# Prevalence of overweight and obesity in students from different altitudinal zones of Jujuy according to three international references (IOTF, CDC and WHO)

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**ABSTRACT**

***Introduction.*** Prevalences of overweight and obesity in students from different altitudinal zones of Jujuy are compared using the International Obesity Task Force (IOTF), the Centers for Disease Control (CDC) and the World Health Organization (WHO) references, and the agreement among them.

***Material and Methods.*** Weight and height data from 15 541 students were grouped in highlands (HL) (≥2500 MASL) and lowlands (LL) (<2500 MASL) and in two age groups (5-6.99 years old and 11-12.99 years old). Overweight and obesity prevalences were calculated according to the different references. The differences in outcome measures and prevalences were established using the $\chi^2$ test and the *t* test, and agreement among the criteria was calculated using the kappa index.

***Results*.** Students from the HL had lower weight, height and body mass index (BMI) values ($p < 0.05$). Overweight and obesity prevalences compared to the WHO reference were higher, except for overweight in students of both sexes, from 11 to 12.99 years old, from the HL and the LL. Regardless of the references, gender and age, overweight and obesity prevalences were generally higher in the LL. Agreement between the IOTF and the CDC was good-very good, and agreement among them and the WHO was fair-moderate.

***Conclusions.*** Students from the HL had a lower overweight and obesity prevalence. The greatest agreement was observed between the IOTF and the CDC references.

***Key words****: obesity, overweight, references, students, altitudinal zonation.*

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## INTRODUCTION

At present, excess fat accounts for one of the most significant malnutrition disorders affecting children and adolescents from countries with different levels of socioeconomic development. An increasing epidemics of childhood obesity (OB) has been recorded worldwide, with a variation in the secular trend observed in different countries.[1] Based on OB prevalence observed in the Americas between 1985 and 2005, it was estimated that by 2010 OB prevalence would be 15% and overweight (OW) prevalence 40%.[2] In Argentina, it has been observed that 5.4% of patients attending a pediatric consultation (10-19 year old patients) are obese and 20.8% are overweight.[3] In 2007, OB and OW prevalences among Argentine students were 2.6% and 19%, respectively.[4] In San Salvador de Jujuy, between 1995 and 2000, different assessment criteria allowed to establish that OB and OW prevalences among students were over 4% and 13%, in that order.[5]

Given that the body mass index (BMI) can be easily measured and is highly correlated to body fat, it is the most commonly used parameter for assessing this type of fat in children and adolescents.[6] Three references were used to define overweight and obesity as per the BMI of children population: IOTF,[7] CDC[8] and WHO.[9] However, several studies have indicated that these references provide varying results in relation to OB and OW prevalence.[10-14] Such differences could influence public policies, and OW and OB prevention and early detection programs.[15]

BMI reveals a positive association with fat and height in children and adolescents;[16,17] for this reason, classifying a child in one or other category, and the resulting OB and OW prevalence could vary depending on their height.

The population in Jujuy has settled at different altitudinal zones (350-4000 MASL). The populations in the highlands (HL), i.e., at or above 2500 MASL, are characterized by having an adaptive response to the environmental conditions typical of the HL (hypoxia, low temperature, little humidity, and limited food resources), a lower height than populations in the lowlands (LL), closer to the sea level.[5] In addition, populations in the HL have higher percentages of unmet basic needs (UBNs) (33.6%) and a high child mortality rate (17/1000 live newborns). By contrast, the LL, home to the capital city of Jujuy, have a more favorable weather, lower percentages of UBNs (2-3%) and a child mortality rate of 13/1000 live newborns.

Estimates of OW, OB and OW+OB prevalences in students from different altitudinal zones of Jujuy are compared using the IOTF, CDC and WHO cutoff values,and the agreement among such references.

## MATERIAL AND METHODS

This was a cross-sectional, ecogeographic study. Weight and height data were obtained from assessments made in first to sixth grade students from Jujuy between 2010 and 2011 in the context of the School Health Program (*Programa de Sanidad Escolar*, PROSANE),[18] which depends on the Ministry of Health of Jujuy. The PROSANE is a national program targeted at assessing the health status of school-aged children, monitoring healthcare provided for any health problem detected, and implementing health promotion and prevention actions in schools.[18] The program aims at assessing children at the initiation and at the end of their primary school courses, i.e., first and sixth grades. Such time points were chosen because at 6 and 11 years old, the most common ages for these groups, they complete their immunization schedule. The sample was made up of all students assessed by the program's Jujuy teams in the different areas of the province.

Height and weight were recorded according to the PROSANE Implementation Manual, using a standing scale and a stadiometer attached to the wall in primary care facilities, by trained personnel, who were coordinated by PROSANE Jujuy.

Weight and height data were grouped according to the geographic location of schools: highlands (HL) (≥2500 MASL) and lowlands (LL) (<2500 MASL).

Two age groups were established: from 5 to 6.99 years old and from 11 to 12.99 years old. The body mass index was calculated (BMI= weight [kg]/height$^2$ [m]). Students were classified as overweight or obese according to the IOTF, CDC and WHO cutoff values.

OW, OB and OW+OB prevalences, and the prevalence percentage differences among references, were calculated by gender, age and geographic region. The statistical significance of differences among the prevalences by gender, age and origin was established using the $\chi^2$ test, while that of height, weight and BMI was calculated using the *t* test. The agreement between the OW and OB criteria was assessed using the kappa (k) index calculated with the SPSS version 17.0 statistical package, and classified as poor (≤0.20), fair (0.20-0.40), moderate (0.41-0.60), good (0.61-0.80) or very good (>0.80).[19]

## RESULTS

A total of 15 541 students were assessed. *Table 1* shows the number of surveyed target schools and the percentage of census population by geographic altitude and age group.

In both genders and age groups, students from the HL had a lower weight, height and BMI; and differences were significant (*Tables 2 and 3*). Regardless of the reference used for both genders and age groups, OW, OB and OW+OB prevalences were higher in the LL; and differences were significant in most comparisons (*Tables 2 and 3*).

When analyzing OW, OB and OW+OB prevalences estimated with the different references, in general it is observed that the WHO prevalences were higher (*Table 2 and 3*). The exception is seen in OW prevalence in 11-12.99 year old boys (*Table 2*) and girls (*Table 3*) from the HL and LL, in which the highest prevalence is obtained with the IOTF reference.

When comparing the references, in the case of OW, the statistical significance varies by gender, age and origin, without any differences in the 5-6.99 year old girls from the HL and LL, the 5-6.99 year old boys from the HL, and the 11-12.99 year old boys and girls from the HL (*Tables 4 and 5*). In the case of OB, the differences among the references were significant in all comparisons, except between the IOTF/CDCin both genders and age groups from the HL (*Tables 4 and 5*). In relation to OW+OB, a similar pattern was observed, with an exception also found in the LL groups (*Tables 4 and 5*).

The agreement among the references ranged from good to very good for the IOTF and the CDC, depending on students' gender, age and

Table 1. *Sample characteristics*

| Characteristic | HL | LL | Jujuy |
|---|---|---|---|
| Number of target schools* | 112 | 265 | 377 |
| Number of surveyed schools (included in this study)* | 20 | 198 | 218 |
| Number of 5-6.99 year old children (% of the census population within this age range**) | 410 (15.6) | 6320 (28) | 6730 (26.7) |
| Number of 11-12.99 year old children (% of the census population within this age range**) | 570 (19.1) | 8241 (30.6) | 8811 (29.2) |
| Percentage sampled of the census population aged (5, 6, 11 and 12 years old)** | 17.4 | 30.6 | 29.2 |

*PROSANE Jujuy; **2010 census.
HL: Highlands. LL: Lowlands.

Table 2. *Mean and standard deviation for weight, height and BMI, and prevalence (%) of overweight (OW), obesity (OB) and OW+OB as per the references for age and origin in boys*

| Age | 5-6.99 years old | | | 11-12.99 years old | | |
|---|---|---|---|---|---|---|
| **Origin** | **LL** | **HL** | **p** | **LL** | **HL** | **p** |
| *n* | **3095** | **212** | | **4130** | **267** | |
| Weight (kg) | 23.5 ± 4.8 | 21.1 ± 3 | <0.0001* | 43.4 ± 11.1 | 37.3 ± 8 | <0.0001* |
| Height (m) | 1.18 ± 0.1 | 1.15 ± 0.1 | <0.0001* | 1.46 ± 0.1 | 1.42 ± 0.1 | <0.0001* |
| BMI | 16.7 ± 2.6 | 15.9 ± 1.9 | <0.0001* | 20.1 ± 4 | 18.5 ± 3.1 | <0.0001* |
| % OW (IOTF) | 15.1 | 10.8 | 0.1086** | 22.7 | 15 | 0.0043** |
| % OW (CDC) | 14.7 | 9.4 | 0.0426** | 17.1 | 12.4 | 0.0567** |
| % OW (WHO) | 17.1 | 13.2 | 0.1698** | 11.6 | 12.7 | 0.6568** |
| % OB (IOTF) | 9.4 | 4.2 | 0.0152** | 10.5 | 3 | 0.0001** |
| % OB (CDC) | 15.8 | 9 | 0.0105** | 17.2 | 5.6 | <0.0001** |
| % OB (WHO) | 30.6 | 18.9 | 0.0004** | 44.1 | 23.6 | <0.0001** |
| % OW+OB (IOTF) | 24.5 | 15 | 0.0023** | 33.2 | 18 | <0.0001** |
| % OW+OB (CDC) | 30.5 | 18.4 | 0.0003** | 34.3 | 18 | <0.0001** |

*t test.
** $\chi^2$.
HL: Highlands. LL: Lowlands.

Table 3. *Mean and standard deviation for weight, height and BMI, and prevalence (%) of overweight (OW), obesity (OB) and OW+OB as per the references for age and origin in girls*

| Age | 5-6.99 years old | | | 11-12.99 years old | | |
|---|---|---|---|---|---|---|
| **Origin** | **LL** | **HL** | **p** | **LL** | **HL** | **p** |
| *N* | **3225** | **198** | | **4111** | **303** | |
| Weight (kg) | 22.6 ± 4.5 | 21.1 ± 4.3 | <0.0001* | 43.5 ± 10.4 | 38.8 ± 8 | <0.0001* |
| Height (m) | 1.17 ± 0.1 | 1.15 ± 0.1 | 0.0063* | 1.48 ± 0.1 | 1.44 ± 0.1 | <0.0001* |
| BMI | 16.5 ± 2.5 | 15.8 ± 2.1 | 0.0001* | 19.8 ± 3.9 | 18.6 ± 3 | <0.0001* |
| % OW (IOTF) | 15.9 | 9.1 | 0.0137** | 20.5 | 12.9 | 0.0018** |
| % OW (CDC) | 15.1 | 8.6 | 0.0163** | 16.4 | 10.2 | 0.0058** |
| % OW (WHO) | 15.6 | 10.1 | 0.0470** | 13.3 | 11.9 | 0.5440** |
| % OB (IOTF) | 9.3 | 5.6 | 0.1029** | 7.1 | 2 | 0.0010** |
| % OB (CDC) | 12.1 | 7.6 | 0.0736** | 10.1 | 3.3 | 0.0002** |
| % OB (WHO) | 25.8 | 15.2 | 0.0012** | 34.3 | 20.1 | <0.0001** |
| % OW+OB (IOTF) | 25.2 | 14.7 | 0.0012** | 27.6 | 14.9 | <0.0001** |
| % OW+OB (CDC) | 27.2 | 16.2 | 0.0009** | 26.5 | 13.5 | <0.0001** |
| % OW+OB (WHO) | 41.4 | 25.3 | <0.0001** | 47.6 | 32 | <0.0001** |

*t test.
** $\chi^2$.
HL: Highlands. LL: Lowlands.

Table 4. *Differences (%) and agreement (kappa) among the references for age and origin in boys*

| **Age** | **5-6.99 years old** | | | | **11-12.99 years old** | | | |
|---|---|---|---|---|---|---|---|---|
| **Origin** | **LL** | **p*** | **HL** | **p*** | **LL** | **p*** | **HL** | **p*** |
| % OW IOTF/CDC | 0.4 | 0.6846 | 1.4 | 0.7511 | 5.6 | <0.0001 | 2.6 | 0.4546 |
| % OW IOTF/WHO | -2 | 0.0352 | -2.4 | 0.5412 | 11.1 | <0.0001 | 2.3 | 0.5195 |
| % OW CDC/WHO | -2.4 | 0.0109 | -3.8 | 0.2791 | 5.5 | <0.0001 | -0.3 | 0.9793 |
| % OB IOTF/CDC | -6.4 | <0.0001 | -4.8 | 0.0727 | -6.7 | <0.0001 | -2.6 | 0.2050 |
| % OB IOTF/WHO | -21.2 | <0.0001 | -14.7 | <0.0001 | -33.6 | <0.0001 | -20.6 | <0.0001 |
| % OB CDC/WHO | -14.8 | <0.0001 | -9.9 | 0.0051 | -26.9 | <0.0001 | -18 | <0.0001 |
| OW+OB IOTF/CDC | -6 | <0.0001 | -3.4 | 0.4189 | -1.1 | 0.3012 | 0 | 0.9103 |
| OW+OB IOTF/WHO | -23.2 | <0.0001 | -17.1 | 0.0001 | -22.5 | <0.0001 | -18.3 | <0.0001 |
| OW+OB CDC/WHO | -17.2 | <0.0001 | -13.7 | 0.0017 | -21.4 | <0.0001 | -18.3 | <0.0001 |
| Kappa IOTF/CDC | 0.71 | - | 0.71 | - | 0.83 | - | 0.87 | - |
| Kappa IOTF/WHO | 0.32 | - | 0.35 | - | 0.32 | - | 0.39 | - |
| Kappa CDC/WHO | 0.48 | - | 0.52 | - | 0.39 | - | 0.42 | - |

* $\chi^2$.
HL: Highlands. LL: Lowlands.

Table 5. *Differences (%) and agreement (kappa) among the references for age and origin in girls*

| **Age** | **5-6.99 years old** | | | | **11-12.99 years old** | | | |
|---|---|---|---|---|---|---|---|---|
| **Origin** | **LL** | **p*** | **HL** | **p*** | **LL** | **p*** | **HL** | **p*** |
| % OW IOTF/CDC | 0.8 | 0.3935 | 0.5 | 0.9986 | 4.1 | <0.0001 | 2.7 | 0.3614 |
| % OW IOTF/WHO | 0.3 | 0.7668 | -1 | 0.8672 | 7.2 | <0.0001 | 1 | 0.8024 |
| % OW CDC/WHO | -0.5 | 0.6014 | -1.5 | 0.7388 | 3.1 | 0.0001 | -1.7 | 0.5907 |
| % OB IOTF/CDC | -2.8 | 0.0003 | -2 | 0.5491 | -3 | <0.0001 | -1.3 | 0.4573 |
| % OB IOTF/WHO | -16.5 | <0.0001 | -9.6 | 0.0030 | -27.2 | <0.0001 | -18.1 | <0.0001 |
| % OB CDC/WHO | -13.7 | <0.0001 | -7.6 | 0.0263 | -24.2 | <0.0001 | -16.8 | <0.0001 |
| % OW+OB IOTF/CDC | -2 | 0.0722 | -1.5 | 0.7842 | 1.1 | 0.2723 | 1.4 | 0.7059 |
| % OW+OB IOTF/WHO | -16.2 | <0.0001 | -10.6 | 0.0120 | -20 | <0.0001 | -17.1 | <0.0001 |
| % OW+OB CDC/WHO | -14.2 | <0.0001 | -9.1 | 0.0350 | -21.1 | <0.0001 | -18.5 | <0.0001 |
| Kappa IOTF/CDC | 0.84 | - | 0.8 | - | 0.83 | - | 0.78 | - |
| Kappa IOTF/WHO | 0.37 | - | 0.44 | - | 0.36 | - | 0.37 | - |
| Kappa CDC/WHO | 0.49 | - | 0.59 | - | 0.35 | - | 0.32 | - |

*$\chi^2$.
HL: Highlands. LL: Lowlands.

origin. However, the agreement among the IOTF/CDC and the WHO was fair to moderate (*Tables 4 and 5*).

## DISCUSSION

Students from the HL had significant lower height, weight and BMI when compared to HL students; this confirms the observations of previous investigations.[20,21] In addition, OW and OB prevalences were lower in the LL. In general, prevalences obtained with the WHO reference were higher, except for the 11-12.99 year old age group. The greatest agreement was observed between the IOTF and the CDC references.

The same differential altitude distribution in the OW and OB prevalences obtained with the CDC and IOTF references was observed in a study conducted in 2008 on 11 431 students aged 12-18 years old from the four regions of Jujuy (Puna, Quebrada, Valle and Ramal).[22]

When comparing the results of this study with a secular trend analysis done between 1995 and 2000 regarding OW and OB of 48 533 students aged 4-10 years old and 11-16 years old from the capital city of Jujuy compared to the IOTF and CDC references, an increase in the prevalences of both phenotypes was observed in adolescents.[23]

Since no local references are available in relation to the BMI, it is not possible to establish if prevalences obtained in the populations from the highlands of Jujuy (*Tables 2 and 3*) actually underestimate or overestimate excess fat. Differences observed among the references also seem to be representative of different populations, as discussed below. Disagreements between the CDC and the IOTF,already described in previous studies with students from Jujuy,[23] ranged between 0.44% and 2.5% for overweight and between 1% and 7% for obesity, which are lower than those observed in this study (*Tables 4and 5*).

Differences among references can be interpreted according to: a) the growth pattern of the populations of Jujuy, which is conditioned by altitude and its associated adverse factors; b) the characteristics of the references.

Differences in the OW and OB prevalences by geographic region can also be interpreted based on the environmental conditions typical of highlands, which interact with the ethnic and genetic background of the Jujuy population. Although it has been established that human populations share a common growth pattern, independently of their ethnicity and geographic location, it cannot be excluded that inter-population anthropometric disparities reflect actual differences in genetic potential and not only the influence of environmental factors, especially in more advanced stages of ontogenesis.[24] Despite the effect of hypoxia on human growth is usually minimized and considered marginal,[25] such effect has been observed in the population of Jujuy even in the prenatal stage.[20,26]

Height accounts for 22% of the BMI variation in children and adolescents.[24,27] For this reason, in elevated regions, children at distribution ends (very high or very low values) can be incorrectly classified as overweight or obese. Particularly, variations in the length of lower limbs and sitting height can affect BMI measurement.[28] Children and adolescents from the Northwest region of Argentina, who grow above 3000 MASL (Catamarca and Jujuy) have a lower standing height, a lower sitting height and shorter lower limbs, and a relative increase of the trunk.[29]

As observed in other populations,[10-14] the differences in OW and OB prevalence among the references are related to sample composition, methods used for generating curves and cutoff values. In relation to sample composition, the main differences lie in the time they were collected, ethnic-geographic origin, screening criteria and health characteristics. In the case of the WHO, for the 2-5 year old population, data are representative of a multicenter, cross-sectional study conducted in children from Pelotas (Brazil), Accra (Ghana), Delhi (India), Oslo (Norway), Muscat (Oman) and David (USA), assessed between 1997 and 2003. For the 5-19 year old population, data were obtained from the National Health and Nutrition Examination Survey (NHANES I), i.e., a USA population assessed in 1971, before the emergence of the obesity epidemics. The IOTF reference sample was made up of data obtained from national, cross-sectional growth surveys conducted in Brazil, Great Britain, Hong Kong, the Netherlands, Singapore and the USA between 1963 and 1993,[7] also before the obesity epidemics. Lastly, the CDC reference sample was made up of national surveys conducted in the USA between 1963 and 1994. Children included in these samples were healthy, but with different growth conditions. While the WHO describes the growth of healthy children under 5 years old in optimal environmental conditions, the CDC and IOTF tables are references that summarize how certain children grow in a specific place and time. Studies conducted in children (0-5 years old) from San Salvador de Jujuy (1200 MASL), comparing the 3rd, 50th and 97th weight and height percentiles calculated using the LMS method compared to the same percentiles of the CDC and WHO references, indicated that the population from Jujuy has a lower weight and height.[23] In terms of height, disagreements were higher with the WHO (1.38 ± 0.65% to 1.87 ± 0.41%) than with the CDC (1.09 ± 0.59% to 1.66 ± 0.34%). The opposite occurred in relation to weight: disagreements were higher as per the CDC (1.82 ± 1.56% to 3.36 ± 1.4%) than the WHO (1.12 ± 1.28% to 2.74 ± 1.49%).[30]

Discrepancies have emerged in relation to which reference should be used in clinical and epidemiological contexts. Some studies have proposed the IOTF reference as the most adequate for clinical contexts and the WHO standard as the preference at the population level because it provides a better classification of overweight and obese individuals.[31] The interpretation of BMI variations should be based on prescriptive standards and, if not available, on references that do not underestimate OW and OB prevalence.[32] Although the impact of differences among references could be trivial at a clinical level when monitoring a child individually, it becomes more relevant at an epidemiological level when assessing the health of a population, as observed in this study. For this reason, it is necessary to use the same reference for individual assessments (clinical context) and population assessments (epidemiological context) so as to ensure a consistent perspective in both contexts.[32] However, the results of this study show that such goal is still out of reach because of the over-estimation of fat excess made by the WHO reference compared to the IOTF and the CDC, and because of the greater agreement between the IOTF and the CDC compared to the WHO for all altitudes.

Although the WHO standard (0-5 years old) has been adopted by 125 countries,[33] including Argentina, the USA, England and other major countries recommend to use local references for children and adolescents.[34] Studies conducted in Latin American populations indicate the same disagreement among references in relation to how OW and OB prevalences are determined, and suggest to exercise caution when using the WHO reference given the ethnic and methodological differences and because it describes growth prescriptively.[13,14,19] Based on national surveys conducted in the USA (1988-1994), Russia (1992) and China (1991), three references were compared: IOTF, WHO and CDC. Such results are partially similar to those of this study in that, although OW+OB prevalence estimations are similar according to the IOTF and CDC references, the WHO shows higher prevalences. However, in general, references show significant differences in OW prevalence. Given the important clinical impact of this diagnosis, authors recommend to be cautious when comparing results based on different references.[35]

One of the limitations of this study is the source of data, which covers only certain age groups by including students who become participants of the education system when starting or ending primary school. Notwithstanding, information related to the age groups considered in this study (5 to 6.99 and 11 to 12.99 years old) is referred to as “census data” because it covers an important percentage of the population from Jujuy in these age groups attending public and private schools (*seeTable 1*). The results of this study comprise two fundamental times of the growth process: childhood and the beginning of adolescence, and are consistent with those found in students of different ages from Jujuy.[22]

Until a greater consensus is achieved regarding the use of references, student populations should be assessed by comparison with different criteria. At the same time, studies on body composition should be encouraged so as to verify the sensitivity and specificity of criteria and BMI cutoff values, depending on the references, as predictors of body fat percentage and morbidity and mortality, which at present are uncommon in students.[17,31] However, based on the fact that, as indicated by the kappa test, a greater agreement is observed between the CDC and IOTF references, and that the IOTF includes populations not only from major countries and is more recent than the other standards, the IOTF reference should be chosen for epidemiological studies on obesity among students.

## CONCLUSIONS

A lower OW and OB prevalence was observed in students from the HL. The greatest agreement was observed between the IOTF and the CDC references.■

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