Positive and negative likelihood ratios of two anthropometric indices (Waist/Height Index versus Abdominal Circumference) in the diagnosis of the pathological nutritional situations overweight and obesity, according to the Fagan's Nomogram

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ABSTRACT

Objective. To determine whether each of two anthropometric indices (Waist/Height Index versus Abdominal Circumference) have sufficient prognostic efficiency or, at least, moderate prognostic efficiency by combining sensitivity and specificity in a single expression using positive and negative likelihood ratios. Material and methods. Quantitative epistemic approach. Descriptive cross-sectional observational epidemiological study without directionality and with prospective temporality. Three hundred adult patients (18–64 years old) of either gender who attended for medical care at the Hospital Integral "Jose Maria Morelos" were studied. As reference test or Gold Standard the Equation of the Metropolitan Life Insurance Company was used. Results. The results for the positive likelihood ratios corresponded to 13.4 and 1.6 for the anthropometric Waist/Height Index and Abdominal Circumference, respectively. The results for the negative likelihood ratios corresponded, respectively, to 0.07 and 0.4 for the anthropometric Waist/Height Index and Abdominal Circumference. Conclusions. It is concluded that the best anthropometric index for the diagnosis of overweight and obesity pathological nutritional situations corresponds to the Waist/Height Index. Furthermore, the results of the positive and negative likelihood ratios report sufficient prognostic efficiencies for the Waist/Height Index. On the other hand, the results of the positive and negative likelihood ratios report, respectively, insignificant prognostic efficiency and scarce prognostic efficiency for the Abdominal Circumference.

Keywords: Positive and Negative Likelihood Ratios, Anthropometric Indices, Overweight, Obesity.

1 INTRODUCTION AND BACKGROUND

Globally, overweight and obesity pathological nutritional conditions are associated with a higher number of deaths than underweight. There are more people with obesity [Body Mass Index (BMI) ≥ 30.00 kg/m²] than with underweight (BMI < 18.50 kg/m²). This is true in all regions except for parts of the African continent that do not border the Mediterranean Sea and the Asian continent. The pathological nutritional situations of overweight and obesity are among the five leading causes of mortality in the world. Approximately 2.8 billion people aged 18–64 years die each year as a corollary of overweight and obesity (WHO, 2000).
Overweight and obesity are two of the most frequent metabolic and nutritional disorders. They constitute an important public health problem in Mexico, since they affect more than 30% of the adult population. Due to the high number of people who suffer from them and the risk they imply in the biological, psychological and social spheres, as well as the physical disability they cause, they lead to an increase in the risk of early mortality in a high percentage, also generating important economic losses (Jackson; Pollock, 1978; Gonzalez; Stern, 1993; Frenk, 1994).

In Mexico, there is insufficient epidemiological information on obesity. Despite this, information is available from some studies carried out in Mexico and national data on obesity obtained from the National Survey of Chronic Diseases (ENEC93).

From an epidemiological approach, obesity can be considered as a risk factor for the development of some diseases, or as a disease in itself. Basically, the risk factors for the development of obesity are genetic, physiological and environmental, including unhealthy lifestyles. Unhealthy lifestyles are the most influential risk factors in the development of obesity (Casillas; Vargas, 1993; Vargas; Casillas, 1993; Tapia; Kuri, 1999). There is no method for estimating body composition that has sufficient statistical precision to be considered a reference method against which to validate other methods. For this reason, different methods coexist with different advantages and disadvantages, with the researcher selecting the one that best suits his or her needs. The most commonly used equations for estimating ideal body weight are Broca's, Devine's, Hamwi's, Lemmen's, Lorentz's, Miller's, Metropolitan Life Insurance Company's, Perroult's and Robinson's equations (Mataix, 2009).

In the present study the Metropolitan Life Insurance Company Equation (Metropolitan Life Insurance Company, 1983), which provides the ideal body weight for both genders, was used as the Gold Standard reference test: PCI= 50 [0.75 x (Height (cm) – 150)].

Medicine –among other sciences– is a science based on probabilities and estimations. Probability is the possibility of occurrence of the hypothesis generated by the clinician when faced with a diagnostic problem (Kassirer, 1989); therefore, when a diagnostic laboratory test is requested, the probability of confirming the diagnosis can be prior –before requesting the analytical request– or subsequent –after receiving the analytical report. The estimate is the level of confidence generated by the laboratory diagnostic test, but this estimate is never total because there is always a level of uncertainty. Therefore, the reliability of a diagnostic test is given by the level of uncertainty it can generate. The usefulness of a diagnostic test is determined by the decrease in the level of uncertainty present before and after it is performed. Likewise, in order to be useful, a laboratory diagnostic test must have excellent sensitivity and specificity values.
The likelihood ratio (LR) describes the probability of having the disease as opposed to not having the disease with a positive test result and the probability of not having the disease as opposed to having the disease with a negative test result (Gallagher, 1998; Hayden; Brown, 1999; Deeks; Altman, 2004).

Likelihood ratios exist for diagnostic tests with positive and negative results. They are easily calculated as the ratio of Sensitivity / (1 – Specificity) for a diagnostic test with a positive result and the ratio (1 – Sensitivity) / Specificity for a diagnostic test with a negative result. According to the results obtained we can evaluate the quality of diagnostic tests as follows: 1) LR+ > 10= excellent test; 2) 5 ≤ LR+ ≤10= good test; 3) 3 ≤ LR+ ≤ 2= fair test; 4) LR+ < 2= useless test; 5) 0.5 ≤ LR− ≤ 1= useless test; 6) 0.2 ≤ LR− ≤ 0.5= fair test; 7) 0.1 ≤ LR− ≤ 0–2= good test; and 8) LR− < 0.1= excellent test (Jaeschke et al., 1994).

The advantage of using the positive and negative likelihood ratios as opposed to the positive and negative predictive values of the diagnostic test lies in the fact that – unlike the latter – they do not depend on the proportion of patients in the sample, but only on the sensitivity and specificity of the test; hence their usefulness when comparing diagnostic tests. The pretest probability is usually known and is no more than the prevalence of the disease to be diagnosed; moreover, it can be obtained by making a rough estimate based on professional experience and/or on the basis of statistical and/or epidemiological data of the disease in which the diagnostic test is applied.

Fagan, in 1975, described a Nomogram for Bayes’ Theorem based on the ability to convert Bayes’ Theorem into a simple linear summation function. Fagan's Nomogram has the following three columns: 1) The first column is the pretest probability of having the disease (red line); 2) The second column is the likelihood ratio (LR); and 3) A line is drawn with a ruler between the pretest probability and the likelihood ratio. The extension of this line (blue line) cuts in the third column the probability of having the disease as a function of the test result (Fagan, 1975; Aznar et al., 2013).

The clinical laboratory – when used correctly – considerably reduces uncertainty and intervenes with the information it provides in 60–70% of medical decisions (Forsman, 1996). To carry out this mission, laboratory physicians – together with clinicians – have to act jointly, implementing strategies to change routines and patterns of analytical tests (Kay, 2001; Rodriguez, 2005) that are unnecessary. Also, whenever possible, the sensitivity and specificity of the most common diagnostic tests should be provided (Lee, 2011). With this practice, the clinical analysis laboratory acquires additional value in the process of quality patient care.

The aim of the present study was to determine whether or not each of the tests (Waist/Height Index versus Abdominal Circumference) has sufficient prognostic efficiency or at least moderate prognostic efficiency by combining sensitivity and specificity in a single expression using positive and negative likelihood ratios.
2 MATERIAL AND METHODS

2.1 EPISTEMOLOGICAL APPROACH

Quantitative approach, probabilistic approach or positivist approach (Hernandez et al., 2016).

2.2 STUDY DESIGN

A cross–sectional descriptive observational epidemiological study without directionality (cause→effect, or effect→cause) and with prospective temporality (Hernandez, 2017).

2.3 UNIVERSE OF STUDY

The study was conducted in 300 patients [119 (39.67%) of the male gender and 181 (60.33%) of the female gender] aged 18–64 years who attended for medical care at the Hospital Integral "Jose Maria Morelos" of the Mayan municipality of Jose Maria Morelos, Quintana Roo, Mexico, in the period from August 1, 2018 to July 31, 2019.

2.4 OPERATIONAL DEFINITIONS OF VARIABLES

**Ideal weight.** The ideal weight is defined as the body weight that confers the highest life expectancy to a person. Various mathematical equations have been developed for the calculation of ideal weight according to population studies. The most commonly used predictive equations for estimating ideal body weight are Broca's, Devine's, Hamwi's, Lemmens's, Lorentz's, Metropolitan Life Insurance Company's, Miller's, Perroul't and Robinson's equations. The values obtained from these predictive equations should be interpreted as indicative. Thus, the more variables the equation contemplates, the better it will estimate and the more it will adapt to the reality of each patient (Mataix, 2009).

**Diagnostic test.** Any more or less complex procedure that aims to establish in a patient the presence of a certain situation, supposedly pathological, not susceptible to be observed directly with any of the five senses (Ruiz; Morrillo, 2004).

**Reference test or Gold Standard.** It is the best existing diagnostic alternative to study a disease or event of interest in terms of sensitivity, specificity, safety, positive predictive value and negative predictive value; consequently, it is the best option for labeling patients with and without the disease or event of interest (Manterola, 2009).
Metropolitan Life Insurance Company equation: 50 \[0.75 \times (\text{Height (cm)} - 150)\].

**True positives (A).** Observation units with the characteristic of interest (disease) that are correctly identified as positive by the diagnostic test (Martinez *et al.*, 2014).

**False positives (B).** Observation units without the characteristic of interest (disease) that are incorrectly identified as positive by the diagnostic test (Martinez *et al.*, 2014).

**False negatives (C).** Observation units with the characteristic of interest (disease) that are incorrectly identified as negative by the diagnostic test (Martinez *et al.*, 2014).

**True negatives (D).** Observation units without the characteristic of interest (disease) that are correctly identified as negative by the diagnostic test (Martinez *et al.*, 2014).

**Sensitivity (A/A+C).** Ability of the diagnostic test to correctly identify those who do have the disease or event of interest. The proportion (to ten-thousandths) is obtained by dividing the number of true positives (A) by the number of diseased patients (A+C). The percentage (to hundredths) is obtained by multiplying the proportion obtained by 10² (Grimes; Schultz, 2002; Fernandez; Diaz, 2003; Gordis, 2004; Ruiz; Morrillo, 2004).

**Specificity (D/B+D).** Ability of the diagnostic test to correctly identify those who do not have the disease or event of interest. The proportion (to ten-thousandths) is obtained by dividing the number of true negatives (D) by the number of healthy patients (B+D). The percentage is obtained by multiplying the proportion obtained by 10² (Grimes; Schultz, 2002; Fernandez; Diaz, 2003; Gordis, 2004; Ruiz; Morrillo, 2004).

**Safety (A+D)/(N).** The safety of a diagnostic test is determined by the positive and negative predictive values. These indices are important for assessing the usefulness of a diagnostic test in the clinical field and on an individualized basis, i.e., for each patient. It is obtained by adding the number of true positives (A) plus the number of true negatives (D); this sum is divided by the total number of patients studied (N); the result obtained represents a proportion (up to ten thousandths), which when multiplied by 10² gives a percentage (up to hundredths) (Grimes; Schultz, 2002; Fernandez; Diaz, 2003; Gordis, 2004; Ruiz; Morrillo, 2004).

**Likelihood ratios.** Likelihood ratios (LR) are a valuable procedure for evaluating a diagnostic test. Likelihood ratios also called prognostic efficiency ratios (PER) combine sensitivity and specificity in a single expression. Likelihood ratios take positive and negative values. They offer the advantage over other indicators that they are not dependent on the prevalence of the disease in a population, or in a representative sample of a population. Each diagnostic test is characterized by two likelihood ratios: 1. The positive likelihood ratio; and 2. The negative likelihood ratio (Donis, 2012).
Positive likelihood ratio. The positive likelihood ratio compares the probability of a sick patient presenting a positive result on a diagnostic test (Sensitivity) versus the probability of obtaining a positive result in a healthy patient (the complement of specificity, i.e., 1 – Specificity) (Martinez–Gonzalez et al., 2014).

Negative likelihood ratio. The negative likelihood ratio is the quotient of the complement of sensitivity by specificity; the negative likelihood ratio assesses the contribution that a negative result makes in the non–confirmation of disease (Martinez–Gonzalez et al., 2014). The negative likelihood ratio is calculated by dividing the probability of a negative result in the presence of disease by the probability of a negative result in the absence of disease. It is therefore the ratio obtained between false negatives (1 – Sensitivity) and true negatives (Specificity). It is always expressed as a proportion (up to tenths). The negative likelihood ratio indicates the probability of a sick patient obtaining a negative result relative to that of a non–sick patient obtaining a negative result. A positive likelihood ratio > 1 indicates that there is a high probability that the patient has the disease and the higher the value obtained the higher the probability of having the disease (Grimes; Schulz, 2005). Conversely, a negative likelihood ratio < 1 decreases the probability that a patient has the disease or event of interest (Grimes; Schultz, 2002; Fernandez; Diaz, 2003; Gordis, 2004; Ruiz; Morrillo, 2004).

Waist/Height Index. For a long time BMI was the parameter par excellence used to assess cardiovascular risk and the nutritional status of individuals; however, over time other indicators emerged, such as the Waist/Height Index, which is nowadays considered more effective than BMI. A recent study that analyzed data from nearly 3,000 adults found that assessing the relationship between waist and height is more effective than BMI for assessing cardiovascular risk and, at the same time, simpler because it is not even necessary to have a scale or measuring tape to measure it. With a simple rope or a loop with which we can mark our height and folding it in half we can know if we have more or less than half our height as waist circumference. If the result of dividing our waist circumference (in cm) by our height (in cm) is 0.5, it indicates the presence of a higher cardiovascular risk. The study found that 12% of people who had a BMI within normal values had an Waist/Height Index at 0.5 which indicated that they had too much fat concentrated in the abdominal area and this was associated with higher cholesterol (C27H46O) and glycosylated hemoglobin (HbA1c) values which is linked to higher cardiovascular risk. These parameters were even lower in those with a high BMI who had an Waist/Height Index at 0.5; therefore, it is believed that BMI that does not assess body fat distribution may erroneously assess 12% of those at risk and that, therefore, Waist/Height Index is more effective and more practical. In fact, we have long known that visceral fat is more dangerous than fat that accumulates in the femorogluteal region; therefore, visualizing where fat is stored in our body, independent of our body weight, may be more valuable in assessing cardiovascular risk (https://www.vitonica.com/anatomia/indice--de--cintura--estatura--mas--efectivo--que--el--imc--para--evaluar--riesgo--cardiovascular; Grimes; Schulz, 2005).
**Abdominal Circumference.** Abdominal Circumference is defined as the minimum waist circumference. There are various criteria for the assessment of cardiovascular disease risk according to the Abdominal Circumference value. The Adult Treatment Panel III establishes a value ≥ 94 cm for the male gender and ≥ 80 cm for the female gender to define abdominal obesity or increased risk (Wang et al., 2005). The International Diabetes Federation establishes values ≥ 90 cm for males and ≥ 80 cm for females (Alberti et al., 2005). On the other hand, the World Health Organization, in 1997, proposed cut–off points or thresholds for the identification of persons at risk establishing the following three categories: 1. Low risk ≤ 93 cm for the male gender and ≤ 79 cm for the female gender; 2. Increased risk 94 cm ≤ Abdominal Circumference ≤ 101 cm for the male gender and 80 cm ≤ Abdominal Circumference ≤ 87 cm for the female gender; and 3. High risk ≥ 102 cm for the male gender and ≥ 88 cm for the female gender. To measure the abdominal circumference only a tape measure is required. To do so, it is necessary to stand with the torso naked, feet together and in front of a mirror to ensure that the measurement is performed correctly. The abdomen is relaxed and the tape measure is placed around the waist at the level of the navel without pressing (WHO, 2000).

2.5 TECHNIQUES AND PROCEDURES

The data were collected at the Clinical Archives Department of the Hospital Integral "Jose Maria Morelos" of the Mayan municipality of Jose Maria Morelos, Quintana Roo, Mexico. The Hospital Integral "Jose Maria Morelos" belongs to the Health Jurisdiction No. 3 of the Mexican state of Quintana Roo. Sanitary Jurisdiction No. 3 is located in the Mayan municipality of Felipe Carrillo Puerto.

2.6 DATA PROCESSING

In the elaboration stage, the data were reviewed (quality control of the information); classified (in qualitative and quantitative scales); computerized (IBM SPSS Statistics 22 software was used); presented (in Tables and Graphs); and summarized (the corresponding summary measures were used for data classified in qualitative and quantitative scales). In the analysis and interpretation stages the data were analyzed and interpreted, respectively.

Contingency tables of 2x2 were constructed from which sensitivity, specificity, safety, and positive and negative likelihood ratios were calculated for each of the two diagnostic tests. The Metropolitan Life Insurance Company Equation (Metropolitan Life Insurance Company, 1983), which provides the ideal body weight for both genders, was used as the Gold Standard reference test. PCI= 50 [0.75 X (Height (cm) – 150)].
3 RESULTS

According to the Gold Standard reference test (Metropolitan Life Insurance Company, 1983) 171 (57.00%) patients were labeled with overweight and obesity and 129 (43.00%) patients were labeled without overweight and obesity. Of the 171 patients labeled as overweight and obese 56 (32.75%) and 115 (67.25%) patients were male and female, respectively. On the other hand, of the 129 patients without overweight and obesity 106 (82.17%) and 23 (17.83%) patients corresponded to the male and female genders, respectively. The 2x2 contingency tables allow the analysis of two dichotomous variables: typically, one independent variable and one dependent variable. For a better understanding of Tables 4 and 5, Table 1 is presented below.

<table>
<thead>
<tr>
<th>Diagnostic test</th>
<th>Disease</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Positive</td>
<td>A (True positives)</td>
<td>B (False positives)</td>
</tr>
<tr>
<td>Negative</td>
<td>C (False negatives)</td>
<td>D (True negatives)</td>
</tr>
<tr>
<td>Totals</td>
<td>A+C (Total number of sick)</td>
<td>B+D (Total number of healthy)</td>
</tr>
</tbody>
</table>

Table 2 shows the main indicators and their corresponding calculations for the study and for the evaluation of the diagnostic tests.

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>A / (A + C)</td>
</tr>
<tr>
<td>Specificity</td>
<td>D / (B + D)</td>
</tr>
<tr>
<td>Safety</td>
<td>A + D / N</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>A / (A + B)</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>D / (C + D)</td>
</tr>
<tr>
<td>False positive probability</td>
<td>B / (B + D)= 1 – Specificity</td>
</tr>
<tr>
<td>Probability of false negatives</td>
<td>C / (A + C)= 1 – Sensitivity</td>
</tr>
<tr>
<td>Proportion of diseased= Disease prevalence</td>
<td>(A + C) / N</td>
</tr>
<tr>
<td>Proportion of healthy</td>
<td>(B + D) / N</td>
</tr>
<tr>
<td>Positive likelihood ratio</td>
<td>Sensitivity / (1 – Specificity)</td>
</tr>
<tr>
<td>Negative likelihood ratio</td>
<td>(1 – Sensitivity) / Specificity</td>
</tr>
</tbody>
</table>

A= True positives; B= False positives; C= False negatives; D= True negatives; and N= A+B+C+D= Total patients studied.

Source: Own elaboration

The prognostic efficiency indices or positive and negative likelihood ratios and the corresponding diagnostic test capability are presented in Table 3 (Altman; Bland, 1994; Altman; Bland, 1994; Harper; Reeves, 1999; Molinero, 2002; Loong, 2003; Centre for Evidence–Based Medicine, 2009).
Table 3. Prognostic efficiency indices (positive likelihood ratio and negative likelihood ratio) according to the corresponding diagnostic test capacity.

<table>
<thead>
<tr>
<th>Prognostic Efficiency Indices</th>
<th>Diagnostic test capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV(+) ≥ 10.0</td>
<td>Sufficient</td>
</tr>
<tr>
<td>RV(+) ≥ 5.0</td>
<td>Moderate</td>
</tr>
<tr>
<td>RV(+) ≥ 2.0</td>
<td>Scarce</td>
</tr>
<tr>
<td>RV(+) ≥ 1.0</td>
<td>Insignificant</td>
</tr>
<tr>
<td>RV(−) ≤ 0.1</td>
<td>Sufficient</td>
</tr>
<tr>
<td>RV(−) ≤ 0.2</td>
<td>Moderate</td>
</tr>
<tr>
<td>RV(−) ≤ 0.5</td>
<td>Scarce</td>
</tr>
<tr>
<td>RV(−) &lt; 1.0</td>
<td>Insignificant</td>
</tr>
<tr>
<td>RV(−) &gt; 0.1</td>
<td>Moderate</td>
</tr>
<tr>
<td>RV(−) &gt; 0.2</td>
<td>Scarce</td>
</tr>
<tr>
<td>RV(−) &gt; 0.5</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

Source: Altman; Bland, 1994; Altman; Bland, 1994; Harper; Reeves, 1999; Molinero, 2002; Loong, 2003; Centre for Evidence–Bases Medicine, 2009.

Table 4 shows the absolute frequencies of the 300 patients by positivity (Waist/Height Index > 0.5 units) and negativity (Waist/Height Index ≤ 0.5 units) and by pathological nutritional situations overweight and obesity, according to the Gold Standard reference test. Sensitivity, specificity, safety and positive and negative likelihood ratios corresponded, respectively, to 0.9357, 0.9302, 0.9333, 13.4 and 0.07.

Table 4. Absolute frequencies of the 300 patients by positivity (Waist/Height Index > 0.5 units) and negativity (Waist/Height Index ≤ 0.5 units) and by pathological nutritional situations overweight and obesity, according to the Gold Standard reference test.

<table>
<thead>
<tr>
<th>WAIST/HEIGHT INDEX (in units)</th>
<th>Gold Standard Reference Test: Metropolitan Life Insurance Company Equation</th>
<th>Overweight and Obesity</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present</td>
<td>Absent</td>
<td></td>
</tr>
<tr>
<td>Positivity &gt; 0.5</td>
<td>160 (52 ♂ y 108 ♀)</td>
<td>9 (1 ♂ y 8 ♀)</td>
<td>169 (53 ♂ y 116 ♀)</td>
</tr>
<tr>
<td>Negativity ≤ 0.5</td>
<td>11 (4 ♂ y 7 ♀)</td>
<td>120 (105 ♂ y 15 ♀)</td>
<td>131 (109 ♂ y 22 ♀)</td>
</tr>
<tr>
<td>Totals</td>
<td>171 (56 ♂ y 115 ♀)</td>
<td>129 (106 ♂ y 23 ♀)</td>
<td>300 (162 ♂ y 138 ♀)</td>
</tr>
</tbody>
</table>

♂= Male gender; and ♀= Female gender.
Source. Own elaboration

- sensitivity= (A / A + C) = (160 / 171) = 0.9357 = 93.57%;
- specificity= (D / B + D) = (120 / 129) = 0.9302 = 93.02%;
- security= (A + D) / (N)= (160 + 120) / (300) = (280) / 300)= 0.9333 = 93.33%;
- razon of positive likelihood= Sensitivity / 1 – Specificity= 0.9357 / 1 – 0.9302= 0.9357 / 0.0698= 13.4= Sufficient prognostic efficiency;
- interval of estimate at the 95% confidence level for the positive likelihood ratio= 7.13→25.00;
- razon negative likelihood ratio= 1 – Sensitivity / Specificity= 1 – 0.9357 / 0.9302= 0.0643 / 0.9302= 0.07= Sufficient prognostic efficiency;
- estimation interval at the 95% confidence level for the negative likelihood ratio= 0.04→0.12.
Table 5 shows the absolute frequencies of the 300 patients by positivity (Abdominal Circumference ≥ 102 cm in the male gender and ≥ 88 cm in the female gender) and negativity (Abdominal Circumference ≤ 101 cm in the male gender and ≤ 87 cm in the female gender) and by pathological nutritional situations overweight and obesity, according to the Gold Standard reference test. Sensitivity, specificity, safety, and positive and negative likelihood ratios corresponded, respectively, to 0.8070, 0.5039, 0.6767 and 1.6 and 0.4.

Table 5. Absolute frequencies of the 300 patients by positivity (Abdominal Circumference ≥ 102 cm in the male gender and ≥ 88 cm in the female gender) and negativity (Abdominal Circumference ≤ 101 cm in the male gender and ≤ 87 cm in the female gender) and by pathological nutritional situations overweight and obesity, according to the Gold Standard reference test.

<table>
<thead>
<tr>
<th>ABDOMINAL CIRCUMFERENCE (in cm)</th>
<th>Gold Standard Reference Test: Metropolitan Life Insurance Company Equation</th>
<th>Overweight and Obesity</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men ≥ 102</td>
<td>138 (45 ♂ y 93 ♀)</td>
<td>64 (6 ♂ y 58 ♀)</td>
<td>202 (51 ♂ y 151 ♀)</td>
</tr>
<tr>
<td>Women ≥ 88</td>
<td>33 (11 ♂ y 22 ♀)</td>
<td>65 (57 ♂ y 8 ♀)</td>
<td>98 (68 ♂ y 30 ♀)</td>
</tr>
<tr>
<td>Negativity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men ≤ 101</td>
<td>65 (57 ♂ y 8 ♀)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women ≤ 87</td>
<td>300 (119 ♂ y 181 ♀)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

♂ = Male gender; and ♀ = Female gender.

Source: Own elaboration

- sensitivity = (A / (A + C)) = (138 / 171) = 0.8070 = 80.70%;
- specificity = (D / (B + D)) = (65 / 129) = 0.5039 = 50.39%;
- safety = (A + D) / (N) = (138 + 65) / (300) = (203) / (300) = 0.6767 = 67.67%;
- positive likelihood ratio = Sensitivity / 1 – Specificity = 0.8070 / 1– 0.5039 = 0.8070 / 0.4961 = 1.6 = Insignificant prognostic efficiency;
- estimation interval at 95% confidence level for the positive likelihood ratio = 1.4–2.0;
- negative likelihood ratio = 1 – Sensitivity / Specificity = 1 – 0.8070 / 0.5039 = 0.1930 / 0.5039 = 0.4 = Scarce prognostic efficiency;
- estimation interval at the 95% confidence level for the negative likelihood ratio = 0.3–0.5.

Sensitivities, specificities, positive and negative likelihood ratios and diagnostic capacities according to tests (Waist/Height Index and Abdominal Circumference) are presented in Table 6 and Graph 1. The results observed for the positive likelihood ratios corresponded to 13.4 and 1.6 for the Waist/Height Index and Abdominal Circumference diagnostic tests, respectively. These results indicate sufficient (≥ 10.0) and insignificant (≥ 1.0) prognostic efficiencies, respectively. The observed results for the negative likelihood ratios corresponded to 0.07 and 0.4 for the Waist/Height Index and Abdominal Circumference
diagnostic tests, respectively. The observed results indicate, respectively, sufficient (≤ 0.01) and scarce (≤ 0.2) prognostic efficiencies.

Table 6. Sensitivities, specificities, positive and negative likelihood ratios, and diagnostic capacities according to tests Waist/Height Index and Abdominal Circumference.

<table>
<thead>
<tr>
<th>Diagnostic tests</th>
<th>Sensitivities</th>
<th>Specificities</th>
<th>Positive Likelihood Ratios</th>
<th>Diagnostic capacities</th>
<th>Negative likelihood ratios</th>
<th>Diagnostic capacities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waist/Height Index (in units)</td>
<td>0.9357</td>
<td>0.9302</td>
<td>3.4</td>
<td>Sufficient</td>
<td>0.07</td>
<td>Sufficient</td>
</tr>
<tr>
<td>Abdominal Circumference (in cm)</td>
<td>0.8070</td>
<td>0.5039</td>
<td>1.6</td>
<td>Insignificant</td>
<td>0.4</td>
<td>Scarce</td>
</tr>
</tbody>
</table>

Source. Own elaboration

Graph 1. Sensitivities, specificities, and positive and negative likelihood ratios, according to tests Waist/Height Index and Abdominal Circumference.

Graph 2. Absolute frequencies of the 300 patients by positivity (Waist/Height Index > 0.5 units) and negativity (Waist/Height Index ≤ 0.5 units) by diagnostic test Waist/Height Index (in units) and by pathological nutritional situations overweight and obesity, according to the Fagan's Nomogram.
Prior probability (odds): 57% (1.3)
Positive test:
Positive Likelihood ratio: 13
95% confidence interval: [7.13→25]
Posterior probability (odds): 95% (17.2)
95% confidence interval: [90%→97%]
(≈ 1 in 1.1 with positive test are sick)

Negative test:
Negative Likelihood ratio: 0.07
95% confidence interval: [0.04→0.12]
Posterior probability (odds): 8% (0.1)
95% confidence interval: [5%→14%]
(≈ 1 in 1.1 with negative test are well)

Interpretation: Waist/Height Index
In the positive test the prior probability (prevalence) corresponds to 57% (171 of 300) while the posterior probability corresponds to 95%. In other words, approximately 100 out of every 110 patients with a positive test are ill. On the other hand, in the negative test the pre-test probability also corresponds to 57% (171 of 300) while the post-test probability corresponds to 8%. In other words, approximately 100 out of 110 patients with a negative test are healthy.

Source: Own elaboration

Graph 3. Absolute frequencies of the 300 patients by positivity (Abdominal Circumference ≥ 102 cm in the male gender and ≥ 88 cm in the female gender) and negativity (Abdominal Circumference ≤ 101 cm in the male gender and ≤ 87 cm in the female gender) according to the diagnostic test Abdominal Circumference (in cm) and by pathological nutritional situations overweight and obesity and Fagan's Nomogram.

Prior probability (odds): 57% (1.3)
Positive test:
Positive Likelihood ratio: 0.63
95% confidence interval: [1.35→1.96]
Posterior probability (odds): 68% (2.2)
95% confidence interval: [64%→72%]
(≈ 1 in 1.5 with positive test are sick)

Negative test:
Negative Likelihood ratio: 0.38
95% confidence interval: [0.27→0.54]

Posterior probability (odds): 33% (0.5)

95% confidence interval: [26%→42%]

Interpretation: Abdominal Circumference

In the positive test the prior probability (prevalence) corresponds to 57% (171 of 300) while the posterior probability corresponds to 68%. In other words, approximately 100 out of every 150 patients with a positive test are ill. On the other hand, in the negative test, the pre–test probability also corresponds to 57% (171 of 300), while the post–test probability corresponds to 33%. In other words, approximately 100 out of 150 patients with a negative test are healthy.

Source: Own elaboration

4 DISCUSSION

The results obtained indicate that Waist/Height Index is the diagnostic test with the greatest capacity to correctly identify those who do have the disease (Sensitivity= 93.57% and the greatest capacity to correctly identify those who do not have the disease (Specificity= 93.02%). In addition, Waist/Height Index is the diagnostic test that resulted with the highest confidence (93.33%), that is, with the highest percentage of true positives and negatives with respect to the total number of patients studied.

Two or more diagnostic tests can be combined to increase the sensitivity or specificity of the screening process. There are two main forms of combination: 1. Parallel testing; and 2. Serial testing. With parallel testing the patient is labeled as positive if he or she tests positive on any of the tests. When diagnostic tests are performed in series the patient is only labeled as positive if he/she tests positive on all tests. The first approach (parallel testing) increases the sensitivity of the diagnostic tests. The second approach (serial testing) increases the specificity of the diagnostic tests (Mausner; Bahn, 1977). This is important because instead of using a single diagnostic test, two or three diagnostic tests can be used in parallel to increase sensitivity or two or three diagnostic tests in series to increase specificity.

Based on the observed results it is concluded that the diagnostic test with the highest sensitivity (93.57%), with the highest specificity (93.02%) and with the highest safety (93.33%) was the Waist/Height Index (in units).

Positive and negative likelihood ratio tests were performed to determine whether or not the tests have sufficient diagnostic ability or at least moderate diagnostic ability by combining sensitivity and specificity in a single expression. The observed result for the positive likelihood ratio test was 13.4 for Waist/Height Index indicating sufficient diagnostic capability. However, the observed result for the positive likelihood ratio test was 1.6 for Abdominal Circumference indicating insufficient diagnostic capability.

The observed result for the negative likelihood ratio test was 0.07 for Waist/Height Index indicating sufficient diagnostic capability. However, the results observed for the negative likelihood ratio test was 0.4 for Abdominal Circumference indicating scarce diagnostic capability.
Based on these results, we recommend the use of the Metropolitan Life Insurance Company Equation, which provides the ideal body weight for the male and female genders, or the use of the predictive or estimating equations (Broca, Devine, Lemmens, Lorentz, Miller, Perroult and Robinson), which also provide the ideal body weight for both genders (Mataix, 2009).

The use of positive and negative likelihood ratios is recommended in order to jointly evaluate the sensitivity and specificity of any diagnostic test, which is not done.

Finally, the Fagan's Nomogram is a useful tool for calculating posterior probabilities once the prior probability or prevalence and the positive and negative likelihood ratios are known.
REFERENCES


