Statistical Modelling of Anthropometric Characteristics Evaluated on Nutritional Status

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Abstract. *The work is aimed to establish mathematical model for functional dependencies of anthropomethric characteristics on nutritional assessment for adolescent pupils in Croatian boarding schools. Investigated are 1117 female and male pupils from 14 to 19 years of age. Experimentally are determined the following parameters: body mass, body weight, body mass index, obesity index, circumference (waist, hips, chest, arm), skin fold thicknesses (subscapular, triceps). Proposed are multivariable linear models for relationships between the parameters of nutritional assessment and intake of principal food components. They are related to intake of energy, protein, fat and carbohydrates. The models are determined for each female and male generation, and evolution of the model parameters through generations is determined. In view of recommended diet allowances (RDA) and econometric considerations, proposed are linear programming models for optimisation of diet planning in the Croatian boarding schools.*

Keywords: nutrition, anthropometry, boarding school, modelling, diet planning.

1.   Introduction

Scientific approach to analysis and programming of nutritional practice in organised institutions, such as boarding schools, should provide a critical evaluation of quality of nutrition and comparison with RDA recommendations, and the experimental determination of anthropometric characteristics enables quantitative analysis of physical status [1-4]. In this work experimental result of nutritional assessments for female and male population of pupils in secondary boarding schools in Croatia, and modelling results of dependencies of anthropometric variables on daily intake of energy, proteins, carbohydrates and fat contents in food, are reported. Developed are linear regression models for experimentally determined anthropometric characteristics of 1117 individual pupils and average intake of macronutrients (proteins, fats, carbohydrates) in 17 individual boarding schools [5]. Overweight is one of most prominent risk factors observed, which could in time lead to heart diseases and causes temporary work disabilities or invalidity in adults [6-8]. Specially is important to determine these relations in young people, as the examined group, that are prepared to enter a profession regarding the prognosis of their working or living ability [9].

2.   Materials and Methods

Experiments were conducted in 17 boarding schools in Croatia, 6 are female boarding schools, 6 accommodate male pupils, and 5 are coeducational boarding schools. In the experiment were included 1117 pupils; 518 female and 599 men. The following anthropometric chracteristics of each student were determined: body weight (BW), body height (BH), circumference of abdomen (CA), hips (CH), upper arms (CUA), and chest (CC), skin folds of triceps (SFT), and subscapular (SFS). From measured anthropometric measures are calculated body mass index (BMI) and obesity index (OI) that are standard morphological parameters for the estimation and prognosis of possible populations tendency to overweight which may in future effect working ability and health. Assessment of nutrient intake is obtained during a period of 7 days. Three acciden-

tal samples of every meal were randomly sampled: breakfast, lunch and dinner. Samples were measured by the modified weight inventory method [1] and their average values were determined. By use of the nutritional data base (USDA Nutritional Data Base, 1998) for each meal are calculated: energy content, proteins, fats, carbohydrates, vitamins, and minerals. All pupils were required to answer a questionnaire with 19 questions. The questionnaire had 4 groups of questions: physical activity, personal view of quality of nutrition in a boarding school, nutritional habits at home, and food intake between meals in a boarding school. Results of the questionnaire were statistically evaluated.

3. Model

The experimental data obtained for intake of energy, proteins, fats and carbohydrates (Fig. 1-2.) are applied for modelling of the anthropometric variables. Proposed are two types of linear models:

a) Energy model

$$AC = a_0 + a_1 \cdot E + e \qquad (1)$$

b) Nutritional model

$$AC = a_0 + a_1 \cdot P + a_2 \cdot F + a_3 \cdot C + e \qquad (2)$$

In the model equation (1), the energy (E) is the input variable and the anthropometric characteristic, AC are: BH, BM, CA, CH, CUA, CC, SFT, SFS, BMI and OI are the output variables. The model parameter a_0 and a_1 are constants estimated by minimisation of the variance between experimental data (i.e. Least Squares Method), and e is modelling and measurement error.
In the nutritional model (2), the vector of the input variables has as components intake of proteins (P), fats (F) and carbohydrates (C).
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Minimised is the variance σ^2 defined by the error vector **e**:

$$\sigma^2 = \frac{1}{N-p} \cdot \mathbf{e}^T \cdot \mathbf{e} \qquad (3)$$

where N is the number of samples, and p is the number of model parameters. The model error is defined as the difference between experimental value of predicted variable y_e and the prediction of a liner model y_m:

$$\mathbf{e} = \mathbf{y}_e - \mathbf{y}_m$$
$$\mathbf{y}_m = \mathbf{X} \cdot \mathbf{a} \qquad (4)$$

In Eq. (4) elements of matrix X are experimental values of regressed data and a is the vector of parameters in the model (1,2). The minimum is obtained for the parameter values given by:

$$\mathbf{a} = \left(\mathbf{X}^T \cdot \mathbf{X} \right)^{-1} \cdot \mathbf{X}^T \cdot \mathbf{y}_m \qquad (5)$$

Estimated are the model parameters for individual age group and gender, model correlation coefficients, standard errors of parameters, and Fisher's test of model significance.

4. Results and Discussion

In Fig 1.and 2. are represented results of average energy intake for female (Fig.1) and male (Fig.2) pupils at investigated boarding schools, and RDA energy recommendation corresponding for gender and age are also depicted.
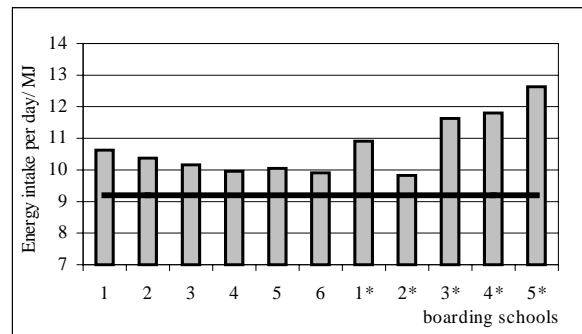

Fig. 1. Average energy intake for female pupils in female boarding schools are denoted by numbers 1-6, and for female pupils in the coeducational schools 1*-5*, RDA recommendation is (-).
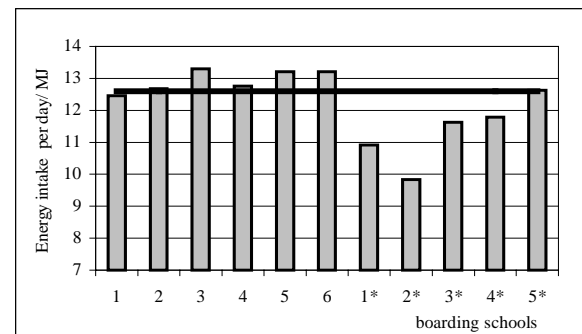

Fig. 2. Average energy intake for male pupils in the male boarding schools are detoned by numbers 1-6, and for male pupils in the coeducational schools 1*-5*, RDA recommendation is (-).

Contribution of proteins, fats and carbohydrates in energy intake for female and male pupils for different boarding schools are calculated from the weight inventory method experimental data and the nutritional data base (USDA Nutrient Data Base, 1998).

Results of the average anthropometric measurements are given in Table 1. All data are arranged according to boarding schools.

variable	female	SD	male	SD
BH /m	166.6	6.17	178.6	7.15
BM /kg	57.3	6.92	69.45	9.95
CA /cm	70.3	6.5	77.2	6.8
CH /cm	96.2	6.1	96.1	6.8
CUA /cm	24.1	2.1	26.3	2.6
CC /cm	88.9	6.2	90.8	7.1
SFT /cm	14.6	4.1	8.8	3.4
SFS /mm	12.2	4.3	9.4	3.3
BMI /kg m^{-2}	20.6	2.2	21.7	2.5
OI	0.73	0.04	0.8	0.04

Table 1. Statistics of main anthropometric variables for female and male pupils in Croatian boarding schools.

A linear model was developed to give emphasis to the contention that an irregular meal planning during a longer period can have a large influence on anthropometric characteristics of an individual, like BM, and BMI what can indirect cause problems associated with overweight. A simple model with energy as the only input variable and a complex or nutritional model with intakes of protein, fats and carbohydrates as the input variables are proposed. In order to detect synergy effect of nutrients in the non-linear model products of intakes, as the input variables are included [2]. In view of possible development of dependencies of anthropological characteristics on duration of specific diet in boarding schools the proposed models are evaluated for each generation, and separately for female and male students. The results of experimental values and model predictions and the corresponding correlation coefficients are given in Fig. 3-5. Regression coefficient is considered as the criteria for a model quality. For each model are determined standard errors of parameters and the regressed variable, and Fisher's coefficient. In all of the cases the linear model with nutrient intakes as variables proved to be the best choice. The time development of the correlation for body mass (R>0.7) and overweight index (R>0.6) proved to be significant. Correlation coefficients of the models for CA, CH, CUA, CC, SFT and SFS show also the same trend, however at lower levels. Those correlation's illustrate not only importance of the amount of the energy intake, more important is what is the energy source.
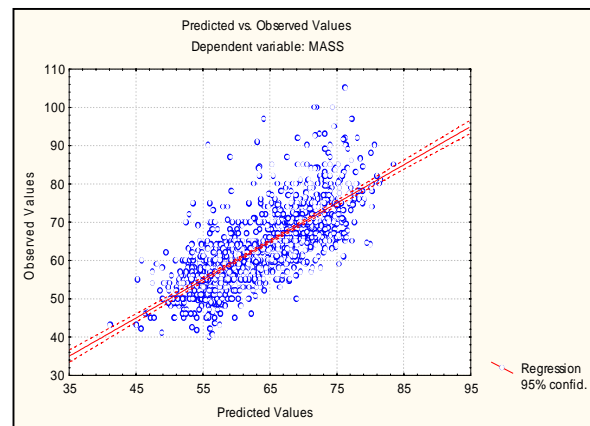

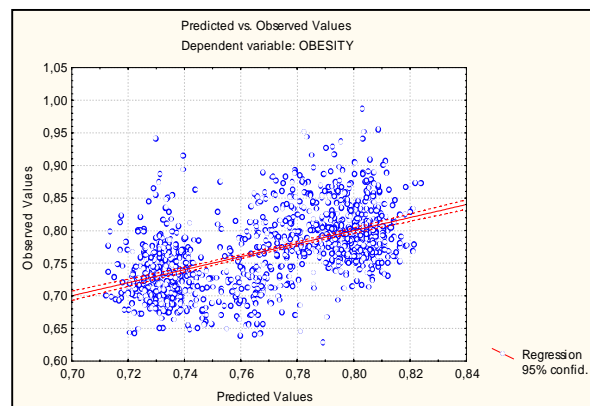Fig. 3. Observed and model predicted values of body mass.

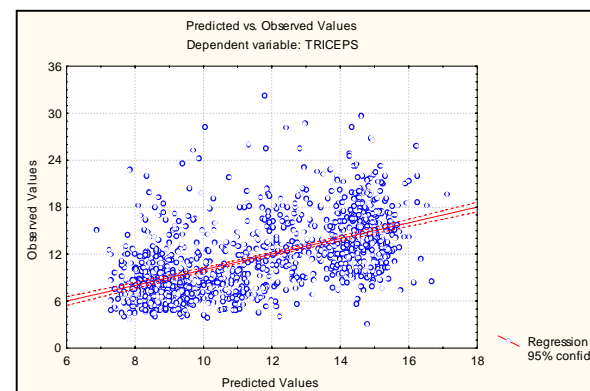Fig. 4. Observed and model predicted values of obesity index.

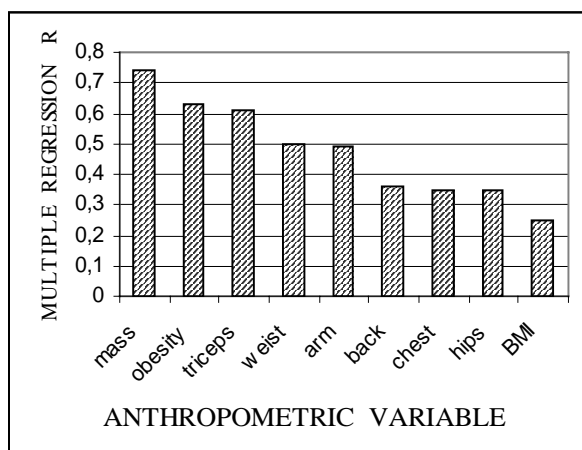Fig. 5. Observed and model predicted values of triceps circumference.

Fig. 6. Multiple regression coefficients R between observed and model predicted values of anthropometric variables.

Multiple regression coeficients R are presented in Fig 6. The highest value is obtained for body mass (BM), R=0.75. The lowest value is observed for body mass index (BMI) due to the simple fact taken this characteristics is essentially determined as a nonlinear function of body mass and body height (BMI=BM/BH^2).

5. Conclusions

On account of effects of long term diet in boarding schools, the extensive anthropological measurements formed a data basis for investigation of hypothesis of functional relationship between diet and nutritional status.

Obtained data revealed significant deficiencies in nourishment. Daily energy intake exceeds the recommended RDA values, or was to low for male students in coeducational boarding schools. Contributions of proteins, fats and carbohydrates in the energy share are not balanced.

Tested are two linear models, but the best results are obtained with linear dependencies of anthropological characteristics with intakes of protein, fats and carbohydrates, the nutritional model.

The correlation coefficients of the models vary depending on anthropometric variable and the maximal coefficient is R = 0.75 obtained for BM of adolescent pupils.

Highest correlation coefficients are obtained with the nutrition model for pupils in the last year of lodging in boarding schools.

6. References

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