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# Non-Linear Relations Between Selected Anthropological Predictors and Psycho-Physiological Exercise-Responses

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**A B S T R A C T**

*In this paper, some very useful non-linear-relation procedures are actualized. The authors have defined the characteristic correlations between a set of anthropological characteristics (14 anthropometric and 14 motor-endurance status variables) and a set of psycho-physiological exercise-responses during the hi-lo and during the step aerobic dance training (heart rate, lactate concentration and rating of the perceived exertion). 60 healthy females served as the sample of subjects (mean age 21±1.4 years). The experiment consisted of two parts. In the first one, the linear correlations between the two sets of the variables were established. In the second part, non-linear (squared) relations, between the variables of the two sets were calculated. Results confirm the statement that the non-linear correlations, in some cases, better determinate the real nature of the relations between the variables, than linear correlation models.*

***Key words:*** *fitness status, RPE, heart rate, lactate concentration, non-linear correlation model, factor analysis*

## Introduction

Defining the correlations between and within different anthropological dimensions is a problem often investigated. Relations between motor and endurance status – on the one hand, and some other anthropological dimensions – on the other, are frequently described[1–3]. However, all the mentioned studies calculated the linear correlation models (univariate or multivariate). But, in the last few years the growing interest for the non-linear models usage in sport sciences has been

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noticed[4,5]. In kinesiology, a deficiency of the non-linear methodological procedures is obvious. Nevertheless, the authors of the present study share the opinion that the non-linear models can be »a step forward«. In some cases, with certain significance, the nature of non-linear relationships between the variables could be observed and explained. For example, Ambrožić[6] clearly and logically explains the established correlation model between the body height–stature, as a criterion, and calf circumference, as a predictor, in the calculated square-function-model. The relation between the stature and calf circumference, is described following the logic of the square surface calculation ($\pi r^2$). Consequently, stature and body weight are highly correlated. »Calf surface« conquers the body weight. Further, »calf-surface« (in the morphological testing non-directly determined by calf-circumference measuring) can be approximately defined as a square surface-magnifying as the square-function of the radius, which finally determines the square-non-linear relation between the calf circumference and stature. The assumption is that a sort of the non-linear correlation exists within some of the motor dimensions, between motor and morphological dimensions, and as supposed, between some anthropological dimensions and psycho-physiological responses to exercise.

*Problem*

Dance aerobic programs, are one of the most popular recreational physical-exercise programs in the world nowadays[7]. Reasons for this fact can be found in its investigated and proven transformational effectiveness, as well as in the supported motivational base[8–11]. Of the numerous types of dance aerobic programs, *step* aerobic and *hi-lo* aerobic, are probably the best known of all. However, for a complete understanding and explanation of the aerobic-dance-phenomenon and training-effects possibilities, a determination of the aerobic dance influence – on the anthropologically different subject -is necessary. A subject's anthropological status dimensions directly determinate the psycho-physiological-responses (PPR) on the exercise-workload. Measuring the PPR, the training instructor, or the subject himself (herself), is able to determinate the adequacy of the training-load. The main scope is on the health-related-adequacy, and also, the transformational-adequacy[7,8,12]. Often, up-front information of the PPR for the certain subject has to be given. Advanced knowledge of PPR is probably one of the most important training factors for a group's training activities (very much like aerobic dance training), because of the impossibility of measuring all the subjects' PPR. Sekulić[13] defined a certain number of the characteristic relations between the selected dimensions of the anthropological status and a set of PPR generated by *hi-lo* and *step* aerobic training. Some relations still exist as unexplained, probably because of the exclusive use of the linear canonical and regression models.

The present study was aimed at investigating the significance and the character of the linear and non-linear ratios between some anthropological dimensions and the psycho-physiological responses of the *hi-lo* and *step* aerobic-dance training workout. The idea was to establish and describe the quantity of the anthropological dimension's influence on the nature of the psycho-physiological responses of the mentioned exercise programs.

## Materials and Methods

*Subjects and variables*

60 females (mean age 21±1.4 years) sampled from the regular recreational aerobic dance participants. All subjects were familiar with the aerobic dance rou-

tines (from 1 month to 4 years of aerobic-dance-training participation).

The sample of the variables consisted of two sets. Anthropological status (1$^{st}$ set) was determined by 14 anthropometrics variables (body height – STATURE, arm length – ARM L, leg length – LEG L, reach height – REACH H, body weight – BW, upper arm circumference – UPPERARM C, thigh circumference – THIGH C, calf circumference – CALF C, femur breadth – FEMUR B, humerus breadth – HUMERUS B, biacromial breadth – BIACROMIAL B, suprailiac skin fold – SUPRAILIAC SF, triceps skinfold – TRICEPS SF, thigh skinfold – THIGH SF, 10 motor tests (determination of the rhythm coordination – DRUM, agility – SHUTTLE, power – SARGENT and MED-BALL, frequency of the movement – HAND-TAPPING and FOOTTAPPING, strength – SIT-UPS, PUSH-UPS and SQUATS), and one aerobic-endurance test (multilevel fitness test – BEEP),

The measurement techniques were similar to those of Bobo and Yarborough[14], Mišigoj-Duraković[15], Grant et al.[16] and Anderson[17]. Five experienced judges determined the characteristic technique and aerobic dance performance-quality of each subject, using videotaped material (TECH*hi-lo*, QUAL*hi-lo*, TECH*step*, QUAL-*step*).

The characteristic psycho-physiological responses (2$^{nd}$ set) was determined by: average heart rate during the cardio session of the *hi-lo* aerobic dance training (HR*hi-lo*) and *step* training (HR*step*), acute lactate concentration at the end of the cardio session of each aerobic dance training workout (LACT*hi-lo* and LACT-*step*) and the »rating of the perceived exertion« (RPE*hi-lo* and RPE*step*). Heart rate was measured using the POLAR ACCUREX PLUS heart rate monitor (metric characteristics of the instrument determinated by Boudet & Chamoix[20]), lactate concentration was measured using the BOEHRINGER MANHEIM ACCUSPORT portable lactate analysator (metric characteristics of the instrument determinate by Bishop[18]), and the RPE was determined on the Borg's rating of the perceived exertion scale (6–20 scale according to Borg[19]. All measuring procedures were similar to those suggested of Sekulić et al.[7], Schuler et al.[21] and De Angelis et al.[22].

### *Experimental design*

In the first phase of the experiment, anthropological testing was performed. Next, small groups (6 to 10 subjects) performed the *hi-lo* aerobic dance program while measuring the HR, LACT and RPE. Likewise, the *step* aerobic training was performed. All the trainings were videotaped. Both programs (hi-lo and step), for all the groups, were identical, programmed beforehand and controlled by an assistant instructor. The technique and quality of the aerobic-dance-performance were determined using the video-recorded material.

### *Methodology*

Because of the relatively large number, the measured anthropological variables were factorized (varimax normalized rotation), separately for the anthropometric as well as for the motor-endurance-set and efficacy-set of the variables, using the Gutman-Kaiser extraction criterion. Calculated and extracted significant factor dimensions were used in the following procedures, as the determinants of the anthropometric and motor status of the subjects.

Linear and non-linear correlations were calculated between the defined anthropological dimensions (factors) and the PPR variables.

The general non-linear square function equation used:

$$y = a + bx + cx^2$$

Where »y« presents the criterion (one of the analyzed psycho-physiological variables), and »x« presents the predictor (one of the anthropological factors).

Statsoft's Statistica version 6.0 was used for all statistical procedures.

## Results

In Table 1, the structures of the successive factors are presented. Three significant morphological factors can be described as: the factor of voluminosity or the more precise – the factor of non-adipose voluminosity (VOL); the second one-factor of the longitudinal dimensionality – body lengths (LONG); and the third one – the factor of the subcutaneous fat (SF). The first factor (VOL) is characterized by the explained variance in body weight, limb circumference and diameter measures. The subjects who are dominant (positively projected) in this factor are probably characterized with a high muscularity (high muscular-voluminosity). On the positive pole of the factor LONG (projections of the length-measures) taller persons are stated, against the shorter persons (negative pole). The third morphological factor differentiates between the subjects by their quantity of subcutaneous fat (SF).

In the set of the motor variables, three significant factors can be named as: POWER (observable projections of the power and agility variables), RHYTHM (highly correlated with the rhythm-coordination and complex-movement-frequency variables), and the shared factor STR/END (determining the strength and aerobic-endurance characteristics of the subjects).

In the set consisting of four characteristic-efficiency variables (technique and quality of aerobic dance performance), one significant factor was extracted, differentiating between the subjects, those who are more (positive pole of the factor) or less (negative pole of the factor) efficient in the aerobic dance elements performance (EFFI).

For further analysis, the factor results of the subjects are calculated.

The results of the linear and the non-linear regression analysis, calculated between the set of the anthropological factors and the set of the PPR measures, are presented in the Table 2. Six significant linear correlation (LIN) coefficients are calculated. VOL and $HR_{hi\text{–}lo}$ are significantly correlated (LIN and NON-LIN-5% of the common variance explained). Past studies[13] proved that the lower $HR_{hi\text{–}lo}$ values are noticed in the highly non-adipose voluminous persons (athletic-type subjects, according to Kretchmer's typography). The factor RHYTHM is significantly correlated with the »training-workload self-perception« during the *hi-lo* aerobic dance training ($RPE_{hi\text{–}lo}$). It is known that subjects with a more developed sense for the RHYTHM have better efficacy in the dance aerobic program performance[7,13]. Therefore, personal perception of the training-exertion (RPE) is probably under the influence of the previously described quality of the program performance. The combined strength-endurance (STR/END) component of the anthropological status is also significantly correlated with the physiological-response-variables, both on the hi-lo and the step aerobic dance training ($HR_{hi\text{–}lo}$, $LACT_{hi\text{–}lo}$, $HR_{step}$, $LACT_{step}$). In the cases listed, as well as in the previously explained relations, a natural logic can be easily followed. High aerobic endurance characterizes the persons with high oxidative-energetic-capacities[23]. High oxidative capacity allows a person performing the workload of relatively higher intensity, while producing the relatively lower lactate concentration. Since the lactate concentration directly (positively) influences the HR value[7], the negative correlation between the RHYTHM and $HR_{hi\text{–}lo}$ and $HR_{step}$, is also clear.

**TABLE 1**
FACTOR STRUCTURE OF THE ANTHROPOLOGICAL DIMENSIONS
(EXPLAINED VARIANCE, % EXPLAINED VARIANCE, FACTOR STRUCTURE – F)

| Morphology | | | | Motor-endurance status | | | | Efficacy | |
|---|---|---|---|---|---|---|---|---|---|
| VAR | F1 | F2 | F3 | VAR | F1 | F2 | F3 | VAR | F1 |
| 1 STATURE (cm) | 0.08 | 0.90 | 0.06 | 1 DRUM (f) | –0.05 | 0.82 | –0.01 | 1 $TECH_{hi\text{–}lo}$ | 0.95 |
| 2 REACH H (cm) | 0.04 | 0.89 | –0.06 | 2 SHUTTLE (s) | –0.71 | –0.14 | –0.28 | 2 $QUAL_{hi\text{–}lo}$ | 0.96 |
| 3 ARM L (cm) | 0.21 | 0.85 | 0.25 | 3 SARGENT (cm) | 0.79 | 0.05 | –0.05 | 3 $TECH_{step}$ | 0.95 |
| 4 LEG L (cm) | 0.19 | 0.84 | –0.05 | 4 MED–BALL (dm) | 0.81 | 0.00 | 0.12 | 4 $QUAL_{step}$ | 0.96 |
| 5 BW (kg) | 0.80 | 0.42 | 0.30 | 5 FOOTTAP (f) | 0.23 | 0.77 | 0.15 | | |
| 6 UPPERARM G (cm) | 0.81 | –0.13 | 0.38 | 6 HANDTAP (f) | 0.01 | 0.08 | 0.45 | | |
| 7 THIGH C (cm) | 0.79 | 0.11 | 0.43 | 7 PUSH-UPS (f) | 0.03 | –0.05 | 0.80 | | |
| 8 CALF C (cm) | 0.83 | 0.03 | 0.30 | 8 SQUATS (f) | 0.30 | 0.27 | 0.55 | | |
| 9 FEMUR B (cm) | 0.84 | 0.19 | 0.12 | 9 SIT-UPS (f) | 0.33 | –0.23 | 0.72 | | |
| 10 HUMERUS B (cm) | 0.64 | 0.17 | –0.18 | 10 BEEP (level) | 0.01 | 0.39 | 0.63 | | |
| 11 BIACROM B (cm) | 0.51 | 0.41 | 0.27 | | | | | | |
| 12 SUPRAIL SF (mm) | 0.19 | 0.22 | 0.67 | | | | | | |
| 13 TRICEPS SF (mm) | 0.23 | 0.03 | 0.66 | | | | | | |
| 14 THIGH SF (mm) | 0.09 | –0.07 | 0.76 | | | | | | |
| Expl.Var | 4.15 | 3.53 | 2.16 | Expl.Var | 2.04 | 1.56 | 2.18 | Expl.Var | 3.66 |
| % Expl. Var. | 29.7 | 25.2 | 15.4 | % Expl. Var. | 20.4 | 15.6 | 11.8 | | |

STATURE – body height; ARM L – arm length; LEG L – leg length; REACH H – reach height; BW – body weight; UPPERARM C – upper arm circumference; THIGH C – thigh circumference; CALF C – calf circumference; FEMUR B – femur breadth; HUMERUS B – humerus breadth; BIACROMIAL B – biacromial breadth; SUPRAILIAC SF – suprailiac skin fold; TRICEPS SF – triceps skinfold; THIGH SF – thigh skinfold; DRUM – rhythm coordination; SHUTTLE – agility; SARGENT – Sargent long-jump test; MEDBALL – medicine ball throwing test; HANDTAPPING – frequency of the movement (hand); FOOTTAPING – frequency of the movement (foot); SIT-UPS – abdominal strength; PUSH-UPS – arm strength; SQUATS – leg strength; BEEP – multilevel aerobic endurance fitness test; TECH*hi-lo* – technique of the hi-lo aerobic program performing; QUAL*hi-lo* – overall quality of the hi-lo aerobic program performing; TECH*step* – technique of the step aerobic program performing; QUAL*step* – overall quality of the step aerobic program performing

**TABLE 2**
LINEAR (LIN) AND NON-LINEAR (NONL) RELATION INDICATORS

| | | | Anthropometric factors | | | | | | Motor-endurance factors | | | | | | Perform. factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | VOL | | LONG | | FAT | | POWER | | RHYTHM | | STR-END | | EFFI | |
| MODEL | | | LIN | NONL | LIN | NONL | LIN | NONL | LIN | NONL | LIN | NONL | LIN | NONL | LIN | NONL |
| HR | r | | 0.23* | 0.23* | 0.07 | 0.1 | 0.18 | 0.2 | 0.06 | 0.08 | 0.07 | 0.07 | 0.26* | 0.29* | 0 | 0.05 |
| hi-lo | const | a | 167.13 | 167.34 | 167 | 166.34 | 167.02 | 167.9 | 167.02 | 166.44 | 167.02 | 167.17 | 167.6 | 168.56 | 167.03 | 166.44 |
| | | b | –2.94* | –2.96 | –0.94 | –1.52 | 2.44 | 3.1 | –0.84 | –1.06 | 0.99 | 1 | –3.51* | –2.3 | 0.18 | 0.45 |
| | | c | | –0.23 | | 0.65 | | –0.89 | | 0.59 | | –0.15 | | 1.56 | | 0.63 |
| LACT | r | | 0.17 | 0.2 | 0.08 | 0.1 | 0.11 | 0.17 | 0.07 | 0.16 | 0.03 | 0.07 | 0.28* | 0.29* | 0.18 | 0.18 |
| hi-lo | const | a | 4.94 | 5.09 | 4.93 | 4.84 | 4.93 | 5.11 | 4.93 | 4.7 | 4.93 | 5.05 | 4.93 | 5.07 | 4.95 | 4.98 |
| | | b | –0.36 | –0.37 | –0.17 | –0.24 | 0.22 | 0.36 | 0.15 | 0.06 | 0.06 | 0.07 | –0.57* | –0.46 | 0.37 | 0.35 |
| | | c | | –0.16 | | 0.09 | | –0.18 | | 0.23 | | –0.12 | | 0.15 | | –0.03 |
| RPE | r | | 0.13 | 0.17 | 0.12 | 0.14 | 0.05 | 0.14 | 0.09 | 0.09 | 0.23* | 0.23* | 0.15 | 0.17 | 0.21 | 0.29* |
| hi-lo | const | a | 12.04 | 11.89 | 12.02 | 11.92 | 12.03 | 12.18 | 12.03 | 11.96 | 12.03 | 12.09 | 12.03 | 12.14 | 12.01 | 12.34 |
| | | b | –0.23 | –0.22 | 0.2 | 0.11 | –0.1 | 0.02 | 0.16 | 0.13 | –0.41* | –0.41 | –0.27 | –0.18 | –0.37 | –0.53* |
| | | c | | 0.15 | | 0.1 | | –0.15 | | 0.06 | | –0.06 | | –0.12 | | –0.35 |
| HR | r | | 0.14 | 0.28* | 0.04 | 0.04 | 0.15 | 0.15 | 0.05 | 0.07 | 0.09 | 0.13 | 0.27* | 0.34* | 0.17 | 0.20 |
| step | const | a | 149.80 | 151.74 | 149.73 | 149.93 | 149.73 | 149.85 | 149.74 | 149.17 | 149.74 | 150.73 | 149.74 | 151.90 | 149.84 | 148.60 |
| | | b | –1.84 | –2.01 | 0.42 | 0.59 | 1.96 | 2.05 | 0.57 | 0.37 | 1.19 | 1.27 | –3.39* | –1.70 | 2.20 | 2.77 |
| | | c | | –2.05 | | –0.19 | | –0.11 | | 0.57 | | –1.00 | | –2.20 | | 1.33 |
| LACT | r | | 0.08 | 0.11 | 0.04 | 0.07 | 0.20 | 0.33* | 0.01 | 0.06 | 0.02 | 0.27* | 0.26* | 0.26* | 0.08 | 0.29* |
| step | const | a | 3.07 | 3.14 | 3.14 | 3.14 | 3.07 | 3.28 | 3.07 | 3.13 | 3.07 | 3.36 | 3.07 | 3.07 | 2.98 | 3.35 |
| | | b | –0.10 | –0.11 | 0.01 | 0.01 | 0.27 | 0.43* | 0.00 | 0.02 | –0.02 | –0.01 | –0.33* | –0.34 | 0.04 | –0.09 |
| | | c | | –0.08 | –0.07 | –0.07 | | –0.21* | | –0.06 | | –0.30 | | 0.00 | | –0.37* |
| RPE | r | | 0.05 | 0.12 | 0.09 | 0.17 | 0.13 | 0.24 | 0.10 | 0.21 | 0.05 | 0.09 | 0.19 | 0.29* | 0.17 | 0.36* |
| step | const | a | 9.33 | 9.48 | 9.33 | 9.12 | 9.34 | 9.62 | 9.34 | 9.64 | 9.34 | 9.47 | 9.34 | 9.69 | 9.32 | 9.89 |
| | | b | 0.10 | 0.09 | 0.17 | 0.00 | –0.26 | –0.05 | 0.20 | 0.31 | –0.12 | –0.11 | –0.37 | –0.10 | –0.35 | –0.50* |
| | | c | | –0.16 | | 0.19 | | –0.28 | | –0.31 | | –0.14 | | –0.36 | | –0.60* |

*p<0.05

VOL – factor of non-adipose voluminosity; LONG – factor of the longitudinal dimensionality; SF – factor of the subcutaneous fat; POWER – factor of the power and agility; RHYTHM – factor of the rhythm coordination; STR/END – factor of the strength and endurance; EFFI – factor of the overall aerobic dance performance efficacy; r – correlation coefficient; a – ordinate segment; b – coefficient of the linearity; c – coefficient of the non-linearity for square function

1.1 Linear relation VOL : $HR_{hi\text{-}lo}$ | 1.2 Nonlinear relation VOL – $HR_{hi\text{-}lo}$

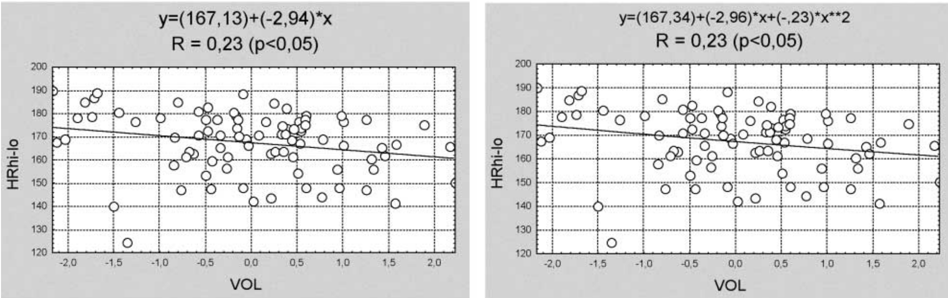


*Fig. 1. Linear and non-linear correlation model for the variables: voluminosity (VOL) and $HR_{hi\text{-}lo}$.*

2.1 Linear relation VOL: $HR_{step}$ | 2.2 Nonlinear relation VOL: $HR_{step}$

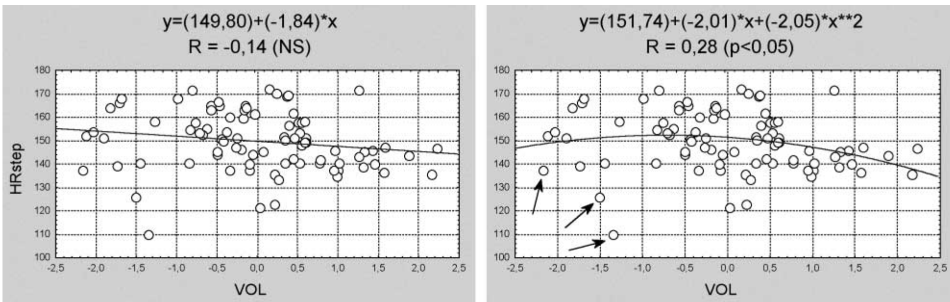


*Fig. 2. Linear and non-linear correlation model for the variables: voluminosity (VOL) and $HR_{step}$.*

3.1 Linear relation RHYTHM: $LACT_{step}$ | 3.2 Nonlinear relation RHYTHM: $LACT_{step}$

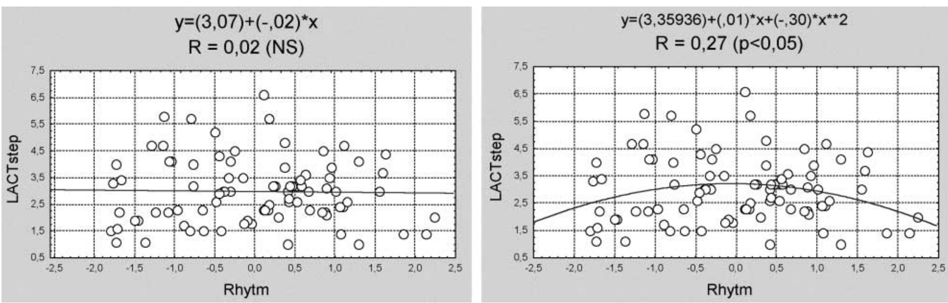


*Fig. 3. Linear and non-linear correlation model for the variables: RHYTHM and $LACT_{step}$.*

4.1 Linear relation EFFI: $LACT_{step}$ 4.2 Nonlinear relation EFFI: $LACT_{step}$

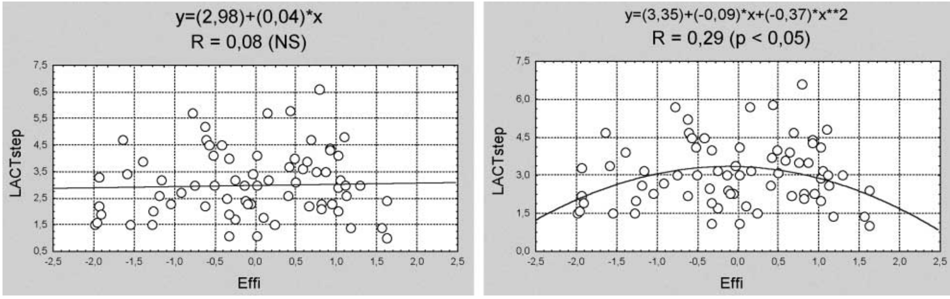


*Fig. 4. Linear and non-linear correlation model for the variables: EFFI and $LACT_{step}$.*

5.1 Linear relation EFFI: $RPE_{step}$ 5.2 Nonlinear relation EFFI: $RPE_{step}$

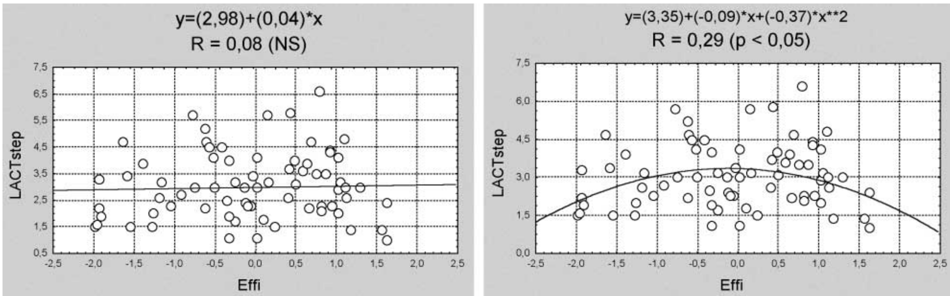


*Fig. 5. Linear and non-linear correlation model for the variables: EFFI and $RPE_{step}$.*

However, the more interesting part of the present investigation, is defining the correlations calculated by the non-linear correlation model. In Table 2, results of the non-linear correlation-calculation are also presented (NONL). Twelve pairs of the variables are significantly correlated by the square-function-correlation calculation.

Generally, a small number of significant linear correlation coefficients could be probably explained by the characteristic subject's variability's in the motor-endurance and morphological status. The sample of the subjects is consisted of recreational aerobic dance participants, which means – very heterogeneous. Therefore, morphological and motor-endurance status are naturally very independent and non-correlated.

## Discussion

As could be seen from the results presented in Table 2, all six pairs of the linear significant correlated variables are significantly correlated using the non-linear equation too. This can be explained by following the example of the correlation between the variables VOL and $HR_{hi–lo}$. Linear and non-linear correlations of these two variables are described by an almost equal correlation coefficient. In the present case, the non-linear correlation did not contribute to a better explanation of the relation. So, the linear-correlation-model calculation is suitable for the correlation-definition. In the same example, the significant function-element »b« can be observed in the linear model, but not in the non-linear calculation. This shows the necessity of the correlation determining by the linear model, in this case. The graphic presentation of the correlation is very useful (Figure 1) for a logical explanation of the results. The non -linearity of the equation (Figure 1.2) is almost indiscernible (the curvature is irrelevant). Therefore, the non-linear equation does not contribute to the explanation of the common variance for these two variables (VOL and $HR_{hi-lo}$). Accordingly, an inspection of the graph, as well as an analysis of the correlation significance, is the only accurate way for the non-linear relation explanation of variables.

The second example explains the problem even better.

The non-linear relation between the variables VOL and $HR_{step}$ is significant. As can be seen in the graphic presentation of the equation (Figure 2), in the middle of the scatter plot, the regression curve changes direction. In the left part of the scatter plot the curve is oriented »neutrally« (parallel with the abscise.). In the right part of the scatter plot, the curve is oriented »negatively« (towards the abscise ). Since the abscise presents the standardized results of the subjects for »voluminosity«, further explanation can be stated. The unexpressed voluminosity (more precisely non-adipose voluminosity) probably has no influence on the physiological response of the training workload (in the specific case determined by the $HR_{step}$). On the other hand, above average VOL (»muscularity« or »athletic constitution«) slightly influences the physiological response to the *step aerobic* training-workload (measured by $HR_{step}$). Probably, if we separate the »nonvoluminose subjects« (on the left side of the scatter plot), and calculate the correlation, no significant coefficients would be found. Also, a negative correlation (probably significant) would be calculated for the »right side« of the scatter plot (»highly muscular« subjects). Another problem has to be addressed. That is the problem of the »outliers«. Notice the three subjects (outliers) pointed out by small arrows in Figure 2.2. Because of the extremely low values of the $HR_{step}$ (110–125 b/min), there is a certain possibility of a measurement error. Accordingly, there is the possibility that the random appearances of the outliers (arrow pointed subjects) changed the correlation coefficient's value, in the linear, as well as in the non- linear model. The small experiment confirms that statement. We excluded the outliers (mentioned three subjects) and calculated the same equations as before (linear and non-linear). As was supposed, the linear correlation coefficient increased ($r = -0.19$, $p>0.05$), and the non-linear coefficient decreased ($r = 0.20$; $p>0.05$). In that case, the false non-linearity is obvious. But, in the specified measurement (measurement of the HR), error is hard to expect, because of the equipment used (the very sophisticated HR monitoring apparatus). Inspection of the videotaped material showed that subjects achieved the analyzed training (*step aerobic*) correctly. Therefore, the previously explained nature of the non-linearity remains.

Figure 3 presents the relation calculated by the linear and nonlinear regression models for the variables RHYTHM and $LACT_{step}$. The linear correlation coefficient is negligible (i.e. not significant), but the nonlinear model determines the common variance at a significant level. The reason for the relatively large difference in the numeric parameters of the correlation equations can be found, analyzing the graphic presentation (Figure 3). The scatter plot is set as a »geometric parable«. Therefore, on the left side of the scatter plot (below the average results on

RHYTHM), a positive correlation between the analyzed variables exists, in spite of the negative correlation–on the right side (above the average RHYTHM results). It seems that for the subjects positioned on the left side of the RHYTHM dimension (low results in the RHYTHM testing), as well as for the subjects positioned on the right side of the same dimension (high results of the RHYTHM testing), a low metabolic training workload can be expected (LACT*step*). The explanation does not seem reasonable, but it is. A reviewing of the videotaped material and past studies' results[7,8] presented the following conclusions. The subjects characterized by low results in the RHYTHM dimension are inefficient in aerobic dance training. The explained inefficiency involves the low engagement of the described participants, during the aerobic dance training. Further, low engagement entails a low energetic training demand, followed by a low metabolic reaction – physiological response (LACT*step*). But, what about the »right« side of the scatter plot (the persons who scored highly in the RHYTHM)? Opposite, these subjects performed the program highly effectively. That »high effectiveness« is an indicator of the »energetic-rationality«[13]. Those subjects have no movement excess or overflow, and they are very rational in spending energy (low LACT values). Accordingly, the highest physiological response ($LACT_{step}$) could be expected for the subjects, who are »average« in the RHYTHM dimension. These subjects (aerobic training participants) are still »efficient enough« in the aerobic dance performance, but not »too efficient« for the extreme rationality, which is followed by the low metabolic demand of the training. The correctness of the previously discussed can be confirmed analyzing Figure 4 and Figure 5, where the relations between »EFFI« dimension (efficacy of the aerobic dance program performance) and the variables $LACT_{step,}$ $RPE_{step}$, are presented. In both cases the same trend of the results can be observed. Regression-curves are parabolic (Figure 4.2 and 5.2). Both, »inefficient« subjects (»inefficient« in the *step*-aerobic-training performance), and »highly efficient« subjects are characterized by a pronounced low metabolic reaction (physiological response), determined by »$LACT_{step}$. The low subjective feeling of exertion (RPE*step*) naturally follows a low metabolic reaction. To simplify the problem, for the »rhythm-insensitive persons«, *step* aerobic training is »too complicated« for their active and unqualified participation. Relative »inactivity« is followed by low metabolic reaction (LACT) thereby inducing low RPE[12]. On the other hand, for the »rhythm – expert« persons, the same training program is too simple, to induce the pronounced metabolic and perceived training-stress reaction. Basically, the *step* aerobic program is »simple« and metabolically undemanding for the selected subjects, characterized by high rhythm-coordination. The best proof is the aerobic–instructors. It is not rare that a single aerobic instructor teaches two, or even three training lessons in a single afternoon, for five or six days a week. This wouldn't be possible with the »normal« metabolic demands of the training. For example, De Angelis et al.[22] defined $6.1 \pm 1.7$ mmol $l^{-1}$ as average lactate concentration during the aerobic dance class for regular participants.

## Conclusion

In some cases, nonlinear models define the true logic of the correlation. A good example is the nonlinear prediction of the lactate concentration according to »aerobic-dance-performance-efficacy« in the first, and according to »rhythm« (as a motor ability) in the second case. Two absolutely different groups (extremely rhythm -coordinated, and non-coordinated) have an extreme low level of physiological response during the *step* aerobic training ($LACT_{step}$). We may suppose that for these two groups (extremely rhythm- coordinated, and non-coordinated) *step* aerobic training is either too complicated (for non coordinated), or on the other hand -too simple (for highly coordinated). The mentioned abstrusity (for non-coordinated), as well as simplicity (for well-coordinated persons), determine energetically undemanding workout for both characteristic groups. Further, the relevant physiological (but also psychological-RPE) reaction on the training exertion is absent. The absence of the ade- quate physic-psychological response in the training implies the low training effects of any workout, which includes the manner of the aerobic dance training as well.

In this paper the authors used linear and square-nonlinear models exclusively. Any further investigations have to explore the possible applicability of the other nonlinear-models (different exponential and logarithmic models).


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## REFERENCES


1. KUKOLJ, M., R. ROPRET, D. UGARKOVIĆ, S. JARIĆ, Int. J. Sports Med. Phys. Fitness, 39 (1999) 120. — 2. EBBECK, V., S. L. BECKER, Res. Q. Exerc. Sport, 65 (1994) 355. — 3. METIKOŠ, D., M. MIŠIGOJ-DURAKOVIĆ, E. HOFMAN, Kinesiology, 22 (1989) 123. — 4. KARNIEL, A., G. F. INBAR, J. Mot. Behav., 31 (1999) 203. — 5. HOUSH, T. J., J. T. CRAMER, A. J. BULL, G. O. JOHNSON, D. J. HOUSH, Eur. J. Appl. Physiol., 84 (2001) 469. — 6. AMBROŽIĆ, F., Kinesiology, 31 (1999) 74. — 7. SEKULIĆ, D., N. RAUSAVLJEVIĆ, M. ŽVAN, Kinesiology, 33 (2001) 27. — 8. SEKULIĆ, D., M. KONDRIČ, G. GURJAN-MANDIĆ, Kinesiologia Slovenica, 1-2 (2001) 45. — 9. SHIMAMOTO, H., Y. ADACHI, M. TAKAHASHI, K. TANAKA, J. Appl. Human Sci., 17 (1998) 109. — 10. GARBER, C. E., J. S. MCKINNEY, R. A. CARLETON, J. Sports Med. Phys. Fitness, 32 (1992) 136. – 11. BERRY, M. J., C. C. CLINE, C. B. BERRY, M. DAVIS, Med. Sci. Sports Exerc., 24 (1992) 946. — 12. BORG, G., P. HASSMEN, M. LAGERSTROEM, Eur. J. Appl. Phys. Occ. Phys., 56 (1989) 679. — 13. SEKULIĆ, D.: Relations between certain anthropological measures and aerobic dance PPR measures. In Croat. Ph.D. Thesis. (Faculty of kinesiology, University of Zagreb, Zagreb, 2002). — 14. BOBO, M., M. YARBOROUGH, Int. J. Sports Med. Phys. Fitness, 39 (1999) 165. — 15. MIŠIGOJ-DURAKOVIĆ, M.: Morphological anthropometric in sports. (Faculty for physical education, University of Zagreb, Zagreb, 1997). — 16. GRANT, S., K. CORBETT, A. M. AMJAD, J. WILSON, T. AITCHISON, Br. J. Sports Med., 29 (1995) 147. — 17. ANDERSON, G. S., Can. J. Sport Sci., 17 (1992) 304. — 18. BISHOP, D., Int. J. Sports Med., 22 (2001) 525. — 19. BORG, G.: Borg's perceived exertion and pain scales. (Human Kinetics, Champagne, 1997). — 20. BOUDET, G., A. CHAUMOUX, J. Sports Med. Phys. Fitness, 41 (2001) 546. — 21. SCHULER, P. B., M. MARTINO, B. R. ABADIE, T. W. STOUT, P. T. CONN, M. Q. WANG, J. Sports Med. Phys. Fitness, 38 (1998) 215. — 22. DE ANGELIS, M., G. VINCIGUERRA, A. GASBARRI, C. PACITTI, J. Sports Med. Phys. Fitness, 78 (1998) 121. — 23. WILMORE, J. H., D. L. COSTILL. Physiology of sports and exercise. (Human Kinetics, Champagne, 1998).



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## NELINEARNE POVEZANOSTI IZMEĐU ODABRANIH ANTROPOLOŠKIH PREDIKTORA I PSIHO-FIZIOLOŠKIH ODGOVORA NA VJEŽBANJE


### S A Ž E T A K

U radu su aktualizirane neke vrlo korisne nelinearne regresijske procedure. Autori su definirali karakteristične korelacije između seta antropoloških varijabli (14 motoričko-funkcionalnih i 14 antropometrijskih varijabli) i seta varijabli za procjenu psiho-fiziološke reakcije na opterećenje, koje je bilo uvjetovano vježbanjem hi-lo i step aerobike (frekvencija srca, koncentracija laktata i razina opaženog napora). Kao uzorak ispitanica u studiji je učestvovalo 69 zdravih mladih žena (21,4±1,4 godine starosti). Eksperiment se sastojao od dva dijela. U prvom su se dijelu izračunale linearne korelacije između dva seta varijabli. U drugom dijelu, izračunate su nelinearne (kvadratne) relacije između istih setova. Rezultati potvrđuju ideju da u nekim slučajevima nelinearni korelacijski modeli, bolje od klasičnih linearnih modela objašnjavaju pravu prirodu odnosa između varijabli.