49 - DEVELOPMENT, VALIDATION AND USE OF THE PREDICTIVE EQUATIONS OF THE DENSITY AND BODY FAT

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Introduction

There is in the literature a variety of techniques and predictive equations (GUEDES, 1994; PETROSKI, 1995; HEYWARD & STOLARCZYK, 2000) of the density and/or of the body fat, making it necessary a more careful evaluation and reflection about its applicability, and the misuse, result in errors of estimates of the body fat (REZENDE et al., 2006).

The anthropometric is a good option for the estimates associated to the amount of body fat, tends in view the narrow relationship between the measures of body density and the dimensions of skinfolds thickness (GUEDES, 2006). In the anthropometric, the skinfolds are the variables more used in equations to esteem the density and /or the percentage of fat, alone or in combination with perimeters, diameters, age, stature, in there another.

The validity of those equations that use skinfolds to estimate the body composition is restricted for the population for the the equation was developed (LUKASKI, 1987). He makes himself necessary to know the population that gave origin the equation, as well as the population that intends to apply it.

In the analyses accomplished about the body composition, it is important to consider the distribution of that body fat. Information related to those aspects, they can be obtained through the calculation of the Body Mass Index (BMI), of the waist hip index (WHI), conicity index (CI) and of the perimeter of the waist (PW) (GUEDES and GUEDES, 1998; GUEDES, 2006), which make her presents in the prediction equations for a lot of times. Besides, other methods that are considered "Standard Gold" in studies of validation of equations as the one of Hydrostatic Weighing and Absorptiometry x-ray of Dual Energy (AXDE) (COAST, 2000; REZENDE et al., 2006).

Inside of that context, it is objectified to do a review on aspects involved in the development process, validation and to provide a reflection concerning the possibilities of applications of the predictive equations of the density and/or body fat.

Methodology

A bibliographical research was accomplished in the scientific literature using the following terms: body composition, body density, body fat, anthropometric, hydrostatic weighs, AXDE, predictive equations and validation. We found articles national and international goods in the databases of PubMed, LILACS and Scielo, besides books and thesis.

Review of Literature

Body composition

The body composition refers to the amount and the several representatives' of the human body proportion (BÖHME, 2000), fat, bones, muscles and residues, which are related with the health, disease and quality of the individual's life (GUEDES, 1994), as consequence, the interest for the study of the body composition has been increasing in the last a hundred years, highlighting Matiegka (MATIEGKA, 1921), one of the first specialists to describe a method anthropometric that consisted of a model of division of the body mass in 4 components: Body mass = E + [P + TS] + M+ R, in that, E = weigh of the skeleton; P = skin; TS = subcutaneous tissue; M = skeletal muscle and R = residue (organs, blood, nervous system, etc.).

The fat excess and of corporal weight it causes several chronic-degenerative dysfunctions and consequently they increase the morbidity indexes and mortality, rebounding in a negative way so much in the quality as in the expectation of the individuals' life (ARAÚJO et al., 2005).

Vague (1947) it can be mentioned as one of the reference authors in what refers to the discussions regarding the distribution of fat body android and genocide. Individuals with distribution fat centripetal, present risks more elevated with relationship to the appearly and the development of metabolic and cardiovascular disturbances (THOMAS, et al., 2004; PITANGA and LESSA, 2005).

Methods of evaluation of the body composition more used in the development and validation of predictive equations

The methods to evaluate the body composition can be classified in direct method, being that in that there are the separation and the weigh of the body components separately (dissection of cadavers), the indirect methods, referring to those in that there is manipulation of the components, but starting from chemical and physical beginnings they seek the extrapolation of the amounts of fat and lean mass and the methods indirect doubly, that are those validated starting from a direct method (COAST, 2001).

Among the doubly indirect methods to anthropometric, especially, the use of the skinfold, perimeters and diameters that are habitually used for determination of the density and/or body fat, due to low operational cost and relative simplicity and validity. When doing use of this technique, they are used not measured low cost operational invasive (COAST, 2001; SAUCER GRANDSON and GLANER, 2007).

Anthropometric

The anthropometric can be defined as the science that studies and it evaluates the size measures, weight and proportions of the human body. The measures of thickness skinfold, circumference and bony diameters, they have frequently been a resource used in the study of the body composition (GUEDES, 1994; GUEDES, 2006), besides of the Body Mass Index (BMI), of the Waist Hip Index (WHI), of the Conicity Index (CI) and of the Perimeter of the Waist (PW) (GUEDES, 2006).

The advantages of using the circumferences in the evaluation of the body composition, base on the possibilities of

reduction of the measure error intra and inter-assessors, in the fact that they are more reproductive than the measures of skinfold thickness, they request smaller technical ability and they allow to evaluate obese people without problem of the limit of opening of the jaw of the compasses (DURNIN and RAHAMAN, 1967).

The thickness of skinfold are measured quite used in the study of the body composition. Through them it is obtained information with relationship to the estimate of the amount of the component of body fat, becoming possible to know the pattern of distribution of the subcutaneous fat tissue for the different anatomical areas (QUEIROGA, 2005).

The bony diameters are found in the literature, with more frequency, in predictive equations of the body density and of the mass free from fat (QUEIROGA, 2005), besides being used for determination of the size of the body framework with base in the stature and in the diameters biacromial (cm) and bitrocanteric (cm). Saint also used to calculate the weight body minimum (McARDLE et al., 2003). It was observed like this, that for the estimate of the percentage of fat, the presence of the diameters is not so mark with relationship to the one of the skinfold, of the circumferences and of the indexes above-mentioned anthropometrics.

The hydrostatic weighting and/or the absorptiometry x-ray of dual-energy (AXDE) it comes being used in the evaluation of the body composition, mentioned in some of them, as techniques “standard gold ". To those two methods, it is noticed the association to the technical anthropometrics in the intuit of developing and/or to validate predictive equations of the body density and/or of fat percentage (McARDLE et al., 2003; SALEM et al., 2006).

Hydrostatic Weighing (Densitometric or Underwater Weighing)

This method calculates the percentage of body fat starting from the body density, that refers the relationship between the body weight and the body volume, being based at the beginning of the mathematician and greek inventor Arquimedes (GUEDES and RECHENCHOSKY, 2008).

The hydrostatic weighing is based on the principle that a body totally submerged in water it suffers action of a force contrary of sustenance, evidenced by weight loss the same to the weight of the moved water. In that way, for that technique, the appraised is submerged in a tank with water, and the body volume is computed with base in the difference among the corporal weight measured in the atmosphere (weigh real) and totally submerged in the water (weigh in the water) (GUEDES and GUEDES, 1998). Advice to adjust the difference of weights for the density of the water and soon after the density of the water is determined. Once certain the body density, takes place the conversion of the values in percentile amounts of fat in relation to the body weight.

Although being a method quite used among the researchers in the studies of validation of methods of the body composition, critics have been made with relationship to its use. It found that among the main limitations of this technique, the use of the model of two corporal compartments has been the more mentioned (REZENDE et al., 2006). It is also stood out that hydrostatic weighing is inappropriate for atmospheres that cannot accommodate a tank of 3.785 liters (GLANER and BRITO, 2007). THE tank should be clean and disinfected regularly and the water should be maintained inside of a width of acceptable temperature, since the density of the water varies with the temperature.

Absorptiometric X-Ray of Dual-Energy (AXDE)

It is an scanning technique that measures different attenuations of x-ray that pass for the body (TRITSCHLER et al., 2003) DXA is a technology that comes being recognized recently as reference method in the analysis of the body composition, although some disagreements exist with relationship to its use (BOTARRO et al., 2000).

Robenoff et al. (1993) they allege that technical AXDE cannot still be classified as a reference method for the analysis of the body composition. Paccini and Glaner (2008) tells that some are evidenced limitations that affect its acuracity, being therefore, necessary new studies objectifying to evaluate of form accurate the use of this apparel in the evaluation of the body composition. By Kohrt (1995), AXDE is a method that comes being used and recognized as a reference method in the analysis of the components of that body composition.

There are in the literature three types of systems AXDE (Lunar, Hologic and Norland), existing among them differences in the hardware configuration and software, and in the calibration methodology, that are reflected in the determination of the values of bony density, and in the percentages tender tissue evaluated by those systems (TOTHILL et al., 1994; PRIOR et al., 1997).

Prior et al. (1997) it stands out that AXDE presents better results in healthy young men than in obese individuals and the precision varies according to the area that is under investigation being the evaluation of the body composition less precise in the trunk compared with the legs.

The tests include a complete scan of the individual's body, what supplies measure of the bony density, of the fat mass and of the thin mass being made a series of traverse scans to the longitudinal axis of the body, with duration of 10 to 20 minutes (BOTARRO et al., 2000). Marques et al. (2000) says that exhibition of AXDE is fast, no-invasive and it can be used in adults, children and special populations (TRITSCHLER, 2003). This technique presents low exhibition to the radiation in relation to the Computerized Tomography (KAMEL et al., 2000).

Statistical procedures employed in the development process and validation of predictive equations

In the development of the equations are habitually used the simple lineal regression, which related a random variable y, with a variable x and the multiple lineal regression, tends an random variable y (dependent) with two or more variable x (independent) (MENDES, 1999).

The accreditation of an equation, for estimate of the body density or percentage of fat in an individual or population, basically it is defined by its validity. Validity of a regression equation refers to the degree of precision with that it estimates the density, the lean body mass or the percentage of an individual's fat (QUEIROGA, 2005).

When you do estimate, is also working with errors in the predictive equations. Lohman (1992) it developed standards for evaluation of prediction errors in equations of the body composition for estimate of the percentage of fat, of the body density (g/cm3) and of the lean mass (Kg), proposing criteria for the validation of equations, as well as EPE, ET, EC and the test " t" of the Student to compare the means among the measured and estimated values.

To evaluate the consistency of a statistical model, the determination coefficient can be used (R) that constitutes a global index of the dependent variation that can be explained for whole the independent variables (WONNACOTT and WONNACOTT, 1980). it is also important the residue analysis, to evaluate deficiencies of the adjusted model, which it also facilitates to visualize the " outliers ", in the attempt of discovering deficiencies in the adjusted model, being the significant divergence in the limits 2, an indication of potential violation of the assumption normality.

When the number of points “outliers” or “differing” points are larger than 5,0% of the total of the number of data, the transformation of those data should be proceeded, when inferior at 5,0%, meets inside of the expected (MENDES, 1999). It is an effective middle to be discovered several types of deficiencies in the adjusted model (SOKAL and ROHLF, 1995).

Regarding the discards of variables, it is important to stand out that before countless independent variables, those should be selected that are significant for the model. One of the used techniques is Stepwise, selection of the beginning for the end (forward selection) (DANIEL, 1978).

The test “t” paired is applied in the validation process since the prediction equation should generate averages of

predictions comparable to the reference averages. The two averages should not differ estatisticament. A large difference between the prediction averages and the reference ones indicates that there is systematic difference (underestimated or overestimated) between the validation samples and of cross-validation, due to technical error or biological variability.

Salem et al. (2006), in one of its studies, aimed to develop and to validate national regression equations to esteem the fat percentage in military of the School of Physical Education of the Army. It used in the validation process the Correlation of Pearson (r), the test " t " of Student pair, the Standard Estimation Error (SEE), the Constant Error (CE) and the Total Error (TE), assisting to the recommendations of Lohman (1992), as well as the Analyze Diagnostic of the Residue (ZAR, 1999).

Glaner and Brito (2007) they developed a research aimed to verify the validity of the equation of Lohman to esteem the percentile of fat in fighters (judo player). The statistical criteria proposed by Lohman were also used (1992), besides using the analysis of the residual scores, based on the proposal of Bland and Altman (1986).

The statistical method of Bland and Altman (1986) it can be used to evaluate the reprodutibility and the error. The use of the validation diagnostic recommended by Zar is also verified (1999), where it consists of analyzing the behavior of the variables used in the equation with the residues studentizados. Salem et al. (2006), it applied this statistical technique in one of its studies, being analyzed the heterocedasticity presence, that is to say, covariance absence among whole the variables of the equations.

Reflecting about the Selection and Possibilities of Application of the Predictive Equations

Reflecting about the process of selection of the “better equation " or equation more adapted for such reality, as well as to analyze its application possibilities, it is not an easy task. Because, they are several the elements that they should be considered, as: cost, validity, aplicability of the method and degree of necessary training to the assessor. It is recommended to verify the predictive equation it was validated in another samples of the population (cross-validation) (GUEDES, 2006; GLANER and BRITO, 2007).

They exist in the literature countless regression equations classified in two groups: specific equations and widespread equations. At first of course the specific equations present larger validity predictive when used in individuals belonging to the same segment of the population of the originated the equation; however, as larger the specificity of the equation, its minor application. In that way, the widespread equations and idealized with base in representative samples of heterogeneous populations in relation to the age and at the level of adiposity they can increase the application options (GUEDES, 2006).

The very widespread equations that embrace wide age groups should be used with caution. The inclusion of individuals of several ages is justified by the fact of obtaining a more heterogeneous and representative sample, but on the other hand, the differences of body composition, happened in function of the age, they can contribute to a larger error of estimate of the body fat. Therefore, besides evaluating the population type used in the validation, the magnitude of the standard error should be observed when opting for the use of those equations (REZENDE et al., 2006).

Before doing use of any regression equation for the estimate of the density and/or body fat aspects they should be observed as: the population that created the equation (specificity), the validity of this for a population in particular (competitive validity) and, its participate. A priori, all equation is valid for its population of origem15.

It is literature more than 100 equations using the measurements anthropometrics in the prediction of components of the body composition (BRODIE et al., 1998). Rezende et al. (2006) it highlights that the equations of Durnin & Wormersley, Jackson & Pollock and Jackson et al., they are the more used in Brazil and some of them, meet in the picture 1, as well as other equations that esteem the percentage of body fat mentioned by Queiroga directly (2005) and Salem et al. (2006).

Square 1: Predictive equations of the body density (BD) and the percentage of body fat (%BF)

Fonte	Grupo Populacional	Idade (anos)	Equações
1. Dumin & Wormersley (1974)	24 estudantes, empresários e profissionais em geral	17-19	DC=1,1620-0,0630*LOG(BC+TR+SB^1+SI)
2. Dumin & Wormersley (1974)	209 mulheres, estudantes, empresárias e profissionais em geral	17-72	DC=1,1765-0,0744*LOG(BC+TR+SB^1+SI^1)
3. Dumin & Wormersley (1974)	272 mulheres, estudantes, empresárias e profissionais em geral	16-68	DC=1,1567-0,0717*LOG(BC+TR+SB^1+SI^1)
4. Jackson & Pollock (1978)	308 homens	18-61	DC=1,1093800-0,0008267(PT^2+AB^1+CX^1)+0,0000016(PT^2+AB^1+CX^1)^2-0,0002574(ID)
5. Jackson & Pollock (1978)	308 homens	18-61	DC=1,18860-0,03045*LOG(PT^2+AB^1+CX^1)-0,00027(ID)
6. Jackson, Pollock & Ward (1980)	249 mulheres	18-55	DC=1,21993-0,03936*LOG(TR+AB^1+SI^2+CX^1)-0,00011(ID)
7. Jackson, Pollock & Ward (1980)	249 mulheres	18-55	DC=1,21389-0,04057*LOG(TR+SI^2+CX^1)-0,00016(ID)
8. Tran & Weltman (1988)	482 homens brancos	22-78	%GC=0,57914807(C^{-1})+0,25189114(C^2)+0,21366088(C^{-2})-0,35595404(PC)-47,371817
9. Vogel, Friedl & Fitzgerald (1990)	286 mulheres brancas e negras militares	18-40	%GC=0,173(C^2)+105,328(LOGPC)-0,515(ES)-1,574(C^{-1})-0,533(C^5)-0,200(C^2)-36,6
10. Salem et al. (2006)	20 homens militares	$\bar{x}$= 27,44	%G = 0,497 x (Pabd) – 0,230 (MC) + 0,793 x (TR) – 20,504

Legend: PT2 = skinfold pectoral, AB1 = skinfold abdominal vertical, CX1 = skinfold thigh average, ID = age, BC = skinfold biceps, TR= skinfold triceps, SB1= skinfold subscapular, SI1= skinfold suprailíac, C1=circumference of the medium abdomen, C2 = circumference of the abdomen: line of the navel (cm), C5 = circumference hip, C12 = valor medium between C1 and C2, C15 = circumference superior ilíaca:previous to the crest iliac (cm), PC = weight, Pabd = perimeter abdominal: measured on top of the umbilical scar.

Final considerations

Before the review about the development, validation and possibilities of application of predictive equations of the density and/or body fat, it is noticed that the taking of decision is not so easy. Any that is the equation of chosen prediction makes her necessary plenty caution with relationship to its use, being necessary to know the reality for the which the equation was developed, as well as its validity, praticity, advantages and limitations.

It was verified that for the development of the equations predictive of the body composition, the use of the simple or multiple lineal regression, comes being used there are several years, tends a considerable acceptability. In the validation studies, the criteria of Loohman (1992) and the analysis of Bland and Altman (1986) they are always presents.

The use of the skinfolds, circumferences and diameters are used in the studies of the body composition, even so, in the estimates of the component body fat, this last one, it is not found with so much frequency, being compared at the two first. Hydrostatic Weighing and Absorptiometry X-Ray of Dual-Energy (AXDE) they are used as techniques “standard gold ". Having, however, still disagreements among some studious, being made necessary new studies in that knowledge field.

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THE DEVELOPMENT, VALIDATION AND USE OF THE PREDICTIVE EQUATIONS OF THE DENSITY AND BODY FAT

ABSTRACT

Several equations are found in the literature, whether specific or widespread, in the intuit of predicting the density and/or the body fat. It objectives to describe aspects involved in the development process, validation and possibilities of applications of the predictive equations of the body fat. A bibliographical investigation was carried out in the scientific literature using the following terms: body composition, body density, body fat, anthropometric, hydrostatic weighing, AXDE, equations predicative and validation.

National and international articles were found in the databases of PubMed, LILACS and Scielo, as well as books. The data of this review allow standing out that the anthropometrics methods, skinfolds, circumferences and diameters are habitually used in the predictive equations to estimate the density and/or the body fat, as well as the hydrostatic weighing and the absorptiometry x-ray of dual energy (AXDE), methods that are considered “Gold Standard". The equations of Durnin & Wormersley, Jackson & Pollock and Jackson et al. are enough used in Brazil. In the development and validation of the predictive equations, technical regression statistics is used (lineal simple or multiple), the correlation of Pearson (r), the paired t test, the standard estimation error (SEE), the total error (TE), the constant error (CE), the diagnostic analysis of the residual of Zar, as well as the method of Bland and Altman. To be perceived that the one taken of decision in the selection of a prediction equation of the body fat is not so easy. It is needed enough caution being necessary to know the reality for which the equation was developed and in which it will be applied, its validity, practicity, advantages and limitations.

Keys Word: Body composition, body density, body fat, predictive equations, validation.

DÉVELOPPEMENT , VALIDATION ET UTILISATION D'ÉQUATIONS PRÉVISIONELLES DE DENSITÉ ET DE LA GRAISSE COPORELLE.

RESUMÉ

Les équations rencontrées dans la littérature sont variées, qu'elles soient spécifiques ou généralisées, dans le but de prévoir la densité et ou la graisse corporelle. Nous nous proposons de décrire les aspects concernant le processus de développement, de validation et des possibilités d'application des équations prévoyant la graisse corporelle. Une rechereche bibliographique a éte réalisée dans les ouvrages scientiphiques utilisant les termes suivants: composition corporelle, densité corporelle, graissse corporelle, anthropométrie, pesage hydrostatique, AXDE, équations de prévisions et validation. Nous avons trouvé des articles nationaux et internationaux dans les bases de données PubMed, Lilacs et Scielo, en dehors des livres.

Les données de cette étude permettent de souligner que les méthods anthropométriques, les plis cutanés, les circonférences et les diamètres sont habituellement utilisés dans les équations prévisionelles pour estimer la densité et ou la graisse corporelle ainsi que le pesage hydrostatique et l'absorptiométrie de rayons x de double énergie (AXDE) qui sont considérés des methods privilégiées. Les équations de Dunin et Wormesley, de Jackson et Pollock et Jackson et al, sont assez utilisées au Brésil. Dans le développement et la validation des équations prévisionnelles, les techniques des statistiques de regression

(linéaire simple ou multiple), la correlation de Pearson (r), le test t assorti, l'erreur patron d'estimation (EPE), l'erreur totale (ET), l'erreur constant (EC), l'analyse diagnostique du résidu de Zar. Ainsi que la méthode de Blandet Altman . On perçoit que la prise de décision dans le choix d'une éqution de prévision de graisse corporelle.n'est pas si facile. Il faut suffisament de prudence et il est nécessaire de connaître la réalité pour laquelle l'équation a été développée et sera appliquée, sa validité, sa praticité, ses avantages et ses limites.

Mots-clés: Composition corporelle, graisse corporelle, équations prévisionnelles, validation.

El desarrollo, validación y uso de las ecuaciones predictivas de la densidad y grasa corpórea

RESUMEN

Diferentes son las ecuaciones encontradas en la literatura, sean ellas específicas o generalizada, en el intuito de predecir la densidad e/o la grasa corpórea. Objetivase describir aspectos envueltos en el proceso de desarrollo, validación y posibilidades de aplicaciones de las ecuaciones predictivas de la grasa corpórea. Fue realizada una investigación bibliográfica en la literatura científica utilizando los siguientes términos: composición corpórea, densidad corpórea, grasa corpórea, antropometría, pesajen hidrostática, DXA, ecuaciones predicativas y validación. Fueron encontrados artículos nacionales e internacionales en las bases de datos PubMed, LILAS y Scielo, además de los libros. Los datos de esta revisión permiten resaltar que los métodos antropométricos, las doblas cutáneos, circunferencias y diámetros son habitualmente utilizados en las ecuaciones predictivas para estimar la densidad e/o la grasa corpórea, así como la pesajen hidrostática y la absortometría de rayo-x de energía dual (DXA), que son considerados métodos "Típico Oro". Las ecuaciones de Durnin & Wormersley, Jackson & Pollock y Jackson et al. Son bastante utilizados en el Brasil. En el desarrollo y validación de las ecuaciones predictivas, son utilizadas técnicas estadísticas de regresión (lineal simple o múltiple), la correlación de Pearson (r), la prueba t pareado, el error típico de estimativa (EPE), el error total (ET), el error constante (EC), el análisis diagnóstica del residuo de Zar, así como el método de Blando y Altman. Percibirse que la tomada de decisión en la selección de una ecuación de predicción de la grasa corpórea no es tan fácil. Es preciso bastante cautela siendo necesario conocer la realidad por la cual la ecuación fue desarrollada y que será aplicada, su validez, practicidad, ventajas y limitaciones.

Palabra llaves: Composición corpórea, densidad corpórea, grasa corpórea, ecuaciones predictivas, validación.

Desenvolvimento, validação e uso de equações preditivas da densidade e gordura corporal

RESUMO

Diversas são as equações encontradas na literatura, sejam elas específicas ou generalizadas, no intuito de predizer a densidade e/ou a gordura corporal. Objetiva-se descrever aspectos envolvidos no processo de desenvolvimento, validação e possibilidades de aplicações das equações preditivas da gordura corporal. Foi realizada uma pesquisa bibliográfica na literatura científica utilizando os seguintes termos: composição corporal, densidade corporal, gordura corporal, antropometria, pesagem hidrostática, AXDE, equações preditivas e validação. Foram encontrados artigos nacionais e internacionais nas bases de dados PubMed, LILACS e Scielo, além de livros. Os dados desta revisão permitem ressaltar que os métodos antropométricos, as dobras cutâneas, circunferências e diâmetros são habitualmente utilizados nas equações preditivas para estimar a densidade e/ou a gordura corporal, bem como a pesagem hidrostática e a absortometria de raio-x de dupla energia (AXDE), que são considerados métodos “Padrão Ouro”. As equações de Durnin & Wormersley, Jackson & Pollock e Jackson et al. são bastante utilizadas no Brasil. No desenvolvimento e validação das equações preditivas, são utilizadas as técnicas estatísticas de regressão (linear simples ou múltipla), a correlação de Pearson (r), o teste t pareado, o erro padrão de estimativa (EPE), o erro total (ET), o erro constante (EC), a análise diagnóstica do resíduo de Zar, assim como o método de Bland e Altman. Percebe-se que a tomada de decisão na escolha de uma equação de predição da gordura corporal não é tão fácil. É preciso bastante cautela, sendo necessário conhecer a realidade pela qual a equação foi desenvolvida e que será aplicada, sua validade, praticidade, vantagens e limitações.

Palavra chaves: Composição corporal, densidade corporal, gordura corporal, equações preditivas, validação.