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Body Fat Mass Relationship with Insulin Resistance in a Population of Algerian Adults

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ABSTRACT

Obesity, a condition considered by the WHO to be an epidemic and a major public health problem due to the severe cardiometabolic complications that accompany it, requires rigorous management. Analysis of body composition, both global and segmental, could be a key element in the exploration of obesity and therapeutic strategies to combat the deleterious effects of fat mass expansion. With this in mind, we sought to examine the relationship between fat mass and certain metabolic disorders, particularly insulin resistance. Our study involved 421 adult subjects, aged 18 to 69 years, of all weights, who underwent anthropometric, bioelectrical impedance, and biological measurements to characterize their body composition and metabolic profile. Measuring body fat percentage proved more relevant than calculating body mass index in characterizing overweight and determining metabolic status, particularly insulin resistance. The body fat percentage threshold at which insulin resistance develops has been assessed; it is 40% in women and 28% in men. Changes in body composition could be a useful indicator of glycemic control, and the importance of favoring a comprehensive approach that integrates body composition into the assessment and treatment of obesity and its metabolic complications is justified.

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Introduction

An excess of body fat (BF) that has harmful effects on health characterizes obesity, recognized as a disease by the WHO since 1997. In obesity medicine, the main goal is to reduce body fat while preserving lean mass (muscles and organs). Thus, the analysis of both global and regional body composition is a key element in the assessment of obese patients (1),(2),(3),(4). Moreover, the epidemiological link between obesity and type 2 diabetes is well established, although the exact mechanisms connecting these two conditions remain poorly understood.

In this context, we conducted a study aimed at examining the relationship between body fat and certain metabolic disorders, particularly insulin resistance (IR).

Materials and Methods

Our study included 421 adults (146 men and 275 women), aged between 18 and 69 years, of all body weights, while excluding:

- Individuals with a pacemaker or other implanted medical devices;
- Individuals with diabetes under insulin therapy;
- Individuals with endocrine disorders other than type 2 diabetes;
- Individuals with conditions that may influence body composition (malnutrition, cancers, end-stage renal disease);
- Individuals with a body mass index (BMI) > 40 kg/m²;
- Individuals with acute illness;
- Pregnant women;
- Patients who have undergone bariatric surgery.

All patients underwent a comprehensive assessment, including anthropometric measurements (weight, height, waist circumference, hip circumference, BMI), bioelectrical impedance analysis (to assess body fat mass), and biological tests (fasting blood glucose, fasting insulin, and calculation of the Homeostasis Model Assessment for insulin resistance, or HOMA index).

Anthropometric Measurements:

- **Weight:** Measured using a BF 508 body composition monitor.
- **Height:** Measured in a standing position, without shoes, with heels together, using a stadiometer.
- **BMI:** Calculated by the body composition monitor.
- **Waist Circumference (WC):** Measured with a measuring tape in a standing position, at the midpoint between the lower rib margin and the anterior superior iliac spine along the mid-axillary line, at the end of a normal expiration, without applying pressure on the skin.
- **Hip Circumference (HC):** Measured with a measuring tape in a standing position at the widest part of the hips.
- **WC/HC Ratio:** Calculated using bioelectrical impedance analysis.

Impedance Measurements

A BodyStat QUADSCAN 4000 bioelectrical impedance analyzer was used. The principle is based on measuring the electrical properties of a biological environment, where impedance corresponds to the resistance offered by tissue to the passage of a low-intensity alternating current.

Measurement Conditions

- A fasting period of at least 4 hours
- Removal of all electrically conductive objects
- Wearing light clothing

Measurement Procedure

- The patient is positioned in the supine position (lying on their back)
- Arms and legs slightly apart
- Two electrodes are placed on the right hand and two on the ipsilateral foot (same side)
- Patient data (sex, age, weight, waist circumference, hip circumference) unregistered into the device.

Biological Measurements

- Fasting blood glucose
- Fasting insulin levels

Calculation of the HOMA index using the following formula

Insulin (mU/L) × Glucose (mmol/L) / 22.5

Results

- Data processing and analysis were performed using SPSS software version 25.0 (IBM SPSS).
- For all statistical tests, a p-value less than 0.05 was considered statistically significant

Table 1: Weight of the Study's Population

Weight	N	Minimum	Maximum	Average	SD	p-value
Men	146	53	114.5	84.75	12.21	< 0.0001
Women	275	49.8	117.7	77.90	14.01	
Total	421	49.8	117.7	80.27	13.79	-
P: Student's t-test						

The mean weight of the study population was 80.27 ± 13.79 kg

Table 2: Height of the Study's Population

Height	N	Minimum	Maximum	Average	SD	p-value
Men	146	1.57	1.92	1.73	0.06	< 0.0001
Women	275	1.41	1.77	1.60	0.06	
Total	421	1.41	1.92	1.64	0.09	-
P: Student's t-test						

The mean height of the study's population was 1.64 ± 0.09 meters

Table 3: Body Mass Index (BMI) of the Study's Population

BMI	N	Minimum	Maximum	Average	SD	p-value
Men	146	19.8	37.4	28.19	3.90	< 0.0001
Women	275	17.9	41.7	30.40	5.23	
Total	421	17.9	41.7	29.63	4.92	-
	P: Student's t-test					

The mean BMI of the study population was 29.63 ± 4.92 kg/m²

Table 4: Waist Circumference (WC) of the Study's Population

WC (cm)	N	Minimum	Maximum	Average	SD	p-value
Men	146	70	123	97.699	10.0415	0.003
Women	275	64	127	94.251	12.0815	
Total	421	64	127	95.44	11.52	-
P: Student's t-test						

The average waist circumference of the study population was 95.44 ± 11.52 cm.

Table 5: Hip Circumference (HC) of the Study's Population

HC (cm)	N	Minimum	Maximum	Average	SD	P-value
Men	146	86	140	103.308	7.8798	< 0.0001
Women	275	85	139	108.658	9.9802	
Total	421	84	145	106.8	9.63	-
P: Student's t-test						

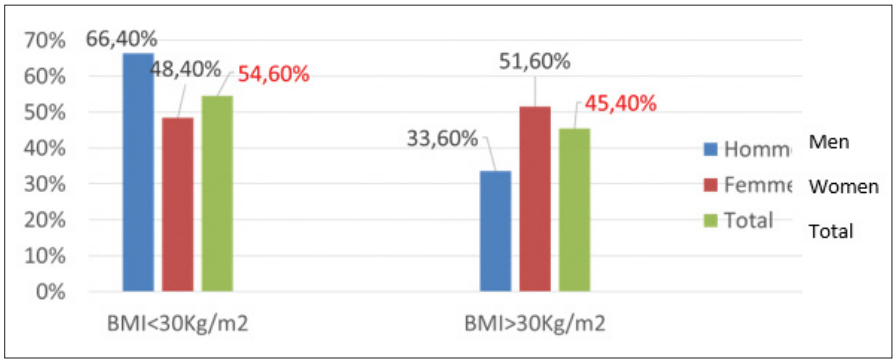
The average hip circumference of the study's population was 106.8 ± 9.63 cm.

Table 6: Waist-to-Hip Ratio (WHR) of the Study Population

WHR	N	Minimum	Maximum	Average	SD	P
Men	146	0.76	1.65	0.9504	0.08424	< 0.0001
Women	275	0.61	1.50	0.8636	0.09691	
Total	421	0.61	1.65	0.89	0.101	-
P: Student's t-test						

The average waist-to-hip ratio (WHR) of the study's population was 0.89 ± 0.10

Distribution of the Population According to Obesity Defined by BMI with a Threshold of 30 kg/m²



Obesity, defined by the WHO as a BMI > 30 kg/m², was present in 45.40% of the study's population, with a significantly higher prevalence among women.

Table 7: Body Fat Mass (kg) and Body Fat Percentage (%) of the Study's Population

	N	Minimum	Maximum	Average	SD	p
Body Fat Mass (Kg)						
Men	146	7.24	42.5	22.99	6.30	< 0.0001
Women	275	12.1	63.7	33.39	9.80	
Total	421	7.24	63.7	29.78	10.04	-
Body Fat Percentage BFP (%)						
Men	146	14.8	37.1	26.80	4.28	< 0.0001
Women	275	24.3	55.3	42.21	6.23	
Total	421	14.8	55.3	36.87	9.25	-
P: Student's t-test						

The body fat mass and body fat percentage measured by bioelectrical impedance were significantly higher in women than in men; they were respectively 33.39 ± 9.08 kg vs. 22.99± 6.30 kg, and 42.21± 6.23 % vs. 26.80± 4.28 %.

Table 8: Prevalence of Obesity Defined by Body Fat Percentage (BFP)

BFP		Men	Women	Total	p-value
<25 % (H), 35 % (F)	N	49	33	82	
	%	33.60	12.00	19.50	
	N	97	242	339	< 0.0001
>25% (M), 35% (W)	%	66.40	88.00	80.50	
	N	146	275	421	-
Total	%	100	100	100	
P; Pearson's Chi-Square Test					

The assessment based on body fat percentage (BFP) revealed a significantly higher prevalence of obesity compared to that determined by BMI: 80.5% versus 45.4%.

The assessment based on body fat percentage (BFP) revealed a significantly higher prevalence of obesity compared to that determined by BMI: 80.5% versus 45.4%.

Table 9: Biological Profile of the Study's Population

	N	Average	SD	P-value
Fasting Blood Glucose (g/l)				
Men	146	1.2364	0.40572	0.037
Women	273	1.1331	0.51783	
Total		1.16	0.47	
Fasting Insulin Levels (µU/l)				
Men	145	11.8353	8.1528	0.23
Women	272	12.9892	11.27455	
Total		12.54	10.31	
HOMA Index				
Men	145	3.6017	3.12422	0.70
Women	271	3.4817	3.04222	
Total		3.51	3.07	
P: Student's t-test				

With significantly higher values observed in male subjects, the average fasting blood glucose level of the population was 1.16 g/L ± 0.47.No significant difference was found between sexes for fasting insulin levels, which averaged 12.54 µU/L ± 10.31, or for the HOMA index, which was 3.51 ± 3.07[1-4].

Table 10: Prevalence of Abnormalities in Carbohydrate Metabolism Parameters

	Men		Women	Total	P
Fasting Hyperglycemia >1.1g/l	N	58	62	120	< 0.0001
	%	39.70	22.70	28.60	
Fasting Insulin >24.9 uU/l	N	11	21	32	0.96
	%	7.60	7.70	7.70	
HOMA >2.44	N	83	159	242	0.77
P ; Pearson's Chi-Square Test	%	57.20	58.70	58.20	

With a Significantly Higher Frequency in Men:

- Fasting hyperglycemia was present in 28.6% of the population, with no significant difference between sexes.
- Fasting hyperinsulinemia was observed in only 7.7% of the population.
- Insulin resistance was identified in 58.2% of the population.

Bivariate Correlation Analysis Between Body Fat Mass and Insulin Resistance

Table 11: Bivariate Correlation in the Total Population

	Fasting Blood Glucose		Fasting Insulin Levels	HOMA
FMP	*r*	-0,03	0.193	0134
	p	0.458	<0.0001	0.006

A significant positive correlation was observed between body fat percentage (BFP) and the two parameters of insulin resistance: fasting insulin levels and the HOMA index.

Table 12: Bivariate Correlation in the Non-Diabetic Population

	Fasting Blood Glucose		Fasting Insulin Levels	HOMA
FMP	r	0.087	0.243	0.244
	p	0.197	<0.0001	<0.0001

A significant positive correlation was observed between body fat percentage (BFP) and the two parameters of insulin resistance: fasting insulin levels and the HOMA index.

Table 13: Bivariate Correlation in the Diabetic Population

	Fasting Blood Glucose		Fasting Insulin Levels	HOMA
FMP	r	-0.086	0.128	0.011
	p	0.231	0.075	0.88

No significant correlation was observed between body fat percentage (BFP) and fasting insulin levels or the HOMA index in the diabetic population.

Characterization of the Relationship Between Body Fat Mass and Insulin Resistance

The following table presents the results of the comparison of body fat mass according to insulin resistance status; a significant association between these two parameters was observed.

Table 14: Comparison of Body Fat Percentage (BFP) According to Insulin Resistance

	Mean	ET	P	FMP<25,35	FMP>25,35	P[a]
HOMA<2.44	34.65	9.16	<0.0001	52 (29.9%)	122 (70.1%)	<0.0001
HOMA>2.44	38.37	8.96		29 (12%)	213 (88%)	
P : Student's t-test, pa Pearson's Chi-Square Test:						

After demonstrating a significant association between body fat percentage (BFP) and insulin resistance, a crude bivariate binary logistic regression was performed (see table below).

Table 15: Crude Bivariate Binary Logistic Regression

	B	S.E.	Wald	Df	P	OR	IC95%
Total Population	1.14	0.26	19.55	1	<0.0001	3.13	1.88-5.19

Excess body fat was found to be associated with a threefold higher risk of insulin resistance; this finding led to the implementation of a bivariate binary logistic regression adjusted for age and sex (see table below).

Table 16: Bivariate Binary Logistic Regression Adjusted for Age and Sex

	B	S.E.	Wald	Df	P	OR	IC95%
Total Population	1.12	0.29	14.90	1	<0.0001	3.05	1.73-5.38

The adjustment was performed for age and sex; after adjustment, the significance of the association was not affected. Excess body fat remained associated with insulin resistance, regardless of the patient's age and sex.

To verify the independence of this association from the presence of diabetes, the logistic regression adjusted for age and sex was repeated separately in diabetic and non-diabetic subjects (the results are presented in the table below).

Bivariate Binary Logistic Regression Adjusted for Age and Sex, Stratified by Diabetes Status

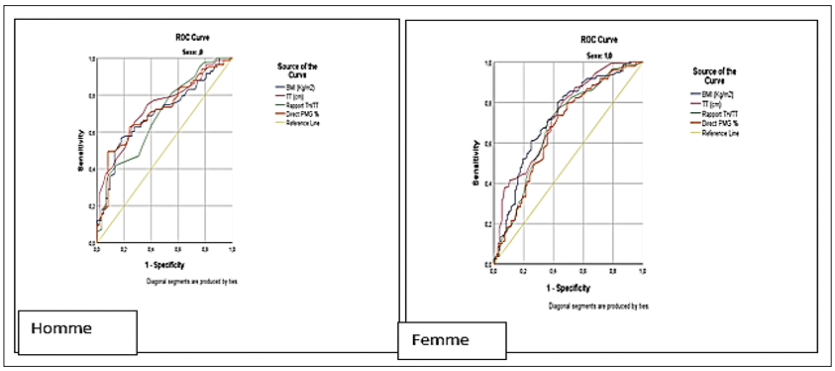
Table 17: Bivariate Binary Logistic Regression Adjusted for Age and Sex, Stratified by Diabetes Status

	B	S.E.	Wald	Df	P	OR	IC95%
Non diabetic	1	0.37	7.28	1	0.007	2.72	1.31-5.62
Diabetic	1.08	0.49	4.87	1	0.027	2.931	1.12-7.6

The independence of the association was confirmed in both diabetic and non-diabetic subjects.

Determining the Level of Adiposity at Which Insulin Resistance Develops

To address this objective, a ROC curve analysis was performed separately for men and women. A comparison of the predictive performance was conducted between the four parameters used to define obesity: body fat percentage (BFP), BMI, waist circumference (WC), and waist-to-hip ratio (WHR).



ROC Curve of Anthropometric Indices for Predicting Insulin Resistance in Men and Women

Table 18: Cut-off Values and Performance of Anthropometric Indices in Predicting Insulin Resistance

	AUC	IC95%	P	Cut-Off	Se (%)	Sp (%)	IY
Men							
BMI	0.7	0.62-0.79	<0.0001	29.05	56.10	82.30	0.39
WC	0.73	0.65-0.81	<0.0001	97.5	65.10	72.60	0.38
WC/HC	0.69	0.60-0.78	<0.0001	0.985	36.10	91.90	0.28
FMP	0.71	0.63-0.80	<0.0001	28.95	49.40	91.90	0.41
Women							
BMI	0.72	0.66-0.78	<0.0001	27.85	79.90	57.10	0.37
WC	0.73	0.67-0.79	<0.0001	88.5	80.50	53.60	0.34
WC/HC	0.68	0.62-0.75	<0.0001	0.845	69.80	64.30	0.34
FMP	0.67	0.60-0.73	<0.0001	41.05	73.60	57.10	0.31

AUC: Area Under the Curve, IY: Youden Index, Se: Sensitivity, Sp: Specificity.

BFP could predict the onset of insulin resistance with a threshold value of 41.05% in women versus 28.95% in men.

Discussion/Conclusion

Our study aimed to highlight the importance of body fat mass as a key indicator in assessing metabolic risks, particularly insulin resistance (IR), among Algerian adults.

The results show that obesity, when assessed using the percentage of body fat mass (PBF), is underestimated by measurements based solely on BMI. This underlines the superiority of body fat assessment over BMI calculation in characterizing excess weight [5].

Moreover, the high prevalence of IR (58.2%) and its significant correlation with excess body fat emphasize the major impact of body composition on metabolic disorders, as well as the interrelationship between fat mass and metabolic status, without overlooking the role of other factors such as android fat distributiona key contributor to macroangiopathic complications and cardiovascular riskassociated with excess weight [6,7].

A study has shown that slight decreases or increases in fat mass are associated with corresponding variations in insulin secretion and insulin sensitivity [8].

It is becoming increasingly likely that, in the future, the effectiveness of glycemic control, particularly in patients with type 2 diabetes, will not be evaluated solely based on glycated hemoglobin levels, but also by considering changes in body composition.

Regardless of age and sex, a correlation has been established between excess fat mass and a threefold increased risk of insulin resistance in both diabetic and non-diabetic individuals. These findings are consistent with the results of the meta-analysis of prospective cohort studies conducted by Bell JA et al., which revealed that the risk of insulin resistance is multiplied by 2.8 in obese individuals [9].

Adipose tissue remodeling in the context of excess weight is believed to promote the production of adipocytokines with harmful metabolic effects. The identification of specific PBF thresholds (40% in women and 28% in men) beyond which the risk of IR increases offers promising perspectives for preventive and targeted interventions.

Our findings reinforce the importance of adopting a comprehensive approach that integrates body composition assessment into the evaluation and management of obesity and its metabolic complications.

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