Polish households include, among others, a highly seasonal character of intake (30–50%), low diversity of species and decreasing importance of self–grown fruit. A seasonal character of fruit consumption was also confirmed in our research. As claimed by Trębacz [2000], the consumption in summer and autumn is dominated by domestic fruits, while the share of exotic fruits prevails in winter and summer. Apples prevail among domestic fruits in summer and autumn (47% share in consumption in 2013). Therefore, apples can be considered as a relatively good, although not rich, source of antioxidants in comparison, *e.g.* with berry fruits (strawberries, raspberries *etc.*, the intake of which is on average lower by half and increases periodically only in the summer period [Gramza–Michałowska & Człapka–Matyasik, 2011; Budżety gospodarstw domowych, 2012, 2013; Trębacz, 2000].

The higher seasonal changes in the antioxidant potential of the diets of regularly exercising women in comparison to not–exercising women are an interesting aspect of the research. The ratio of total antioxidative density of women's diet for the season of the highest and the lowest antioxidative potential (summer *vs.* spring) was 1.9 for physically–active women and 1.2 for non–active women. It needs to be emphasised that the annual average total antioxidative potential of diets of physically–active and non–physically–active women was almost the same, with the ratio of the total antioxidative density of their diets being at 1.0. In spring, *i.e.* the season of the lowest intake of antioxidants, the antioxidant density of physically–active women decreased below 13000 μmolTE/1000 kcal, and in summer, in the season of the largest availability of fresh fruit, it was almost twice as high (with summer *vs.* spring difference of about 12000 μmolTE/1000 kcal). This proves high susceptibility of physically–active women to seasonal fluctuations in the supply of fruit, and maybe a lower ability to replace fruit with other foods providing a good source of antioxidants beyond the summer season. Not–regularly exercising women were characterised by a low range of seasonal variability in antioxidant intake (spring *vs.* summer difference below 4000 μmolTE/1000 kcal). In spring, a period of limited availability of fruit, the share of antioxidants originating from bitter chocolate and total sweets in diets of not–exercising women grew almost two–fold in comparison to the summer period. An increased intake of sweets could make it difficult for not–regularly exercising women to maintain sustained energy balance and contribute to a higher body fat content in comparison to regularly exercising women.

It is necessary to underline that our results do not support the hypothesis that people who exercise regularly tend to choose a healthy, differentiated diet better balanced in natural antioxidant components. Physical activity generates specific nutritional needs; the exercising increases energy demand to a large extent, which might provide to this oxygen and increase oxidative stress level. Literature data suggest that those who exercise regularly or occasionally should ingest supplementation and foods rich in antioxidants [Clarkson, 1995; Kanter, 1998; Cooper *et al*., 2002]. Therefore, persons regularly practicing sports should carefully balance their intake of compounds counteracting oxidative stress and reduce seasonal fluctuations in the supply of dietary antioxidants.

In summary, it is worthwhile to notice that individual dietary choices are influenced by many factors. In Poland it is mainly affected by the level education, income and employment status [Wądołowska *et al*., 2010]. Differences in social classes with regard to food choices and consumption are clearly defined by Drewnowski *et al.* [2004]. The net income and the amount money spent on food is a key factor in the consumption of food, especially meat, vegetables and fruit. In our study, we aimed to eliminate factors like income and education level, and physical activity level, as we emphasize, was the only life style factor that might influence food consumption.

The limitation of the study is the small size of the sample (48 women), although the dietary data collecting method – separately for each of the four seasons – makes it possible to estimate the total antioxidative potential of women's diets on the basis of information originating from 192 dietary interviews. Secondly, the use of the ORAQ as the index of antioxidant potential is discouraged and discussed [Pompella *et al*., 2014] owing to not fully explored metabolism of phytochemicals. The authors agree with this opinion. The ORAC density was used as the indicator of diet intake and quality. The verification of the absorption of phytochemicals in the body could provide other biochemical indicators identified in body fluids, which were not the subject of the study. Furthermore, it is clear that the comparison between groups can be made, thus the compared groups are remaining under a similar influence. This intensifies the concluding strength.

SUMMARY

The total antioxidative density of women's diets and the intake of dietary sources of antioxidants were not related to the physical activity of respondents. All women were characterised by seasonal fluctuations in the intake, which was higher in physically–active women than in physically non–active women. The antioxidative density of women's diets was the highest in summer, lower in autumn and winter and the lowest in spring.

In physically–active women, seasonal fluctuations in the antioxidative potential of their diets depended to the higher extent on changes in fruit consumption. Not–regularly exercising women compensated for a decreased intake of fruit in spring with an increased intake of sweets, including bitter chocolate

ACKNOWLEDGEMENTS

Part of results published in this work was presented at the 12th International Congress of Obesity (12–20 March 2014) as a poster presentation in Track 6: entitled 'From home environment to society: causes and consequences' and was published as abstract in Obesity Research Journal [Członka–Matyasik *et al*., 2014]. The authors thank professor Lidia Wądołowska for valuable comments.

This research work was partially financed under contract: POIG 01.01.02–00–061/09.

REFERENCES

1. Adamczyk G., Selected aspects of consumer behaviour and patterns of food consumption in households in the 1990s. Roczniki Akademii Rolniczej w Poznaniu – CCCXLIII. Ekon., 2002, 1, 31–41 (in Polish).
2. Agudo A., Cabrera L., Amiano P., Ardanaz E., Barricarte A., Berenguer T., Chirlaque M.D., Dorronsoro M., Jakszyn P., Larrañaga N., Martínez C., Navarro C., Quirós J.R., Sánchez M.J., Tormo M.J., González C.A., Fruit and vegetable intakes, dietary antioxidant nutrients, and total mortality in Spanish adults: findings from the Spanish cohort of the European Prospective Investigation into Cancer and Nutrition (EPIC–Spain). Am. J. Clin. Nutr., 2007, 85, 1634–1642.
3. Ainsworth B.E., Haskell W.L., Whitt M.C., Irwin M.L., Swartz A.M., Strath S.J., O'Brien W.L., Bassett D.R. Jr, Schmitz K.H., Emplaincourt P.O., Jacobs D.R. Jr, Leon A.S., Compendium of physical activities: an update of activity codes and MET intensities.. Med. Sci. Sports. Exerc., 2000, 32, Suppl., S498–S516.
4. Budżety gospodarstw domowych 2012 r. GUS. Warszawa 2013 (in Polish).
5. Cai H., Shu X–O., Hebert J.R., Jin F., Yang G, Liu D–K., Gao Y–T., Zheng W., Variation in nutrient intakes among women in Shanghai, China. Eur. J. Clin. Nutr., 2004, 58, 1604–1611.
6. Cao G., Booth S.L., Sadowski J.A., Prior R.L., Increases in human plasma antioxidant capacity after consumption of controlled diets high in fruit and vegetables. Am. J. Clin. Nutr., 1998, 68, 1081–1087.
7. Capita R., Alonso–Calleja C., Differences in reported winter and summer dietary intakes in young adults in Spain. Int. J. Food. Sci. Nutr., 2005, 56, 431–443.
8. Clarkson P.M., Antioxidants and physical performance. Crit. Rev. Food. Sci. Nutr., 1995, 35, 131–141.
9. Cooper C.E., Vollaard N.B., Choueiri T., Wilson M.T., Exercise, free radicals and oxidative stress. Biochem. Soc. Trans., 2002, 30, 280–285.
10. Członka–Matyasik, M., Ast K., Wadolowska L., Total antioxidant capacity and its dietary sources and seasonal variability in diets of women with different physical activity level. Obesity Rev., 2014, Suppl. 2, 177–205 (abstract).
11. Davies K.J., Quintanilha A.T., Brooks G.A., Packer L., Free radicals and tissue damage produced by exercise. Biochemical and biophysical research communications. 1982, 107, 1198––11205.
12. Dekkers J., van Doornen L., Kemper H., The role of antioxidant vitamins and enzymes in the prevention of exercise–induced muscle damage. Sports Med., 1996, 21, 213–238.
13. Dilis V., Trichopoulou A., Antioxidant intakes and food sources in Greek adults. J. Nutr., 2010, 140, 1274–1279.
14. Dutton G.R., Napolitano M.A., Whiteley J.A., Bess H.M., Is physical activity a gateway behavior for diet? Findings from a physical activity trial. Prev. Med., 2008, 46, 216–221.

15. Franzini L., Ardigò D., Valtueña S., Pellegrini N., Del Rio D., Bianchi M.A., Scazzina F., Piatti P.M., Brighenti F., Zavaroni I., Food selection based on high total antioxidant capacity improves endothelial function in a low cardiovascular risk population Nutr. Metab. Cardiovasc. Dis., 2012, 22, 50–57.
16. Gacek M., Assessment of the level of nutrient intake in a group of young women engaged in recreational fitness. Rocz. Panstw. Zakł. Hig., 2009, 60, 375379 (in Polish).
17. Gałek A., Targoński Z., Nutrition and its effect on the antioxidant potential level of organisms and on the genesis of some diseases connected with it. Żywność. Nauka. Technologia. Jakość. 2003, 34, 5–13 (in Polish).
18. Gramza–Michałowska A., Człapka–Matyasik M., Evaluation of the antiradical potential of fruit and vegetable snacks. Acta Sci. Pol., Technol. Aliment., 2011, 10, 61–72.
19. Ilow R., Regulska–Ilow B., Różańska D., Tangermann S., Grajeta H., An estimate of the total potential of antioxidant status of selected products consumed by the students of the Medical Academy in Wrocław, Poland in the years 2005–2007. Bromat. Chem. Toksykol. – XLV, 2012a, 3, 995–1000 (in Polish).
20. Ilow R., Regulska–Ilow B., Misiewicz D., Różańska D., Kowalisko A., Biernat J., The total antioxidant capacity of of selected products consumed by the 50–year–old residents of Wroclaw in 2008. Bromat. Chem. Toksykol. – XLV, 2012b, 3, 989–994.
21. Kanter M., Free radicals, exercise and antioxidant supplementation. Proc. Nutr. Soc., 1998, 57, 9–13.
22. Karolkiewicz J., Michalak E., Pospieszna B., Deskur–Śmielecka E., Nowak A., Pilaczyńska–Szcześniak Ł., Response of oxidative stress markers and antioxidant parameters to an 8–week aerobic physical activity program in healthy, postmenopausal women. Arch. Gerontol. Geriatr., 2009, 49, e67–e71.
23. Kay C.D., Kris–Etherton P.M., West S.G., Effects of antioxidant–rich foods on vascular reactivity, review of the clinical evidence. Curr. Atheroscler. Rep., 2006, 8, 510–522.
24. Kowalkowska J., Słowińska M.A., Słowiński D., Długosz A., Niedźwiedzka E., Wądołowska L., Comparison of a Full Food––Frequency Questionnaire with the Three–Day Unweighted Food Records in young Polish adult women: Implications for dietary assessment. Nutrients, 2013, 5, 2747–2776 (in Polish).
25. Kowrygo B., A study of the influence of market economy on the realm of food and nutrition in Poland. Rozpr. Nauk. Monogr. SGGW., 2000 (in Polish).
26. Liu Y.–J., Zhan J., Liu X.–L., Wang Y., Ji J., He Q.Q., Dietary flavonoids intake and risk of type 2 diabetes: A meta–analysis of prospective cohort studies. Clin. Nutr., 2014, 33, 59–63.
27. Lukaski H.C., Johnson P.C., Bolenchuk W.W., Lykken G.L., Assesment of fat free mass using bio–electrical impedance measurement of the human body. Am. J. Clin. Nutr., 1985, 41, 810–817.
28. Ou B., Hampsch–Woodill M., Prior R.L., Development and validation of an improved oxygen radical absorbance capacity assay using fluorescein as the fluorescent probe. J. Agric. Food Chem., 2001, 49, 4619–4626.
29. Pompella A., Sies H.A., Wacker R., Brouns F., Grune T., Biesalski H.K., Frank J., The use of total antioxidant capacity as surrogate marker for food quality and its effect on health is to be discouraged. Nutrition, 2014, 30, 791–793.
30. Prior R.L., Gu L., Wu X., Jacob R.A., Sotoudeh G., Kader A.A., Cook R.A., Plasma antioxidant capacity changes following a meal as a measure of the ability of a food to alter *in vivo* antioxidant status. J. Am. Coll. Nutr., 2007, 26, 170–181.
31. Przybyłowicz K., Wądołowska L., Biochemical and anthropometrical parameters and physical activity of women – a short report. Pol. J. Food Nutr. Sci., 2009, 59, 271–273.
32. Qureshi S.A., Lund A.C., Veierød M.B., Carlsen M.H., Blomhoff R., Andersen L.F., Ursin G., Food items contributing most to variation in antioxidant intake; a cross–sectional study among Norwegian women. BMC Public Health, 2014, 16, 14, 45.
33. Rautiainen S., Serafini M., Morgenstern R., Prior R.L., Wolk A., The validity and reproducibility of food–frequency questionnaire–based total antioxidant capacity estimates in Swedish women. Am. J. Clin. Nutr., 2008, 87, 1247–1253.
34. Svilaas A., Sakhi A.K., Andersen L.F., Svilaas T., Ström E.C., Jacobs D.R. Jr, Ose L., Blomhoff R., Intakes of antioxidants in coffee, wine, and vegetables are correlated with plasma carotenoids in humans. J. Nutr., 2004 , 134, 562–567.
35. Szponar L., Wolnicka K., Rychlik E., Photo Album of Products and Dishes. 2008, Wyd. IŻŻ, Warszawa (in Polish).
36. Trębacz A., Consumer dessert apples preferences. 2000, *in:* Proceedings of Third National Conference of Horticultural entitled “Opportunities and risks for the domestic gardening after the Polish accession to the European Union”, 13–14 Dec 2000, AR, Lublin, pp. 233–242 (in Polish).
37. U.S. Department of Agriculture, Agricultural Research Service. 2010. Oxygen Radical Absorbance Capacity (ORAC) of Selected Foods, Release 2. Nutrient Data Laboratory Home Page: [http://www.ars.usda.gov/nutrientdata/orac].
38. Vollaard N.B.J., Shearman J.P., Cooper C.E., Exercise–induced oxidative stress myths, realities and physiological relevance. Sports Med., 2005, 35, 1045–1062.
39. Wądołowska L., Validation of food frequency questionnaire – FFQ– Evaluation of the repeatability. Bromat. Chem. Toksykol., 2005, 38, 27–33 (in Polish).
40. Wądołowska L., Żywieniowe podłoże zagrożeń zdrowia w Polsce. 2010, Wyd. UWM, Olsztyn (in Polish).
41. Watzl B., Kulling S.E., Möseneder J., Barth S.W., Bub A., A 4–wk intervention with high intake of carotenoid–rich vegetables and fruit reduces plasma C–reactive protein in healthy, non–smoking men. Am. J. Clin. Nutr., 2005, 82, 1052– 1058.
42. Wood L.G., Garg M.L, Smart J.M., Scott H.A, Barker D., Gibson P.G., Manipulating antioxidant intake in asthma: a randomized controlled trial. Am. J. Clin. Nutr., 2012, 96, 534–543.

Submitted: 11 May 2014. Revised: 4 August 2014. Accepted: 3 October 2014. Published on–line: 4 November 2014.