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Obesity in the Natural History of Type 1 Diabetes Mellitus: Causes and Consequences

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1. Introduction

There has been a worldwide epidemic increasing in the prevalence of sedentary, overweight and obesity that comes with modernity and urbanization (Wang et al., 2002). The consequence is the development of insulin resistance (IR) and type 2 diabetes (T2D). This is classically defined as a metabolic disease that occurs due to a higher IR that leads to a slow setting of lower insulin production (more relative than absolute), in general in adult age. T2D is associated also with a genetic predisposition. The majority of T2D individuals are overweight or obese and the ones who do not, at least present increased abdominal adipose mass (ADA, 1997). The rising prevalence of overweight and obesity is happening also in children and adolescents (Pinhas-Hamiel et al., 1996; Willi & Egede, 2000; Rosenbloom et al., 1999). The metabolic syndrome (MS), which physiopathology is based on IR, shows the same trend in children and adolescents (Jago et al., 2008), as well as isolated pre-diabetes (Li et al., 2009).

In parallel, it has been seen an elevation in the number of type 1 diabetes (T1D) cases and its establishment at a younger age (EURODIAB ACE Study Group, 2000). T1D is characterized primarily by a pancreatic beta cell destruction, which may lead to ketosis. It can be classified as autoimmune (with positive anti-islet, anti-insulin, anti-GAD, anti-IA2 and/or anti-IA2 beta antibodies) or idiopathic, in which no autoantibodies can be detected, and occurs more frequently in individuals of African-American or Asian origin. Multiple genetic predisposition and environmental factors are involved with T1D (ADA, 1997). At least one of those autoantibodies is present in 85-90% of T1D on diagnosis. The treatment for T1D consists of multiple insulin injections, known as intensive treatment, to obtain adequate glycemic control and therefore prevent micro (The DCCT Research Group, 1993) and macrovascular (Nathan et al., 2005 and 2003) chronic complications. However, it can be followed by weight gain most of the times (Arai et al., 2008), which can amplify the risk of cardiovascular disease (CVD) in spite of good glycemic control. This weight gain can start on puberty and persist along adulthood (Särnblad et al., 2007). Therefore, some of these patients present clinical features of both T1D and T2D, confounding its classification. This phenotype was initially called double diabetes (DD) (Libman & Becker, 2003; Becker et al.,

2001), and is characterized by positive pancreatic autoantibodies in patients with clinical features of T2D, as IR and overweight and/or obesity (Pozzilli & Buzzetti, 2007; Gilliam et al., 2005; Reinehr et al., 2006), as shown in Table 1 (Pozzilli & Buzzetti, 2007) and in Figure 1.

| | T1D | DD | T2D |
|--|--|--|---|
| Age at disease onset | Childhood +++ Adolescence +++ Adult + | Childhood ++ Adolescence ++ Adult (LADA) + | Childhood + Adolescence ++ Adult +++ |
| Major genetics predisposition | MHC class I and II, <i>InsVNTR</i> , <i>CTLA-4</i> , <i>PTPN22</i> | ? | <i>APM1</i> , <i>PPARγ 2</i> , <i>PtdCho-1</i> , <i>TCF7L2</i> |
| Environmental factors | Diet, viruses Cow's milk in infancy | Life style (diet, sedentary life) | Life style (diet, sedentary life) |
| Circulating antibodies to β cells | +++ | + | - |
| T cell-mediated immunity to β cells | +++ | ++ | - |
| C-peptide secretion | - | + | +++ |
| IR | -/+ | ++ | +++ |
| Inflammatory markers (cytokines, adipokines) | + | ++ | +++ |
| Macrovascular complications | + | ++ | +++ |

Table 1. Clinical and pathogenic features of DD compared to T1D and T2D (Pozzilli & Buzzetti, 2007).

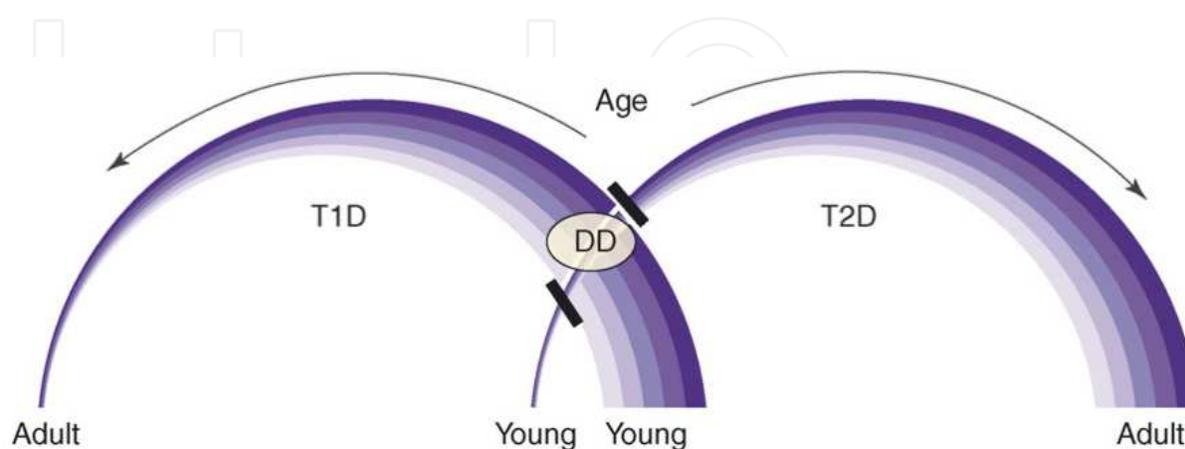


Fig. 1. Schematic representation showing where DD lies in respect to age and the two types of diabetes, as illustrated by two 'rainbows' (Pozzilli & Buzzetti, 2007).

2. Obesity as a accelerate factor to type 1 diabetes mellitus development

Studies with streptozotocin-induced diabetic baboons showed that to have an abnormal glucose tolerance it is necessary an isolated huge loss of beta-cell mass or a moderate loss of these cells associated to an IR (McCulloch et al., 1991), that could be in humans the physiologically IR of adolescence (Acerini et al., 2000) or gestation (Buschard et al., 1987), periods with higher incidence of T1D, or pathological situations like infection (usually one of the triggering factors of T1D) or weight gain.

Others studies suggest that the increase in the body mass index (BMI) and the consequent IR may accelerate the β cell destruction process in individuals predisposed to T1D, due to the release of obesity-related cytokines that show inflammatory and/or immunomodulatory properties (Aldhahi & Hamdy, 2003), triggering diabetes. This hypothesis may be reinforced by one study that correlated high anti-GAD levels with high BMI (Rolandsson et al., 1999). Two interesting data from studies with non-obese diabetic (NOD) mice are that hyperinsulinemia, an IR marker, precede clinical T1D (Armani et al., 1998) and that T1D incidence falls after treatment with rosiglitazone, an insulin sensitizer drug (Beales & Pozzili, 2002).

The IR, autoimmunity and apoptosis of the β cells constitutes the three factors of the called "accelerator hypothesis", proposed by Wilkin (Wilkin, 2001), that contemplate the factors presented in both more common types of diabetes, that is, T2D and T1D. There is a constitutional (intrinsic) high speed of apoptosis of β cells that is necessary to the development of diabetes, but rarely enough. The other two factors, extrinsic, that can speed the apoptosis of beta-cells are IR (result of weight gain and/or physical inactivity) and autoimmunity against beta-cells.

It is known that obese individuals have elevated serum levels of leptin, a cytokine secreted by adipocytes in proportion to adipose tissue mass and that is responsible, among other functions, for regulating food intake and thus BMI. Moreover, leptin controls the cellular immune response and is involved in the pathogenesis of autoimmune diseases (Lord, 2002). Studies have shown that administration of leptin in NOD mice promoted an early inflammatory infiltrate in the pancreatic islets, increased production of interferon gamma (IFN-gamma) by T lymphocytes, which accelerated the establishment of a T1D (Matarese, 2002 e 2005).

On the other hand, adiponectin, another important cytokine produced by adipose tissue, inversely proportional to its fat mass, can decrease the systemic and pancreatic islets inflammatory process, acting as a protective factor in the development of T1D, in addition to reducing IR (Kadowaki et al., 2006; Wellen & Hotamisligil, 2005).

However, development report (OECD, 2009) from 16 countries does not show any obvious relationship between national estimates of childhood obesity prevalence and incidence rates of T1D (Table 2). Therefore, obesity does not account for the wide between-country differences in T1D incidence, which range from 0.57 per 100 000 person-years in China to more than 48 per 100 000 person-years in Sardinia and Finland in the 0- to 14-year age group (Daneman, 2006).

On the other hand, in a meta-analysis of nine studies (eight case-control studies and one cohort study) comprising a total of 2658 cases (Verbeeten et al., 2011), seven reported a significant association between childhood obesity, BMI or %weight-for-height and increased risk for T1D. Four of these studies reported childhood obesity as a categorical exposure and

produced a pooled odds ratio of 2.03 (95% CI 1.46–2.80) for subsequent T1D, but with age at obesity assessment varying from age 1 to 12 years (Figure 2). A dose-response relationship was supported by a continuous association between childhood BMI and subsequent T1D in a meta-analysis of five studies (pooled odds ratio 1.25 (95%CI 1.04–1.51) per 1 SD higher BMI) (Figure 3).

| Country | T1D incidence rate in children aged 0-14 years (per 100.000 person-years) | % of children aged 11-15 years overweight or obese |
|-------------|---|--|
| Finland | 57,4 | 15,8 |
| Sweden | 41 | 10,5 |
| Norway | 27,9 | 10 |
| UK | 24,5 | 12 |
| Denmark | 22,2 | 9,7 |
| Canada | 21,7 | 21,3 |
| USA | 20,8 | 29,8 |
| Netherlands | 18,8 | 8 |
| Germany | 18 | 12 |
| Ireland | 16,3 | 14,2 |
| Iceland | 14,7 | 14,5 |
| Spain | 13 | 16,7 |
| Poland | 12,9 | 11,2 |
| France | 12,2 | 10,5 |
| Greece | 9,9 | 18,8 |
| Italy | 8,4 | 18,3 |

Table 2. Relationship between Type 1 diabetes incidence and prevalence of childhood overweight or obesity in 16 Organization for Economic Co-Operation and Development (OECD) countries, from Health at a Glance 2009: OECD Indicators (OECD, 2009).

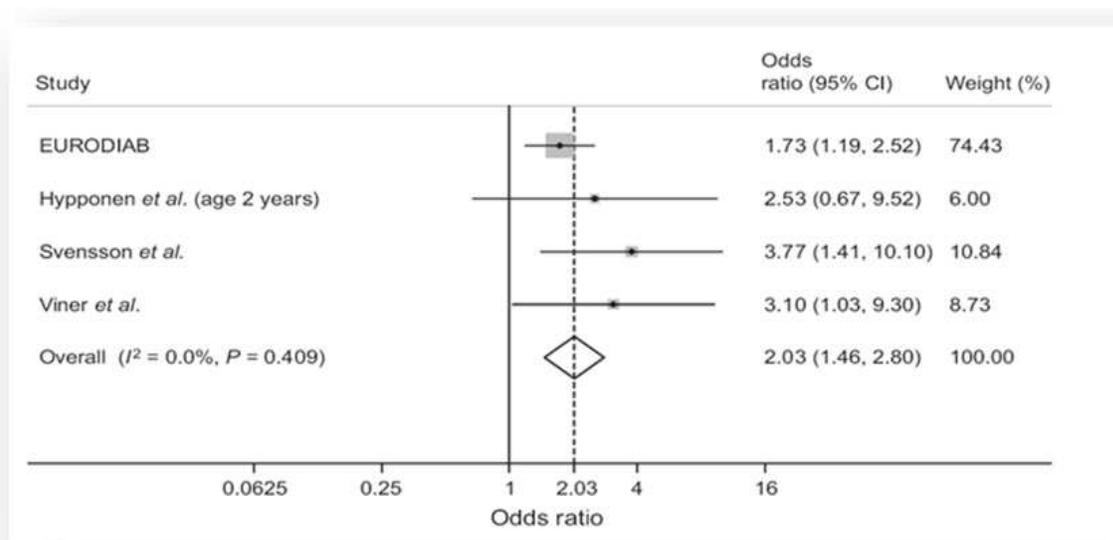


Fig. 2. Meta-analysis (fixed-effects inverse variance model) of studies of childhood obesity as a risk factor for subsequent T1D (Verbeeten *et al.*, 2011).

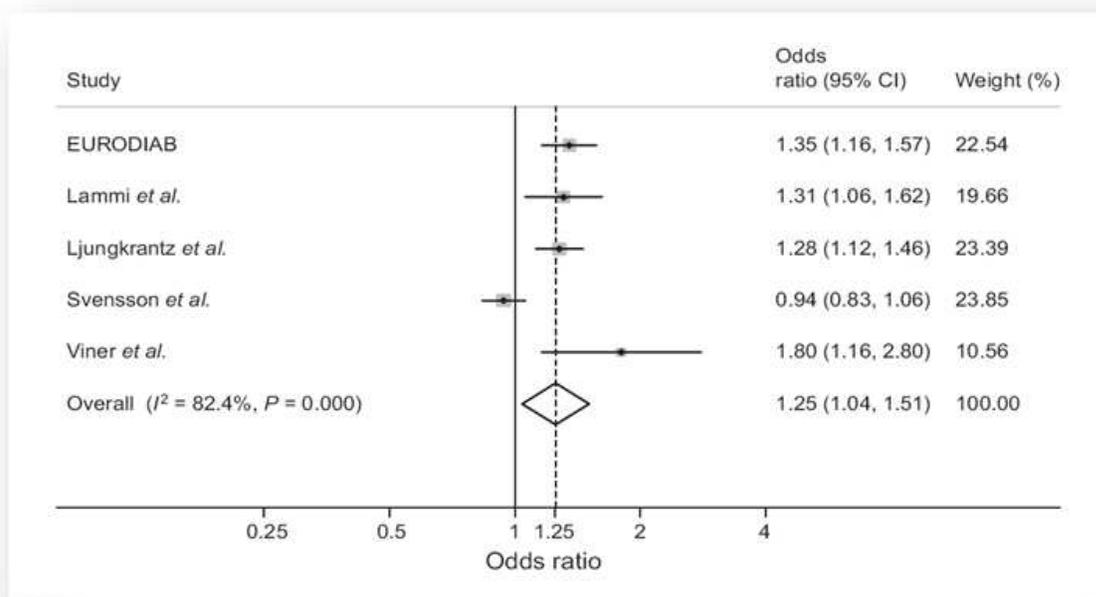


Fig. 3. Meta-analysis (random-effects inverse variance model) of studies of childhood BMI as a risk factor for subsequent T1D. Odds ratios correspond to a 1-unit increase in BMI standard deviation score (SDS)(Verbeeten *et al.*, 2011).

3. Obesity after clinical Type 1 diabetes diagnostic

If on one hand intensive insulin prevents microvascular and macrovascular complications associated with poor glycemic control, the other brings an increased risk of severe hypoglycemia and weight gain, traditionally viewed as a normalization of weight, i.e. the correction of glycosuria, diuresis, and wasting with the initiation of insulin therapy. Insulin stimulates lipogenesis, inhibits protein catabolism, and slows basal metabolism. Other important aspect is the abnormal physiological route of insulin via its peripheral administration in those with T1D, which is also associated with reduced energy metabolism (Charlton & Nair, 1998). Classically normal or underweight, the phenotype of the T1D individuals is thus changing. A follow-up of 18 years of 589 individuals from the Pittsburgh Epidemiology of Diabetes Complications Study (EDC), a cohort of childhood-onset T1D, showed an increase in the prevalence of overweight by 47% (from 28.6% at baseline to 42%) and of obesity by sevenfold (from 3.4% at baseline to 22.7%), concomitantly with the highest prevalence of intensive insulin therapy - 7% and 82% were on intensive insulin therapy (≥ 3 insulin injections per day or on insulin pump) at baseline and 18 years after, respectively (Conway *et al.*, 2010). Although injection frequency increased, total daily insulin dose decreased from 0.76 to 0.62 U/kg/day. Figure 4 shows the temporal patterns in the prevalence of being overweight and obese and the use of intensive insulin treatment, and these data was not influenced by the aging of the cohort and survivorship, as can be seen on Table 3. (age-group-specific prevalence for the 40–49-year-old age group by time period): overweight or obesity were present in 25% of the T1D individuals in 1986–1988 and in 68.2% in 2004–2007 (Conway *et al.*, 2010).

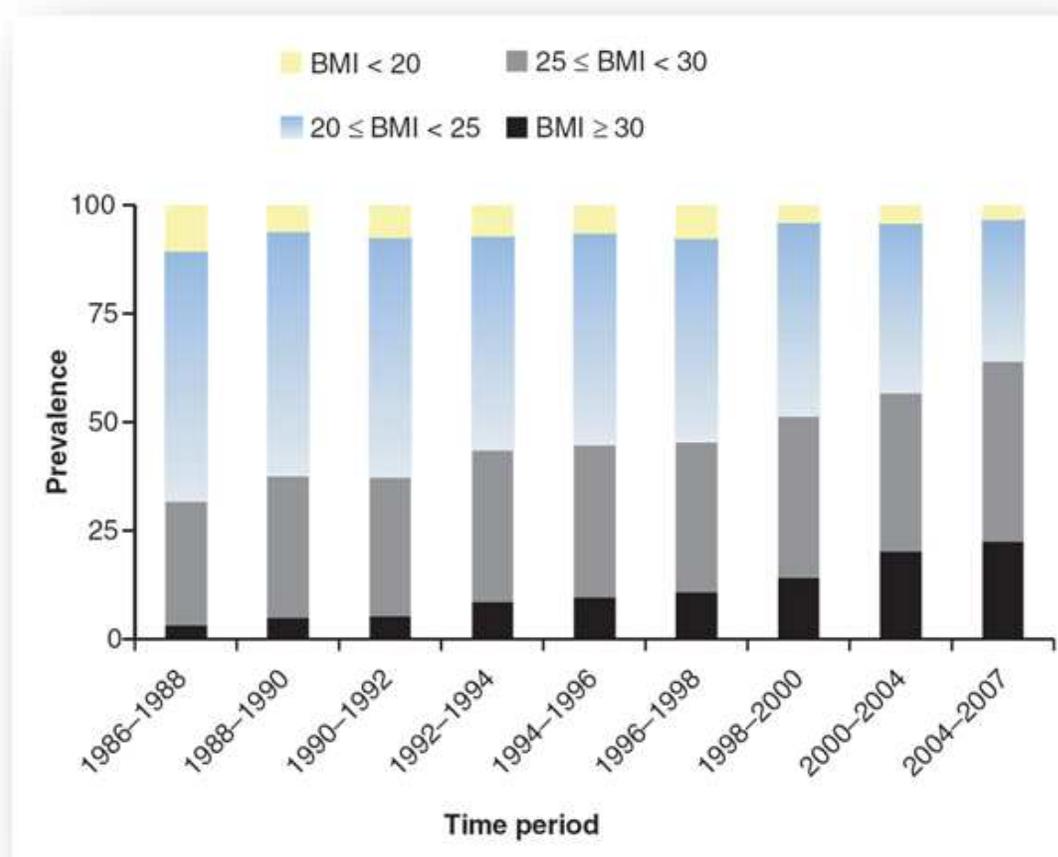


Fig. 4. Temporal patterns in overweight and obesity in Type 1 diabetes (Conway et al., 2010).

| | BMI < 20 kg/m ² (underweight) | 20 ≤ BMI < 25 kg/m ² (normal weight) | 25 ≤ BMI < 30 kg/m ² (overweight) | BMI ≥ 30 kg/m ² (obese) |
|-----------|---|---|--|---------------------------------------|
| 1986-1988 | 4 (9.1) | 29 (65.9) | 10 (22.7) | 1 (2.3) |
| 1988-1990 | 3 (5.8) | 29 (55.8) | 17 (32.7) | 3 (5.8) |
| 1990-1992 | 6 (8.5) | 43 (60.6) | 18 (25.4) | 4 (5.6) |
| 1992-1994 | 10 (12.2) | 39 (47.6) | 27 (32.9) | 6 (7.3) |
| 1994-1996 | 14 (11.9) | 58 (49.2) | 35 (29.7) | 11 (9.3) |
| 2004-2007 | 5 (2.9) | 50 (28.9) | 79 (45.7) | 39 (22.5) |

Table 3. Age-specific prevalence of underweight, normal weight, overweight, and obese for those aged 40-49 years in each time period, n (%) (Conway et al., 2010)

The prevalence of overweight/obesity in this T1D population was lower at baseline than general population (31.9 vs. 55.9%), although the incidence in both was similar after a mean of 7 years' follow-up (12%), and after 18 years' follow-up the prevalence of overweight in T1D people appear to have increased at a faster pace than in the general population.

Predictors of weight change were a higher baseline HbA1c, symptomatic autonomic neuropathy (inversely), overt nephropathy (inversely), and going onto intensive insulin therapy during follow-up. By the end of this study, 24% of the T1D people had died. Thus, as overt nephropathy and symptomatic autonomic neuropathy are associated with weight loss, the survivors are biased toward weight gain. The EDC Study also showed that, in T1D with a higher baseline HbA1c, moderate weight gain did not adversely affect the cardiovascular risk profile and favorably influenced the lipid profile in the setting of ameliorated glycemic control, but increased LDL cholesterol levels in the absence of a major improvement in glycemic control (Williams et al., 1999). Subjects who gained the least weight had the lowest LDL cholesterol levels at the follow-up period regardless of changes in HbA1c category. But when the weight gain after insulin was great, case of part of the patients who received intensive treatment in the Diabetes control and complications trial (DCCT) study and placed in the highest quartile of change in BMI, there was unmasking of central obesity or even MS in T1D (Purnell et al., 1998). These patients gained an average of 14 kg during the course of the study, about twice the weight gain equivalent to the third quartile of intensive care and the last quartile of patients on conventional treatment. Patients with the highest weight gain had the highest values of waist-hip ratio, blood pressure and insulin requirements when compared to the group with the same degree of glycemic control and also in intensive care, but who did not gain much weight. These youngsters also had a relatively atherogenic lipid profile, with elevations to levels of triglyceride, LDL cholesterol and apolipoprotein B (apoB) compared to their peers, also intensively treated, but without similar weight gain. The DCCT study (Purnell et al., 2003) also showed that the presence of family history of T2D was one of the strongest predictors for the weight gain in individuals with T1D who underwent intensive insulin therapy in the DCCT. In individuals with a family history of T2D, the weight gain, the final weight, the central fat distribution assessed by waist circumference, the insulin dose (units/kg/day) and degree of dyslipidemia were higher than in those without history familial T2D. Dyslipidemia included increases in triglycerides (TG) in VLDL particles and IDL (intermediate-density lipoprotein), which changes are common in individuals with central adiposity (Terry et al., 1989) and T2D (Brunzell & Chait, 1997). This could correspond to the expression of genes predisposing to T2D in this population. The findings of this study support the hypothesis that insulin treatment allows the expression of various components of MS in individuals with T1D who have family history of T2D, but also suggests that this group should be monitored more closely and earlier in relation to their potential of developing macrovascular complications, which is responsible for most of the increase in mortality found in patients with T1D (Laing et al., 1999), more than three times the general population.

4. Type 1 diabetes and Metabolic Syndrome

The insulin resistance is a soil to MS development and it is present during T1D evolution, even because of weight gain or because of the glucotoxicity – there was shown a proportion

between fasting glycemic and IR, and improvement of glycemic control is linked to better insulin sensitivity, for example contributing to the so-called period of "honeymoon", the remission phase of diabetes, well known by clinicians, and may occur in up to 50% of patients during the first year of disease (DCCT Research Group, 1987). Yki-Jarvinen et al. (1986), studied insulin sensitivity using the hyperinsulinemic euglycemic clamp in 15 adult patients with T1D and normal BMI during the first 2 weeks, 3 months and 1 year after clinical diagnosis. In the first two weeks of diagnosis, they had a decrease in insulin sensitivity when compared to controls. However, three months after diagnosis, there was an improvement in insulin sensitivity in these patients, and it became similar to that of controls. Importantly, this improvement in insulin sensitivity coincided with the period of "honeymoon" in these patients, and showed a good correlation with HbA1c values and insulin doses in the treatment. Insulin sensitivity of patients who entered clinical remission was 40% greater than those who did not have this condition. Recently, our group performed a cohort and multicenter study (Gabbay et al, 2005; Dib, 2006) to determine the prevalence of MS in a group of patients with T1D and assessing their relation with the time of diagnosis. The study included 524 (276 females) T1D (according to the criteria of the Brazilian Diabetes Society and American Diabetes Association) with an average age of 20 ± 9 years and divided according to the time of T1D in 4 groups: G-I, ≤ 5 years ($n = 264$), G-II, 6-10 years ($n = 108$), G-III, 11-15 years ($n = 96$) and G-IV, > 15 years ($n = 56$). In these groups were analyzed BMI (kg/m^2), total daily doses of insulin for treatment ($\text{U}/\text{kg}/\text{day}$), HbA1c values and the prevalence of MS. The criterion used for characterization of MS was the one of the World Health Organization, that is, diabetes mellitus and 2 or more of the following: increase in waist circumference (criterion set for youth) (Freedman et al., 1999), $\text{TG} \geq 150 \text{ mg}/\text{dL}$ or $\text{HDL-C} < 40 \text{ mg}/\text{dL}$ (males) and $< 50 \text{ mg}/\text{dL}$ (females), urinary albumin excretion ($\geq 20 \mu\text{g}/\text{min}$) and hypertension (according to criteria adjusted for age and sex) (Brazilian Hypertension, Heart and Nephrology, Societies 2002). The daily insulin dose and HbA1c values were significantly lower in G-I than in other groups (G-I: 0.7 ± 0.3 , G-II: 1.1 ± 0.3 , G-III: 1.0 ± 0.3 and G-IV: $0.8 \pm 0.2 \text{ U}/\text{kg}/\text{day}$, $p = 0.000$) and (G-I: 8.7 ± 2.6 , G-II: 9.5 ± 2.2 , G-III, 9.5 ± 2.3 and G-IV: $9.4 \pm 2.8\%$, $p = 0.000$), respectively. There was a significant increase in the values of waist circumference (G-I: 71.9 ± 2.2 , G-II: 75.7 ± 11.1 , G-III: 76.5 ± 8.4 and G-IV: $80.2 \pm 7.5 \text{ cm}$, $p = 0.000$) and BMI (G-I: 20.6 ± 3.8 , G-II: 22.4 ± 3.6 , G-III: 22.5 ± 3.1 and G-IV: $23.1 \pm 4.1 \text{ kg}/\text{m}^2$, $p = 0.000$) after 5 years of diagnosis of T1D. However, it is important to note that the BMI values were not superior to classical criteria of obesity or even overweight. The prevalence of MS (G-I: 5.1, G-II: 11.2, G-III: 18.9 and G-IV, 31.5%, $p = 0.000$) increased with time of diagnosis (Figure 5). The odds ratio (OR) for the development of MS in the other groups in relation to G-I was significant G-III onwards, being equal to 3.59 and 7.18 for this for G-IV in relation to G-I, both with $p = 0.001$. That is, the odds for the development of MS in patients with T1D and over 15 years of diagnosis is 618% higher than under 5 years of disease. Similarly, the odds for the development of MS for patients with T1D between 11 and 15 years duration is 259% higher than those with less than 5 disease in this group of patients. Other factors related to insulin resistance, such as visceral fat, BMI and TG, even when considered separately, also increased with the duration of the disease.

In another study (Giuffrida et al., 2005), 500 T1D patients [age 19.7 ± 8.9 years (mean \pm SD), 52% female], we observe that, also analyzed separately, the prevalence of microalbuminuria (G-I: 24.1%, G-II, 25.0%, G-III: 31.0% and G-IV: 55.6%, $p < 0.05$) and hypertension (G-I, 8.3%;

G-II: 13.6%, G-III: 28.6% and G-IV: 44.4%, $p = 0.000$) increased with duration of disease. Data from these studies suggest that chronic glucotoxicity (elevated HbA1c) and factors involved in diabetic nephropathy (microalbuminuria and hypertension) may be one of the mechanisms for the development of MS in T1D, among many others.

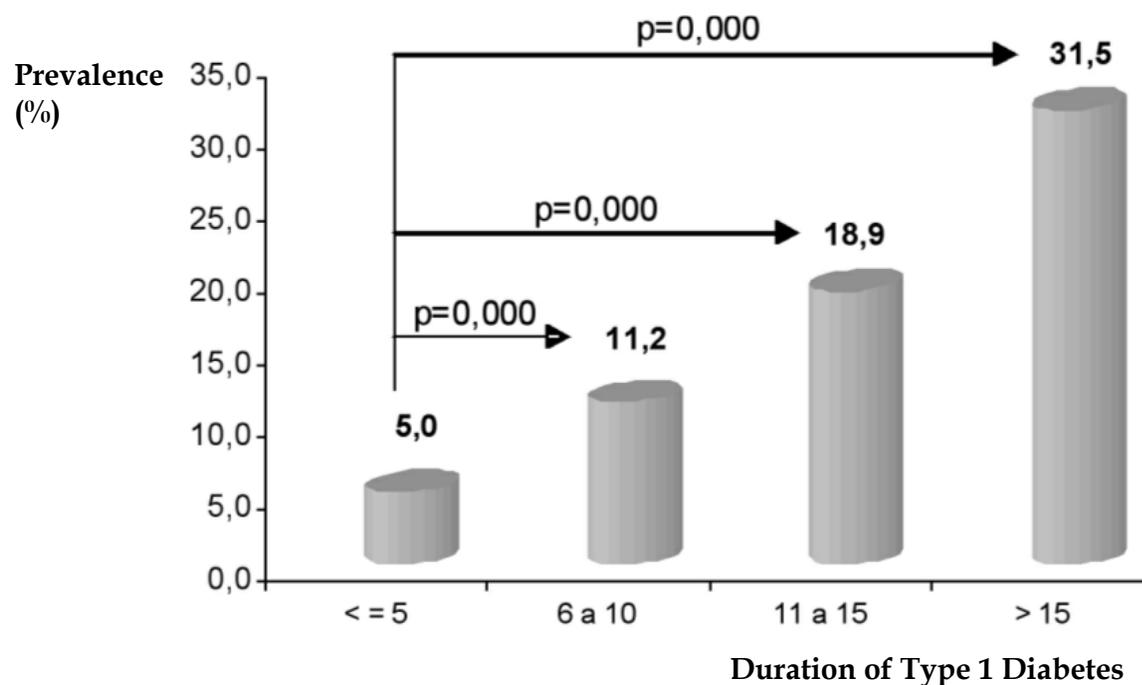


Fig. 5. Prevalence of MS in patients with T1D, according to disease duration. (Dib, 2006)

Aiming to compare the prevalence of MS using the ATP III criteria modified for age in our group of T1D, we studied 521 (51.2% female, age 20 ± 9 years; time of diagnosis of diabetes: 7.7 ± 6.9 years and HbA1c: $9.0 \pm 2.4\%$) and found that this was equal to 12% (unpublished data).

The lowest concentration in the insulin in the liver causes a decrease in the synthesis of GHBP levels (Growth Hormone Binding Protein) (Bereket et al., 1999) that leads to a decrease in GH action, in the values of IGF-1 and in the inhibitory counter-regulation of this hormone, resulting in an exaggerated secretion of GH and increased insulin resistance.

The realization of a strict glycemic control in T1D, according to current guidelines, many often leads to use of supraphysiological doses of insulin, which could result in a stimulation of androgen synthesis, mediated by insulin, as occurs in cases of insulin resistance. Accordingly, the prevalence of Polycystic Ovary Syndrome (PCOS) and other symptoms and signs of hyperandrogenism were evaluated in a group of 85 patients with T1D (Escobar-Morreale et al., 2000). PCOS was defined by the presence of menstrual changes and clinical or laboratory evidence of hyperandrogenism. Other causes of elevated androgen hormones were excluded. Eighteen normal eumenorrheic women served as controls. Thirty-three patients (38%) presented with T1D changes associated with an androgen excess (16 with PCOS and 17 with hirsutism without menstrual abnormalities). The patients with T1D and PCOS had elevated total and free testosterone and androstenedione but normal levels of sex-hormone binding globulin (SHBG) and dehydroepiandrosterone sulfate (DHEAS). However, despite the finding of a high prevalence of hyperandrogenism (including PCOS and hirsutism), there was no difference between clinical variables such as duration of

diabetes, age at diagnosis, conventional or intensive insulin treatment, average daily dose of insulin or glucose control between the T1D patients with and without hyperandrogenism in study.

The gold-standard method for evaluating IR is the hyperinsulinemic euglycemic clamp that directly measures the relationship between blood glucose and insulin levels, but it is difficult to be executed on a large scale since it is an invasive and expensive procedure. For this reason, HOMA-IR is used as a surrogate method to indirectly measure IR, calculated through fasting glycemia and insulinemia relationship. On the other hand, this calculation cannot be used for T1D as these patients do not produce endogenous insulin. So to evaluate the insulin sensitivity in these patients – eGDR calculation (Equation 1) was developed that shown a good correlation with hyperinsulinemic euglycemic clamp (Chillarón et al., 2008):

$$\text{eGDR (mg.kg}^{-1}\text{.min}^{-1}) = 24,4 - 12,97 \text{ (W/H)} - 3,39 \text{ (Hypertension)} - 0,60 \text{ (HbA1c)} \quad (\text{E1})$$

In which W/H is the waist-hip ratio(cm), hypertension is the presence or absence of hypertension (0 = no and 1 = yes) and the value of HbA1c is represented in %. It is also a good predictor of mortality, coronary arterial disease (CAD), microalbuminuria - a precocious hallmark of endothelial dysfunction (Pambianco et al., 2007) - and MS for T1D individuals, according to IDF (International Diabetes Federation), WHO (World Health Organization) and NCEP/ATPIII modified by AHA (American Heart Association).

As we know the insulin resistance is linked to an ectopic store of fat in insulin sensitive tissues like liver and muscle, but it is not clear if this fat accumulation leads to a hyperinsulinemic state or if it is its consequence. In a study with T2D patients, the glycemic control obtained after 67 hours of insulin treatment caused an accrual in intramyocellular and intrahepatic lipid content measured by nuclear magnetic resonance (NMR) spectroscopy, without compromising insulin sensitivity (Anderwald et al., 2002). Like T2D individuals, the intramyocellular lipid content in T1D ones was increased compared to controls and there was a direct relation with the glycemic control (Sibley et al., 2003).

There has been also noted a clear association between IR and visceral fat store, that can take its content extended in consequence of intensive insulin treatment independently of the type of diabetes, aggravating the CVD risk. In the DCCT study, the subgroup of T1D individuals that received intensive insulin treatment had a higher growth in BMI compared to the ones who were treated conventionally and it was noted a stronger correlation of this BMI variation with visceral fat deposit than with subcutaneous fat (Sibley et al., 2003). In this study, there are also demonstrations of direct association between visceral fat content and hepatic lipase, which favors the emergence of atherogenic dyslipidemia in these intensive treated individuals that put on more weight, reaching lipid levels similar to those of the conventionally treated group, suggesting loss of the benefits of intensive insulin therapy on lipids in this group of patients who had an excessive weight gain.

In other study (Nadeau et al., 2010), lean T1D adolescents with short time of disease (average of 7.5 years) without any inflammatory, clinical or lipid abnormalities had a IR - measured by hyperinsulinemic euglycemic clamp - similar to non diabetic obese adolescents and a superior IR than control subjects matched for age, pubertal stage, physical activity level and BMI, despite normal waist and intramyocellular lipid content.

There was also a demonstrated association between fat mass and blood pressure levels in T1D children and adolescents – high fat content, identified by the bioimpedance (BIA), and BMI were related to higher systolic and diastolic blood pressure (Pietrzak et al., 2009). The BIA is an easy, noninvasive, portable, no risk, relatively inexpensive method to measure the percentage of fat and provides results comparable to dual energy X-ray absorptiometry (DXA) (Elberg et al., 2004; Völgyi et al., 2008), that is reliable but expensive, requiring trained operators, individuals exposed to ionizing radiation and is not portable (Thomson et al., 2007).

There are data indicating good correlation between BIA and DXA, including Brazilian (Brulio et al., 2010) and T1D subjects (Leiter et al., 1994). Although overestimating the percentage of fat in lean individuals and underestimate it in obese (Sun et al., 2005), proves useful for predicting metabolic risk (including IR) as well as BMI and waist circumference (Lee et al., 2008). Through the BIA, it is possible to calculate the CDI (central fat distribution index), which assesses the impact of subcutaneous fat in the central fat distribution, and can be measured by dividing the area of abdominal subcutaneous fat mass by total fat (Silva et al., 2009). This measure seems to be relevant in that, according to some studies (Silva et al., 2009; Van Harmelen et al., 1998), the main source of leptin is the abdominal subcutaneous adipose tissue, either by mass effect - the subcutaneous adipose tissue is the major fat depot - as to produce more leptin (larger cell size and leptin gene expression) than omental adipose tissue. However, depending on the impedance (eg the trunk), the results may vary according to position changes, skin temperature, variation in electrode impedance and errors in their placement (Scharfetter et al., 2001).

A new adipokine identified visfatin, increases in proportion to visceral fat mass (Fukuhara et al., 2005) and decreases after gastric band placement (Haider et al., 2006). It is high in individuals with T2D (Chen et al., 2006) and even more in T1D (López-Bermejo et al., 2006), suggesting that its rising is linked to deterioration of pancreatic β cells. In vitro, visfatin activates the insulin receptor regardless of fasting state, increasing glucose uptake in muscle and adipose tissue and reducing hepatic glucose production independently of insulin levels (Fukuhara et al., 2005).

Hyperhomocysteinemia, known risk factor for coronary atherosclerosis (Okada et al., 1999), has also been shown to be detrimental to pancreatic insulin secretion (Patterson et al., 2006). The C-reactive protein (CRP), an inflammatory marker that confers increased risk for atherosclerosis (Hayaishi-Okano et al., 2002), is increased in T2D patients (Nabipour et al., 2008) and obese subjects (Richardson et al., 2009), and also relates to the control of diabetes (King et al., 2003), i.e. may increase due to the weight gain caused by intensive control of diabetes (Schaumberg et al., 2005).

Ferritin is another acute phase inflammatory marker, correlate positively with CRP and BMI (Richardson et al., 2009), and also more specifically with visceral adiposity and insulin resistance (Iwasaki et al., 2005), leading to increased ferritin levels in T2D patients, concurrent with an augmentation of visfatin (Fernandez-Real et al., 2007).

Recently, several studies have indicated that the gene associated with fat mass and BMI (FTO) has an important genetic effect on BMI and risk of obesity through the rs9939609 polymorphism. This polymorphism is linked to an impaired responsiveness to satiety, ie have an effect on appetite (Wardle et al., 2008). The homozygous AA genotype results in an average gain of 3 kg or 1 unit of BMI over the TT genotype. There is evidence that this

polymorphism is linked to BMI gain in subjects with T1D (Gu et al., 2010) and higher levels of leptin and CRP (Welsh et al., 2010).

5. Conclusion

Obesity may both contribute to the onset of T1D as being a consequence of intensive treatment with insulin, that is, good glycemic control in T1D can lead to excessive weight gain in predisposed individuals (eg relatives of T2D), IR and consequently MS. Thus, the current approach of patients T1D should happen as it is done in T2D, multifactorial with an early and intensive monitoring of lifestyle, blood glucose, blood pressure and lipids, with the aim of identifying, correcting these factors and potentially reduce the high risk for cardiovascular disease in these patients. So gain weight can accelerate the presentation and modify the initial T1D phenotype as increase the cardiovascular risk factors during evolution do the disease .

6. References

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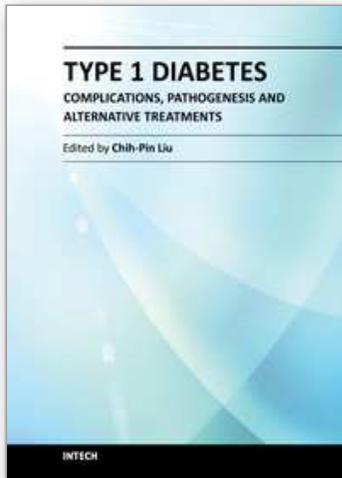
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This book is intended as an overview of recent progress in type 1 diabetes research worldwide, with a focus on different research areas relevant to this disease. These include: diabetes mellitus and complications, psychological aspects of diabetes, perspectives of diabetes pathogenesis, identification and monitoring of diabetes mellitus, and alternative treatments for diabetes. In preparing this book, leading investigators from several countries in these five different categories were invited to contribute a chapter to this book. We have striven for a coherent presentation of concepts based on experiments and observation from the authors own research and from existing published reports. Therefore, the materials presented in this book are expected to be up to date in each research area. While there is no doubt that this book may have omitted some important findings in diabetes field, we hope the information included in this book will be useful for both basic science and clinical investigators. We also hope that diabetes patients and their family will benefit from reading the chapters in this book.

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