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ORIGINAL ARTICLE

# Gender and Age – Dependent effect of type 1 diabetes on obesity and altered body composition in young adults

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## Abstract

**Introduction and objective.** The aim of the study was to evaluate the influence of age and gender on the prevalence of overweight and obesity, body composition and fatty tissue distribution in young adults with type 1 diabetes.

**Material and methods.** 197 patients with type 1 diabetes aged 20–40 years participated in the study. The control group consisted of 138 healthy adults. Body weight, height, waist and hip circumferences were measured. Analysis of body mass composition was performed using the bioimpedance. Study groups were stratified into cohorts aged <30 and 30+ years.

**Results.** Overweight and obesity were diagnosed in 35.5% and 13.2% of diabetic patients and in 26.1% and 7.3% of the control group, respectively (p=0.016).

In the whole study group, advanced age (OR=1.10; p<0.001) and diabetes mellitus (OR=2.25; p=0.001) predisposed patients to excess body weight. Women had a lower prevalence of overweight and obesity, but a trend toward excessive body mass was observed in diabetic females (OR=1.18; p=0.181). Diabetic females more often had abdominal obesity than control females (mean difference – 19.2%; p=0.020). Higher total body fat mass was found in the diabetic group (p=0.037). Diabetic females had a higher amount of absolute (p<0.001) and relative body fat mass (p=0.002), fat free mass (p=0.007), relative arm (p=0.007), leg (0<0.001) and trunk (p-=0.006) fat mass than control females. Diabetic males showed only higher relative fat mass of the lower limbs compared to control males (p=0.018).

**Conclusions.** Patients with type 1 diabetes develop overweight and obesity in early adulthood more frequently than the general population and are characterized by higher body fat mass. Gender-related differences in body weight and composition in young type 1 diabetic adults were found.

## Key words

obesity, body composition, type 1 diabetes, gender

## INTRODUCTION

A patient with type 1 diabetes has been traditionally described as having normal body weight and a patient with type 2 diabetes as overweight or obese; however, nowadays, phenotypic changes occur and overweight and obesity have become much more common among type 1 diabetic patients [1]. The problem of overweight and obesity is important due to their relationship with vascular complications.

Microangiopathy and macroangiopathy cause major morbidity and mortality among type 1 diabetic patients, and coronary artery disease is a leading cause of death in this group [2]. The high risk of these complications is related not only to inadequate metabolic control but also to decreased insulin sensitivity [3]. Insulin resistance is an important risk factor for cardiovascular disease and increased morbidity and mortality in the general population [4]. It was also found that insulin resistance is associated with the presence of microalbuminuria, endothelial dysfunction, disorders of coagulation and fibrinolysis, and increased chronic inflammation.

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Great progress in type 1 diabetes therapy has been achieved in recent years. Intensive insulin therapy has improved glycaemic control and reduced the development of diabetic vascular complications. However, insulin itself promotes weight gain which, in turn, increases cardiovascular risk [5, 6]. Obesity, especially abdominal obesity, is a strong predictor of insulin resistance.

In the last few decades, an epidemic of overweight and obesity has been observed in the general population of most western countries. Some studies have shown that this epidemic could also affect individuals with type 1 diabetes.

## OBJECTIVE

The aim of this study was to evaluate the effect of patients' age and gender on the prevalence of overweight and obesity, and on body composition and fatty tissue distribution in young adults with type 1 diabetes, and in healthy controls.

## MATERIALS AND METHOD

Patients with type 1 diabetes who regularly attended the same diabetic outpatients' clinic were recruited. The study was performed between 1 March 2010 – 28 February 2012 in all patients who were admitted for a routine thrice-yearly

follow-up. The inclusion criteria were: age 20 – 40 years, age at diabetes onset <20 years, duration of the disease >2 years. Exclusion criteria were: advanced stages of chronic diabetes complications, additional disease or medication which could affect body weight. All patients were treated with functional intensive insulin therapy (multiple insulin injections ≥ 4/day or pump therapy). The study group comprised 197 patients (119 men and 78 women).

The control group was also recruited between 1 March 2011 – 28 February 2012 and consisted of students and staff of the 4th Medical University Hospital in Lodz, Poland, and partners or friends of diabetic patients. Inclusion criteria were no personal history of diabetes or impaired glucose tolerance, age 20–40 years. Exclusion criteria were any chronic or acute diseases or medication that could affect body weight and body mass composition. The control group consisted of 138 adults (73 men and 65 women).

The study protocol was approved by the Ethical Committee of the Medical University of Lodz; all participants provided informed consent.

Body weight was measured using a medical scale with an accuracy of 100 g. The subjects were examined in a fasting state, wearing only underwear. Height was measured to the nearest 5 mm. Waist and hip circumferences were assessed with a flexible measuring tape with 5 mm accuracy. The body mass index (BMI) was calculated using the standard formula (weight/height$^2$). HbA1c was measured using an HPLC method (Variant, BIO RAD, Germany).

Analysis of body mass composition was performed using the bioimpedance method with the Body Composition Analyser BC 418 MA Segmental Body (Tanita Corporation, Tokyo, Japan) with a built-in 8 electrode 4 limb system [7].

Overweight was defined as a BMI of 25.0 – 29.9, obesity as a BMI of 30.0 or higher. Abdominal obesity was diagnosed according to International Diabetes Federation criteria [8].

The study groups were stratified into two cohorts aged <30 and 30+ years.

**Statistical analysis.** All statistical analyses were carried out using STATISTICA 10.0 package (Statsoft, Tulsa, Oklahoma, USA). P values of less than 0.05 were considered significant. Continuous variables were reported as median and quartiles due to non-normal distribution. The Mann- Whitney U test was used for comparisons. Comparison of categorical variables data were performed with the Yates corrected Chi-square test. Logistic regression was used to find interaction between excessive body mass and diabetes, age, and gender.

## RESULTS

Type 1 diabetic patients were characterized by higher waist and hip circumferences, as well as higher body weight and BMI in comparison to the control group (Tab. 1). Among type 1 diabetic patients, overweight occurred in 35.5% (95%CI 29; 1–42.4%) and obesity in 13.2% (95%CI 9; 2–18.4%), and differed from controls in whom the prevalence of overweight and obesity equaled 26.1% (95%CI 19.5–34.0%) and 7.3% (95%CI 4.0–12.8%), respectively (p=0.016).

When the patients were stratified into two cohorts, only in the <30 years group was the prevalence of overweight and obesity higher in diabetic patients than in the controls (33.6% [95%CI 26.7–41.2%] and 12.0% [95%CI 7.8–18.0%] vs. 19.2% [95%CI 12.5–28.3%] and 3.2% [95%CI 1.1–9.0%]; p<0.001; mean difference; obesity – 14.4% [95%CI 14.2–12.9%], overweight – 8.8% [95%CI 6.7–9]). No significant differences were found in the 30+ years group (43.59% and 17.95% vs. 40.91% and 15.91%; p=0.905) (Fig. 1).

**Table 1.** Comparison of clinical features between type 1 diabetic and control groups

| Parameter | Diabetic group (median and quartiles) N=197 | Control group (median and quartiles) N=138 | P |
|---|---|---|---|
| Male/Female | 119 (60.4%) /78 (39.6%) | 73 (52.9%) /65 (47.1%) | 0.171 |
| Age (years) | 25.7 (22.4–31.1) | 26.3 (22.7–33.3) | 0.120 |
| Duration of diabetes (years) | 14.7 (10.6–19.5) | | |
| HbA1c (%) | 7.3 (6.6–8.2) | | |
| Body height (cm) | 173 (166–180) | 173 (165–180) | 0.871 |
| Body weight (kg) | 74.5 (64.6–85.7) | 70.7 (59.0–71.6) | 0.008 |
| BMI (kg/m2) | 24.9 (22.3–27.7) | 23.1 (20.8–25.8) | <0.001 |
| Waist circumference (cm) | 85 (77–94) | 82 (74–90) | 0.010 |
| Hip circumference (cm) | 99 (93–106) | 97 (91–103) | 0.008 |
| WHR (cm/cm) | 0.86 (0.79 - 0.92) | 0.84 (0.77–0.90) | 0.145 |

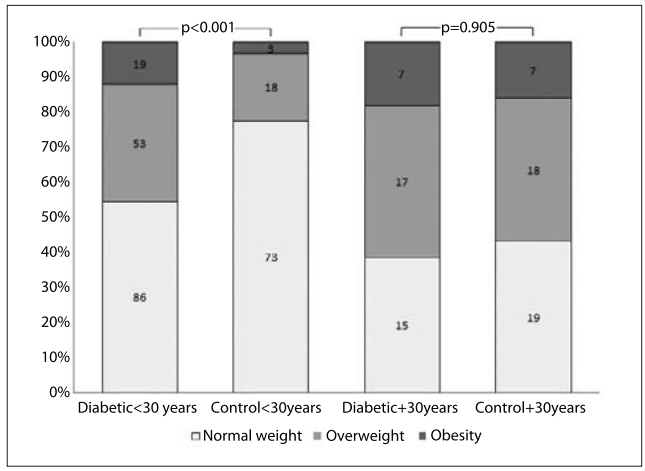


**Figure 1.** Prevalence of overweight and obesity in diabetic and control groups

Subgroup analysis among men and women showed that there were no differences in the prevalence of overweight and obesity between males and females with diabetes (p=0.122), but among healthy controls, excessive body weight was more frequent in males (p=0.021). In males with diabetes, the prevalence of overweight and obesity was similar to that in control males (p=0.472), but females with diabetes were more frequently overweight and obese than control females (26.9% [95%CI 18.3–37.7] and 15.4% [95%CI 9.0–25.0] vs. 16.9% [95%CI 9.7–27.8] and 4.6% [95%CI 1.5 – 12.7]; mean differences: overweight-10% [95%CI 8.6–9.9]; obesity-9.8% [95%CI 7.5–12.3]; p=0.020) (Fig. 2).

There were no significant differences in the prevalence of abdominal obesity between diabetic patients and the control group (48.2% [95%CI 41.4–55.2] vs. 37.7% [95%CI 30.0–46.0%]; p=0.056), nor between women and men with diabetes (50.0% [95%CI 39.2–60.8%] vs. 47.1% [95%CI 38.3–56.0%]; p=0.403). Women with diabetes had more frequent abdominal obesity than control females (50.0%

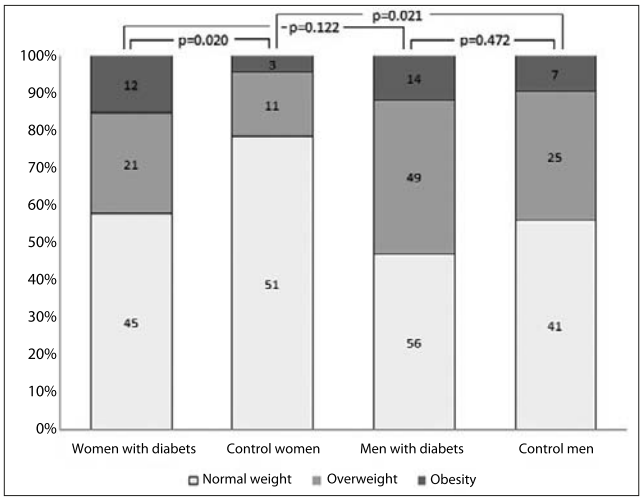


**Figure 2.** Prevalence of overweight and obesity stratified by sex

[95%CI 39.2–60.8%] vs. 30.8% [95%CI 20.9–42.8%]; p=0.020, mean difference – 19.2% 95%CI[0.9–18.0%]), while no such differences were observed between men with or without diabetes (47.1% [95%CI 38.3–56.0%] vs. 43.8% [95%CI 33.1–55.2%]; p=0.663).

Logistic regression showed that overall, study group age and diabetes mellitus predisposed patients to excess body weight (Tab. 2). Women had a lower prevalence of overweight and obesity, but women with diabetes mellitus had a tendency to excessive body mass (OR=1.18 [95%CI 0.93–1.51] p=0.181).

**Table 2.** The factors determining excessive body mass in the whole study group

| | Estimate | p | OR | 95%CI |
|---|---|---|---|---|
| Diabetes mellitus | 0.8098 | 0.001 | 2.25 | 1.38–3.66 |
| Female | –0.6722 | 0.005 | 0.52 | 0.32–0.82 |
| Age | 0.0935 | <0.001 | 1.10 | 1.05–1.15 |

Bioimpedance body composition analysis revealed that there were no significant differences between diabetic patients and controls except for higher total body fat mass.

Subgroup analysis among men and women showed that diabetic women were characterized by a higher amount of absolute and relative body fat and by a higher amount of fat free mass compared to females in the control group.

The relative fat content of the upper limbs, lower limbs and the trunk was also greater in diabetic females. Among men, only greater relative mass of adipose tissue of the lower limbs was observably higher in patients with diabetes than in healthy controls (Tab. 3).

**Table 3.** Comparison of body composition parameters between the type 1 diabetic and control groups

| Parameter | Diabetic group (median and quartiles) N=197 | Control group (median and quartiles) N=138 | P |
|---|---|---|---|
| Fat mass (kg) | 15.8 (13.0–21.1) | 14.1 (10.0–19.2) | 0.037 |
| Relative fat mass (%) | 21.9 (15.9–28.6) | 21.0 (14.0–21.0) | 0.284 |
| Fat free mass (kg) | 59.1 (48.2–66.8) | 54.5 (44.2–68.0) | 0.086 |
| Predicted muscle mass (kg) | 56.4 (45.5–63.7) | 52.1 (42.0–64.9) | 0.110 |
| Arm fat mass (%) | 20.6 (15.5–28.9) | 20.2 (16.0–26.3) | 0.252 |
| Leg fat mass (%) | 23.7 (15.2–33.1) | 22.7 (13.2–30.9) | 0.716 |
| Trunk fat mass (%) | 21.4 (14.8–27.8) | 20.4 (14.6–25.4) | 0.136 |

## DISCUSSION

The presented study revealed that adult patients with type 1 diabetes were more frequently overweight and obese before 30 years of age than their healthy peers. The prevalence of overweight and obesity in the control group, corresponds with current Polish data (Tab. 5) published by the Central Statistical Office [9], which indicates that the control group can be considered representative of the general population.

**Table 5.** The prevalence of overweight and obesity in the Polish population [1]

| Age group | Population (%) | | Women (%) | | Men (%) | |
|---|---|---|---|---|---|---|
| | Overweight | Obesity | Overweight | Obesity | Overweight | Obesity |
| 20–29 years | 24.4 | 5.2 | 13.3 | 3.7 | 36.6 | 6.9 |
| 30–39 years | 35.9 | 10.8 | 27.7 | 7.1 | 51 | 15.1 |

An increasing prevalence of overweight and obesity has been observed in the general population in almost all countries [10, 11]. In cross-sectional analyses of data of European Adult Cohort Populations the authors also observed a strong increase in obesity prevalence with increasing age, especially among women between the ages of 30–65 years [11].

According to the literature, prevalence of overweight and obesity among type 1 diabetic patients varies in different populations. Excessive body mass was found in 38.5% of a cohort of Dutch type 1 diabetic children [6]. Among Italian adolescents with type 1 diabetes, 24.5% were overweight and 3.9% obese [12]. Among adults, prevalence of excessive body mass in the presented study was lower than in patients from the USA, but higher than in Japanese subjects [13]. In Japan, in patients with the onset of type 1 diabetes below 20 years of

**Table 4.** Comparison of body composition parameters between women and men in the type 1 diabetic and in control groups

| Parameter | Women (median and quartiles) | | P | Men (median and quartiles) | | P |
|---|---|---|---|---|---|---|
| | Diabetic | Control | | Diabetic | Control | |
| Fat mass (kg) | 19.4 (14.5–27.3) | 14.7 (11.9–19.7) | <0.001 | 13.7 (8.8–19.0) | 12.3 (8.6–18.7) | 0.481 |
| Relative fat mass (%) | 29.9 (24.3–36.0) | 25.8 (21.7–30.6) | 0.002 | 17.3 (12.7–21.9) | 15.4 (12.2–20.8) | 0,315 |
| Fat free mass (kg) | 46.3 (43.0–50.5) | 43.9 (42.2–47.2) | 0.007 | 64.9 (60.8–71.8) | 67.4 (60.6–72.3) | 0.443 |
| Predicted muscle mass (kg) | 44.0 (40.4–47.2) | 41.6 (40.1–44.8) | 0.016 | 61.9 (57.7–68.6) | 64.3 (57.1–69.0) | 0.422 |
| Arm fat mass (%) | 31.4 (23.5–37.3) | 26.0 (22.0–32.1) | 0.007 | 16.2 (12.9–20.2) | 16.7 (12.5–19.7) | 0.741 |
| Leg fat mass (%) | 33.8 (30.2–38.3) | 30.9 (27.4–34.3) | <0.001 | 16.0 (12.1 19.3) | 13.6 (9.9–17.8) | 0.018 |
| Trunk fat mass (%) | 26.9 (20.3–33.0) | 22.2 (16.9–27.3) | 0.006 | 18.2 (12.2–24.4) | 16.3 (11.9–23.1) | 0.581 |

age, the prevalence of overweight was 17.5 % and prevalence of obesity was 2%. Rather surprisingly, the prevalence of excess body mass in type 1 diabetic patients was lower than in the general Japanese population [13]. Also, the findings of Shay et al. from the USA indicate that patients with type 1 diabetes had lower BMI, weight, waist circumference, lower amount of free fat mass, leg and trunk fat mass than the general population [14].

In the Pittsburgh Epidemiology of Diabetes Complications (EDC) Study, an increasing trend in the prevalence of excessive body mass among type 1 diabetic patients was revealed. At baseline, overweight was observed in 28.6% and obesity in 3.4% of subjects. After an 18-year follow-up, the prevalence of both increased respectively to 47% and 22.7%. The change in overweight and obesity prevalence over time was not attributable to the aging of the cohort alone, but also to a number of clinically-relevant factors [1]. At baseline, 7% of patients used intensive insulin therapy, while at follow-up 82% of the patients were treated with this method, which may have had a strong impact on the results. In the current study, all patients were treated with functional intensive insulin therapy.

Subgroup analysis among men and women showed that the higher prevalence of overweight and obesity in diabetic patients in comparison to the control group was restricted to women. A Swedish study showed a similar trend to the presented study; at the age of 18, diabetic girls were heavier and had higher BMI than control girls, which was not observed among boys [15]. Krishnan S. et al. also found that female adolescents with type 1 diabetes had more centrally distributed fat [16]. However, the reports from Italy revealed no gender difference, suggesting that the gender differences may be influenced by locally specific factors [12].

The explanation of the tendency to gain weight in type 1 diabetic patients is very complex. The increasing prevalence of overweight and obesity may result from the overall trend observed in the general population, from an anabolic effect of insulin treatment, or from a higher caloric intake as a result of fear of hypoglycaemia [12, 17]. The Diabetes Control and Complications Trial (DCCT) Research Group demonstrated that patients treated with intensive insulin therapy gained an average of 4.6 kg more than those on conventional therapy during a 5-year follow-up period [18].

Insulin itself promotes weight gain as it stimulates lipogenesis, inhibits protein catabolism, and slows down basal metabolism. These effects are also enhanced by peripheral insulin administration, which is associated with a reduced energy metabolism. In subjects with type 1 diabetes, insulin therapy induces insulin resistance selective for carbohydrate metabolism. Consequently, insulin doses need to be increased to maintain glycaemic control but, as insulin maintains its role in lipogenesis and protein metabolism, intensification of insulin treatment promotes fat mass increases and lean body mass gain [19].

Bioimpedance analysis of body mass composition in the presented study showed increased body fat mass in diabetic patients. After performing analysis in the gender subgroup, diabetic women had a greater percentage of fat in the upper and lower limbs and in the trunk, whereas diabetic men were characterized only by higher relative lower limbs fat mass. Dunger et al. observed that girls with type 1 diabetes had a higher percentage of body fat than the control girls, whereas there was no difference between the type 1 diabetic and control boys [20]. Diabetic girls also gained more body fat than their healthy peers during puberty stages. These gender differences may be associated with sexual dimorphism in insulin resistance and growth hormone levels. This is supported by an earlier study that showed a lower glucose disposal rate and higher rates of growth hormone release in females during the hyperinsulinaemic-euglycaemic clamp [21].

According to some authors, the metabolic influence of adipose tissue may not be homogenous across anatomic regions or levels of obesity. Shay et al. showed that greater lower limbs' fat mass was significantly associated with higher insulin resistance in healthy men and women [22]. In another study, leg fat mass favourably influenced insulin resistance in obese non-diabetic women, but did not do so in obese non-diabetic men [23]. According to Shay et al., in comparison to adults with normal glucose tolerance, leg fat mass did not show any positive association with insulin sensitivity in type 1 diabetes [14].

In the presented study, diabetic females demonstrated not only a greater amount of fat mass but also fat free mass. Rosenfalck et al. observed that during the first year after the onset of type 1 diabetes, patients' body weight increased, both in total fat mass and in lean body soft tissue mass [24].

Reports from the DCCT/EDIC and Pittsburgh Epidemiology of Diabetes Complications (EDC) demonstrated that increased adiposity resulted in an adverse lipid and haemodynamic profile and long-term complications. The EDC study showed, however, that excess weight in association with improved glycaemic control was less harmful with respect to the cardiovascular disease risk profile [18, 25]. Due to the complexity of this problem, longitudinal studies are needed to assess the association between diabetes, excessive body mass, and body mass composition.

## CONCLUSIONS

Patients with type 1 diabetes develop overweight and obesity before 30 years of age more frequently than the general population and are characterized by higher body fat mass. Gender-related differences in body weight and body composition in young type 1 diabetic adults were observed. Excessive body mass and abdominal obesity were more common in women.

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