Coll. Antropol. **37** (2013) Suppl. 2: 153–159
Original scientific paper

Nonlinear Relationships between Anthropometric and Physical Fitness Variables in Untrained Pubescent Boys

Nataša Zenić, Nikola Foretić and Mateo Blažević

University of Split, Faculty of Kinesiology, Split, Croatia

ABSTRACT

Previous studies evidently actualized nonlinear regressions as a step forward in defining the true nature of the relationships between anthropometric and physical fitness (PF) variables in trained subjects. In this paper we have sampled 1176 nontrained boys aged 14–16 years and tested them on (1) five anthropometric predictors, including: body height, body weight, triceps skinfold, upper arm circumference, and body mass index (BMI); and (2) five PF criteria measuring: static (static strength) and dynamic muscle endurance (repetitive strength), aerobic endurance, explosive strength, and coordination. Linear ($y = a + bx$) and nonlinear (second-order polynomial: $y = a + bx + cx^2$) regressions were calculated simultaneously. BMI is found to be the most significant anthropometric predictor of PF status. Although the calculation and interpretation of nonlinear regressions are far more complicated in comparison to those of linear regressions, the variance of the criteria are in some cases far better explained through a significant nonlinear model. Even more, we have found evidence that an exclusive discussion of the linear correlation model could lead to serious interpretative mistakes. This mostly relates to the fact that a linear regression model implies a continuous relationship (dependence) between the predictor and the criteria, while a nonlinear one effectively identifies possible breakpoints in the regression line and consequently highlights the real nature of the relationship between variables.

Key words: *nonlinear regressions, anthropometry, physical fitness, testing*

Introduction

Studies have regularly investigated the influence of the different anthropometric dimensions and measures in relation to physical performance variables[1]. In sports, such approach is interesting since it is well known that anthropometric measures can significantly influence the level of the characteristic sport achievement. At the same time, the problem is studied in physical education and sport-recreation because of the natural and expected influence of morphological status on different physical performance variables, which are at the same time directly related to overall physical routine, health status, and/or independent living and quality of life (e.g., in older age)[2]. However, most of these studies mentioned so far used linear, univariate, and/or multivariate statistical techniques in explaining the characteristic interrelationships between the studied variables. At the same time, recent investigations found nonlinear regressions highly applicable in defining the true logic and nature of the interrelationships between the variables observed[3–8]. For instance, Sekulic et al. (2005)[4] studied linear and nonlinear relationships between anthropometric predictors and physical fitness (PF) criteria in physical education students, and concluded that nonlinear relationships between anthropometric predictors and PF criteria can be expected when: a) there is evident cause (for example – biomechanical and/or physiological cause) why two absolutely different subgroups of subjects should reach equal results on the criterion and b) if a nonlinear relationship can be explained following some evident nonlinear-square basis. At the same time, nonlinear relationships were discussed in studies that dealt with simple anthropometric predictors and achievement in swimming[5], and/or the nonlinearity of the regression curves in evidencing the influence of latent anthropological predictors and psycho-physiological exercise responses[3]. However, all of the mentioned studies dealt with selected and therefore, to some extent,

Received for publication November 25, 2012

trained subjects. This undoubtedly allowed authors to explain the nonlinear logic of the relationships but also left open the question about possible interrelationships between morphological (anthropometric) and motor-endurance variables in untrained subjects. In one of the rare studies that dealt with untrained subjects, Huang and Malina (2007)[7] evaluated the relationship between BMI and four components of health-related PF in a nationally representative sample of Taiwanese youth 9–18 years of age. Authors found a parabolic relationship in some cases, which practically supports the findings of Sekulic et al. (2005)[4] when they evidenced a nonlinear relationship between anthropometrics and motor-endurance status in some physical fitness variables (see previous text). However, Huang and Malina (2007)[7] studied a very large sample of subjects while: (1) not controlling for the subjects' overall and sport-related physical activity (e.g., authors included athletes and non-athletes within the sample), and (2) calculating the relationship for subjects of widely varied ages (9–18 years). Although clear and understandable in conclusion, the reviewed study left some questions unanswered. First, there is a certain possibility that the athletes included in the study were the main cause of the parabolic relationship between BMI and PF variables. Briefly, pubescent athletes are expected to be of average BMI (plotted on the abscise) and to have the highest physical fitness achievement (plotted on the ordinate)[9], which consequently could „parabolize« the relationship between BMI and the PF criterion. Second, and more important, because of the subjects' large age variance, we can argue that growth and maturation changes influenced the BMI and PF status, which practically evidences the covariating effect of the subjects' age on the interrelationship between BMI and PF status.

Therefore, the aim of the present study was to study the possible nonlinear nature of the relationships between simple anthropometric predictors and PF variables in untrained healthy boys aged 14–16 years. The idea was to study a relatively large sample of non-trained subjects of the same age since previous studies dealing with this topic evidenced nonlinear relationships mostly in trained subjects[3–5] and/or sampled subjects highly variable in age[8].

Materials and Methods

The sample comprises 1176 boys aged 14–16 years. All subjects were healthy with no evident motor aberrations, and all regularly participated in the mandatory physical education throughout the high school education. For the purpose of this study, we have selected only boys who did not participate in any form of systematic sport training for the last 5 years. The subjects were measured at the beginning of their 3rd or 4th high school grade (each subject was measured only once). All subjects were residents of Splitsko Dalmatinska Županija in southern Croatia. The variables consisted of five PF tests and three anthropometric variables. The PF variables included tests of muscular dynamic endurance – repetitive strength (SIT-UPS), muscular static endurance – static strength (ARM-HANG), coordination (POLYGON), explosive strength (LONGJUMP), and aerobic endurance (6MIN). The anthropometric variables comprised body height (BH), body weight (BW), triceps skinfold (TrSF), upper arm circumference girth (UAC), and calculated body mass index (BMI). SITUPS was measured as the maximal number of the sit-ups done in 60 seconds with knees bent; ARM-HANG as the length of time the subject can keep the position of the bent arm hang; POLYGON as the time needed to execute the simple 10-meter polygon while crawling backward, and passing over (3 m) and under (6m) 40-cm-high obstacles; LONGJUMP as the distance achieved in standing long jump; and 6MIN as the maximal distance covered in a 6-minute run/walk[10]. The anthropometric variables were measured by standard techniques[11], while BMI was calculated as BMI = BW(kg)/BH(m)^{2}. The data were collected from 2003 to 2008, and all measurements were done by the same person. We calculated the descriptive statistics and conducted the Kolmogorov – Smirnov test for all the variables. But, due to the large number of subjects (more than 1000 examinees), the said test was inappropriate, and therefore, the distribution was tested by Skewness and Kurtosis (see Results). Linear and nonlinear correlations between anthropometric variables and motor-endurance variables were calculated. The general nonlinear square function equation (second-order polynomial model) used was: $y = a + bx + cx^2$, where »y« presents the criterion (one of the analyzed PF variables) and »x« presents the predictor (one of the anthropometric measures). All coefficients were considered significant at a level of 0.95 ($p < 0.05$). StatSoft Statistica version 6.0 was used for all the statistical procedures.

TABLE 1
DESCRIPTIVE STATISTICS (X – MEAN; SD – STANDARD DEVIATION; SKEEKWNESS; KURT – KURTOSIS) OF THE MEASURED VARIABLES

	X±SD	SKE	KUR
BH (cm)	181.17±6.72	–0.19	–0.43
BW (kg)	74.27±9.02	0.02	0.12
UAC (cm)	27.43±1.76	0.14	2.63
TrSF (mm)	13.56±5.87	1.73	5.33
BMI (kg/m^2)	22.6±2.27	0.70	0.63
LONG-JUMP (cm)	218.41±22.95	–1.29	9.84
POLYGON (s)	10.64±1.64	0.84	2.16
SIT-UPS (rep)	48.80±7.29	0.38	1.10
ARM-HANG (s)	46.03±16.06	–0.11	–0.08
6MIN (m)	1222.63±182.38	–0.73	1.85

LEGEND: BH – body height; BW – body weight; UAC – upper arm circumference; TrSF – triceps skinfold; BMI – body mass index; LONG-JUMP – standing long jump; POLYGON – coordination polygon test; SIT-UPS – number of sit-ups in 30 seconds; ARM-HANG – static muscular endurance measured by bent arm hanging; 6MIN – aerobic endurance measured by distance achieved during 6 min run/walk test

Results

Table 1 shows the results for the subjects in all the measured anthropometric and motor-endurance variables. As said in the Methods section, the normality of the distribution was not tested using the Kolmogorov-Smirnov test due to the large number of subjects examined. The Skewness and Kurtosis showed mostly symmetric and mesokurtic (normally distributed) data. However, for LONG-JUMP evident negative asymmetric of the distribution should be noted. At the same time, distributions of the UAC, LONG-JUMP and POLYGON are platykurtic (the high dispersion of the results). Those notations should be overviewed in forthcoming discussion of the linear and nonlinear regressions.

In Table 2 the results of the linear and nonlinear regression calculated between the anthropometric characteristics (predictors) and physical fitness variables (criteria) are presented. Of the total of 50 calculated regressions (25 linear and 25 nonlinear), 20 linear and 19 nonlinear calculations reached a satisfactory level of significance ($p < 0.05$). First, we must point out the relatively low percentage of common variance explained (up to 30%). Therefore, we can suggest that some other predictors (e.g., lean muscle mass, cardiorespiratory fitness, etc.) should be studied in the future because of their possible higher significance in the explanation of the criteria.

In the Figures 1–6 some characteristic significant relationships between anthropometric predictors and PF criteria are presented. In all the presented relationships, nonlinear (second-order) regression explained more of the criterion variance than did the linear one (see Table for more details). However, the presented relationships are chosen because of some characteristic problems and interpretations. More precisely, the graphics are chosen in order to present two very specific problems in nonlinear regressions: (1) problem of the outliers, and (2) different shapes of the nonlinear regression curves.

TABLE 2

LINEAR AND NONLINEAR REGRESSION MODELS BETWEEN ANTHROPOMETRIC PREDICTORS AND PHYSICAL FITNESS CRITERIA (A – COEFFICIENT OF THE INTERCEPTION; B – LINEAR REGRESSION COEFFICIENT; C – NONLINEAR REGRESSION COEFFICIENT; R – MULTIPLE CORRELATION; RSQ – COEFFICIENT OF THE DETERMINATION)

CRITERION	PREDICTORS	Model	R	R^2	a	b	c
LONG-JUMP	BH (cm)	Linear	0.31*	0.09	25.98	1.06*	
		Nonlinear	0.33*	0.10	–1459.83*	17.55*	–0.05*
	BW (kg)	Linear	0.06	0.00	230.20*	–0.15*	
		Nonlinear	0.30*	0.09	–84.60*	8.43*	–0.05*
	UAC (cm)	Linear	0.00	0.00	216.09	0.08	
		Nonlinear	0.23*	0.05	–396.22*	44.71*	–0.81*
	TrSF (mm)	Linear	0.42*	0.18	241.14*	–1.67	
		Nonlinear	0.43*	0.18	246.68*	–2.39*	0.01*
	BMI (kg/m²)	Linear	0.31*	0.09	285.34*	–2.94*	
		Nonlinear	0.39*	0.15	–94.19*	29.86*	–0.7*
POLYGON	BH (cm)	Linear	0.12*	0.01	16.18*	–0.03*	
		Nonlinear	0.15*	0.02	108.38*	–1.05*	0.00*
	BW (kg)	Linear	0.07	0.00	8.32*	0.03*	
		Nonlinear	0.23*	0.05	19.95*	–0.28*	0.00*
	UAC (cm)	Linear	0.07	0.00	8.74*	0.06*	
		Nonlinear	0.12*	0.01	28.19*	–1.34*	0.02*
	TrSF (mm)	Linear	0.27*	0.07	9.60*	0.07*	
		Nonlinear	0.30*	0.09	8.64*	0.20*	–0.00*
	BMI (kg/m²)	Linear	0.30*	0.09	5.73*	0.21*	
		Nonlinear	0.31*	0.09	16.62*	–0.72*	0.02*
SIT-UPS	BH (cm)	Linear	0.20*	0.04	8.47	0.22*	
		Nonlinear	0.20	0.04	–23.45	0.57	–0.00
	BW (kg)	Linear	0.04	0.00	51.46*	–0.03	
		Nonlinear	0.05	0.00	41.15*	0.24	–0.00
	UAC (cm)	Linear	0.02	0.00	46.40*	0.08	
		Nonlinear	0.02	0.00	62.68*	–1.09	0.02
	TrSF (mm)	Linear	0.18*	0.03	51.98*	–0.23*	
		Nonlinear	0.18	0.03	52.07*	–0.24*	0.00
	BMI (kg/m²)	Linear	0.21*	0.04	64.68*	–0.7*	
		Nonlinear	0.27*	0.07	–15.28*	6.2*	–0.14*

TABLE 2
CONTINUED

CRITERION	PREDICTORS	Model	R	R^2	a	b	c
ARM-HANG	BH (cm)	Linear	0.10*	0.10	1.44	0.24*	
		Nonlinear	0.12*	0.01	643.55*	–6.87*	0.01*
	BW (kg)	Linear	0.36*	0.12	93.60*	–0.64*	
		Nonlinear	0.38*	0.14	–6.44	2.09*	–0.01*
	UAC (cm)	Linear	0.26*	0.06	112.05*	–2.40*	
		Nonlinear	0.28*	0.07	–75.95	11.29*	–0.24*
	TrSF (mm)	Linear	0.46*	0.21	63.18*	–1.26*	
		Nonlinear	0.48*	0.23	72.48*	–2.47*	0.03*
	BMI (kg/m²)	Linear	0.52*	0.27	129.51*	–3.69*	
		Nonlinear	0.53*	0.28	15.66*	6.14*	–0.21*
6MIN	BH (cm)	Linear	0.10*	0.01	699.80*	2.88*	
		Nonlinear	0.10	0.01	962.25	–0.02	0.00
	BW (kg)	Linear	0.20*	0.04	1526.91*	–4.09*	
		Nonlinear	0.21*	0.04	813.14*	15.38*	–0.13*
	UAC (cm)	Linear	0.21*	0.04	1839.39*	–22.48*	
		Nonlinear	0.24*	0.05	–404.39	141.08*	–2.96*
	TrSF (mm)	Linear	0.34*	0.11	1366.81*	–10.64*	
		Nonlinear	0.34	0.11	1352.5*	–8.78*	–0.05
	BMI (kg/m²)	Linear	0.35*	0.12	1841.86*	–27.30*	
		Nonlinear	0.38*	0.14	–68.45	137.84*	–3.53*

LEGEND: LEGEND: BH – body height; BW – body weight; UAC – upper arm circumference; TrSF – triceps skinfold; BMI – body mass index; LONG-JUMP – standing long jump; POLYGON – coordination polygon test; SIT-UPS – number of sit-ups in 30 seconds; ARM-HANG – static muscular endurance measured by bent arm hanging; 6MIN – aerobic endurance measured by distance achieved during 6 min run/walk test; * denotes significant coefficients

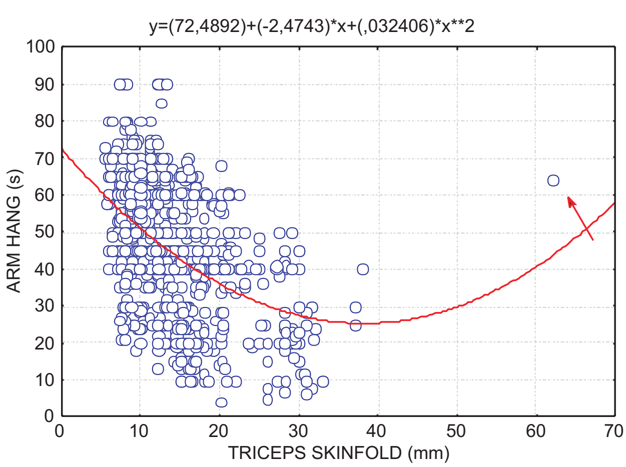

Fig. 1. Nonlinear regression between skinfold measure (triceps skinfold) and static muscular endurance (ARM HANG) for pubescent untrained boys when outliers are included in the model.

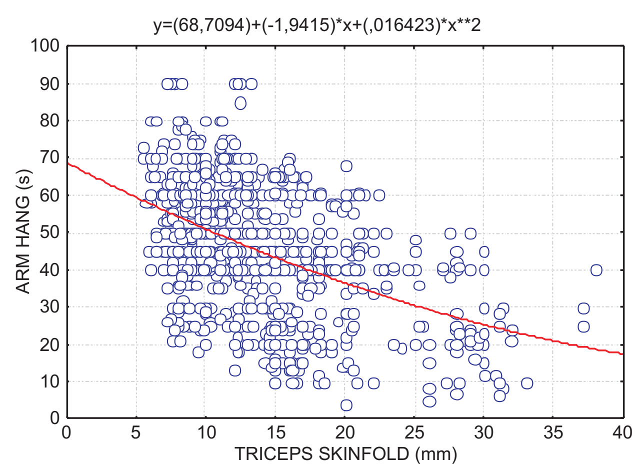

Fig. 2. Nonlinear regression between skinfold measure (triceps skinfold) and static muscular endurance (ARM HANG) for pubescent untrained boys when outliers are not included in the model.

Discussion

Authors have already nonlinearly correlated morphological predictors and PF criteria[4]. However, in comparison to our results, they have found less common variance than we did herein (30% *vs*. 10%). This difference between previous and our study in the quantity of the explained variance probably relates to the fact that authors previously mostly sampled trained subjects[3–4]. There is no doubt that in those investigations systematic physical exercise directly influenced the PF variables independently of the subjects' morphological status. It led to the smaller influence of the morphological predictors on PF status. For that reason, in the experiment presented

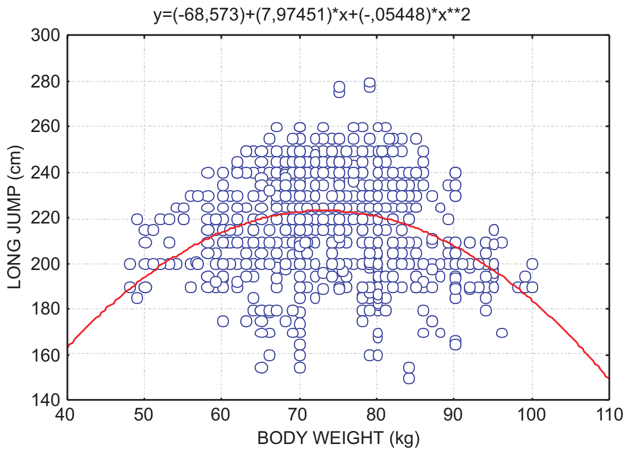

Fig. 3. Nonlinear regression model between body weight and explosive strength (LONG JUMP) for pubescent untrained boys.

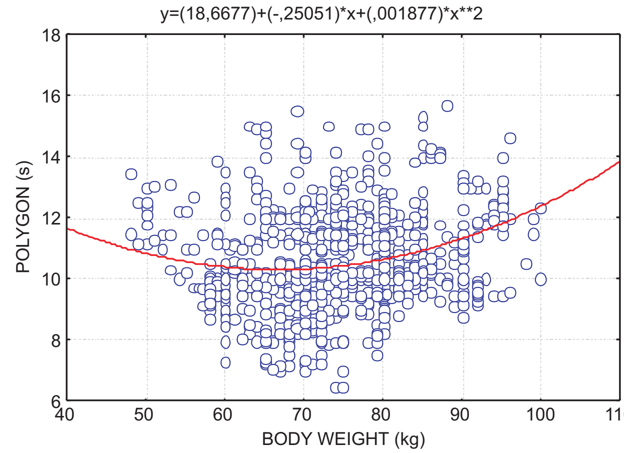

Fig. 4. Nonlinear regression model between body weight and coordination (POLYGON) for pubescent untrained boys.

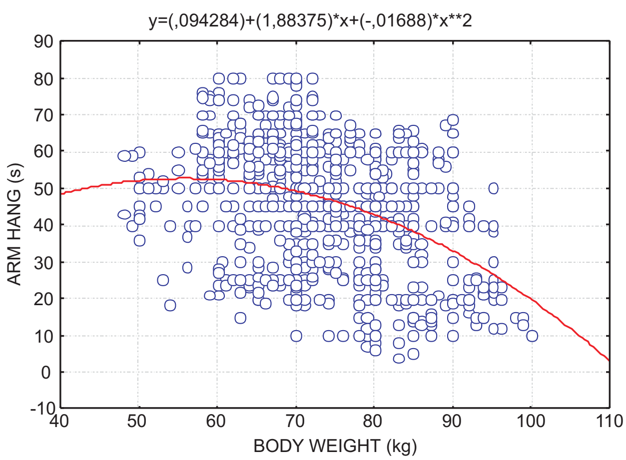

Fig. 5. Nonlinear regression model between body weight static muscular endurance (ARM HANG) for pubescent untrained boys.

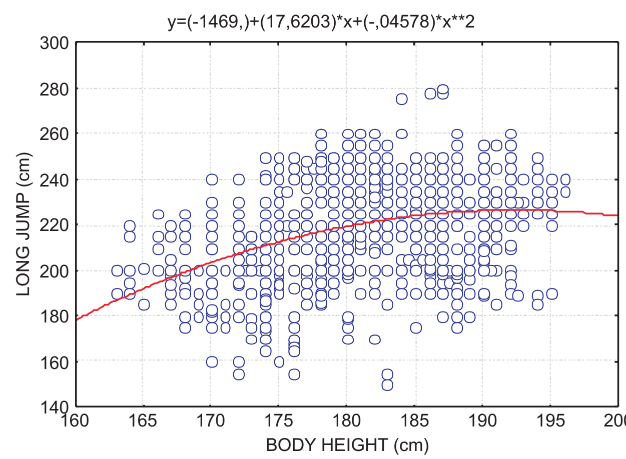

Fig. 6. Nonlinear regression model between body height and explosive strength (LONG JUMP) for pubescent untrained boys.

herein, we have intentionally selected untrained subjects and calculated relationships. The results evidently support our experimental approach (note that we explained three times more of the common variance than previous studies did). In the following text, two characteristic problems of nonlinear regression calculations will be discussed: the influence of outliers on the nonlinear regression significance and the characteristics of the different shapes of nonlinear regression curves.

The nonlinearity of a relationship caused by failure in the measurement (observational/measurement error)

One of the problems that could appear in the case of a nonlinear estimation is the problem of »outliers«. Briefly, and as presented in the Figure 1, the ARMHANG is nonlinearly dependent on the SF measure. But, even in studies where significant number of subjects is observed as we did herein (more than 1000 subjects), only one outlier can initiate serious mistake in the interpretation of the relationship. Figure 1 shows the calculated nonlinear curve. The nonlinear regression is significant (the »c« element reached statistical significance – see Table 2), and the »U« shape of the regression curve could be interpreted accordingly. However, there is no doubt that the subject pointed to by the small arrow should be observed as a measurement error. Briefly, the value of the SF is 62 mm, which is formally and practically impossible[12]. Therefore, this result (e.g., this subject) should be excluded from all statistical procedures and, consequently, regression calculation. After we did it, the regression curve changed shape (Figure 2) and, even more important, the nonlinear »c« element of the equation was no longer significant. Consequently, in this case we are discussing »false nonlinearity«, which is practically only detectable through a graphical presentation of the regression curve. On the other hand, »outliers« must not be exclusively judged as measurement errors. For example, Sekulic et al., in a 2003[3] study of nonlinear regressions between latent motor variables and psycho-physiological exercise response variables, found »outliers« but did not exclude them from the calculations. In short, in the mentioned study, two cases curved the regression line (in very much the same way as we presented in Figure 1), but authors[3] additionally checked the measurement procedure, defined the »outliers« as »true results«, and persisted in the interpretation of the nonlinear relationship between variables.

Different shapes of nonlinear regression curves between anthropometric predictors and physical fitness criteria

Previous studies demonstrated different shapes of nonlinear relationships between the variables studied[4,8,13,14]. Generally, two types of the nonlinear second-order polynomial curve can be expected: (1) geometric parabola, if there is evident cause (for example, a biomechanical and/or physiological cause) why two absolutely different subgroups of subjects should reach equal results on a criterion and (2) parallel-changing to a positive or a negative relationship (or vice versa), in cases when a nonlinear relationship can be explained following some evident nonlinear-square basis[4–6]. In case of parabolic (and/or »U«-shape) relationships, authors evidenced nonsignificant linear relationships between the variables. The results of our study evidently support those conclusions. Briefly, in the case of the two parabolic (»U«-shape) relationships we have presented herein (see Figures 3 and 4), the nonlinear relationship explained a significant part of the criterion variance (9% and 5%); this was not the case when we previously calculated linear relationships (less than 1% in both linear calculations). Evidently, as observable in the first part (left side of the scatterplot) of Figure 3, a positive relationship between BW and LONGJUMP exists, which changed to a negative one on the right side of the scatterplot, forming the characteristic parabolic shape of the regression curve. On the contrary, the first part (left side of the scatterplot) of the relationship between BW (predictor) and POLYGON (criterion) presented in Figure 4 evidences a negative relationship between the variables, which changed to a positive one on the right part of the scatterplot (»U« shape). In both cases, however, and as suggested previously[4] the linear regression did not reach statistical significance. The nature of this somewhat complex relationship is at the same time logical. First, we must note that POLYGON is measured in seconds, meaning that a numerically lower result evidences superior achievement on the test. Therefore, the first part of the scatterplot presents a positive influence of an increase in body weight (e.g., in muscle mass) on complex movement coordination achievement (e.g. the integration of processes ranging from how muscles interact with the skeletal system to neural processes controlling them both in the spine and the brain). The second part of the scatterplot evidences a negative influence of body fat increase (e.g., overweight) on the result of the test. In contrast, in the case of the linear regression calculation between BH and LONGJUMP, and BW and POLYGON (see Figures 5 and 6), the linear regression was significant, but the nonlinear second-order polynomial not only explained more of the criterion variance but also revealed the true nature of the relationship between the variables. Briefly, BW was not observed as a predictor of static muscular endurance (ARMHANG) in subjects who are below average in this anthropometric measure (in our case, subjects less than 70 kg; Figure 5). For those subjects, static muscular endurance is probably mostly related to neuromuscular capabilities and not to morphological anthropometric measures. However, when BW is above average (70 kg in our study) there is a certain possibility that BW is related to prevalence of body fat values, which is almost certainly ballast mass in static muscular endurance performance. This naturally linearizes the relationship between those variables, evidencing the negative relationship between BW and PF in overweight subjects, which is already frequently evidenced[15–17]. The second curvilinear relationship presented is also interesting (Figure 6). Although genetically predetermined, BH is an indicator of growth and development during puberty (e.g., maturity status)[12]. Subjects advanced in maturity status are known to be also advanced in strength capacities[18]. Consequently, the positive linear correlation between BH and LONGJUMP does not surprise us ($R = 0.31$). However, the nonlinear regression ($R = 0.33$) evidenced the real logic of the relationship between these two variables (Figure 6). In short, development of muscle structures (muscle tissue and tendons) does not linearly follow growth (e.g., increase in BH), especially during accelerated growth periods (e.g. periods in life-time where exponential changes in growth and development are occurring)[12, 19–20]. Therefore, the positive – changing to »zero« correlation between BH and LONGJUMP should be evidenced as nature of the relationship between those two variables for untrained healthy pubescent boys we have studied herein. One can argue that there was no need for nonlinear regression calculation since the linear one explained a significant proportion of the criterion variance. However, and as suggested previously[3–5], we are of the opinion that the exclusive calculation and interpretation of the linear correlation will lead to serious interpretative error. Briefly, the linear correlation will be interpreted accordingly (e.g., the predictor negatively influences the criterion), but as discussed before, this will be only »partially« true, since the predictor (in our case, BW) negatively influences the criterion only in some specific circumstances (e.g., in overweight subjects).

Conclusion

The results presented and discussed so far have led us to the following conclusions:

- In comparison to BH, BW, skinfold, and girth measure, BMI should be considered as the most significant anthropometric predictor of PF status in untrained pubescent boys.
- The nonlinear regressions allowed us to define the true nature of the relationship between the variables we have studied herein (anthropometric predictors

and physical fitness criteria). On the other hand, there is no doubt that the calculation and interpretation of the nonlinear regressions are far more complicated in comparison to those of linear regressions.

- When the nonlinear regression is evidenced as significant, the only way to discuss the real nature of the relationship between variables is through a graphical presentation of this relationship. In doing so, one should pay special attention to possible outliers as eventual measurement errors and act accordingly.

We strongly suggest parallel usage and calculations of the linear and nonlinear regression models since the exclusive use of linear correlation could lead to serious misinterpretations of the relationships between variables.

Acknowledgements

Support of the Ministry of Science, Education and Sport of Republic of Croatia is gratefully acknowledged (Project No 315-1773397-3407)

R E F E R E N C E S

1. KEOGH JWL, HUME PA, PEARSON SN, MELLOW PJ, J Strength Cond Res, 23 (2009) 2256. DOI: 10.1519/JSC.0b013e3181b8d67a — 2. TAYLOR MJ, MAZZONE M, WROTNIAK BH, Pediatr Phys Ther, 17 (2005) 180 — 3. SEKULIĆ D, VISKIĆ-ŠTALEC N, RAUSAVLJEVIĆ N, Coll Antropol, 27 (2003) 587 — 4. SEKULIĆ D, ZENIĆ N, MARKOVIĆ G, Coll Antropol, 29 (2005) 723 — 5. SEKULIĆ D, ZENIĆ N, GRČIĆ-ZUBČEVIĆ N, Coll Antropol, 31 (2007) 803 — 6. WILLIAMS PT, Med Sci Sports Exerc, 37 (2005) 1893 — 7. HUANG YC, MALINA R, Med Sci Sports Exerc, 39 (2007) 701. DOI: 10.1249/mss.0b013e31802f0512 — 8. HUANG YC, MALINA R, Int J Pediatr Obes, 5 (2010) 404. DOI: 10.3109/17477160903497902 — 9. WITT KA, BUSH EA, J Am Diet Assoc, 105 (2005) 599 — 10. KATIĆ R, PEJČIĆ A, BABIN J, Coll Antropol 28 (2004) 357 — 11. MIŠIGOJ-DURAKOVIĆ M, Kinantropologija – biološki aspekti tjelesnog vježbanja (Kineziološki fakultet Sveučilišta u Zagrebu. Zagreb, 2008) — 12. MALINA R, BOUCHARD C, BAR-OR O, (Growth, Maturation, and Physical Activity-2nd Edition, Human Kinetics, 2004) — 13. MARKOVIĆ G, SEKULIĆ D, Coll Antropol, 30(3) (2006) 607. — 14. NEDELJKOVIĆ A, MIRKOV D, MARKOVIĆ S, JARIĆ S, J Strength Cond Res, 23 (2009) 1593. DOI: 10.1519/JSC.0b013e3181a9ebce — 15. KATIĆ R, SRHOJ LJ, PAŽANIN R, Coll Antropol, 29 (2005) 711 — 16. SPORIS G, JUKIC I, BOK D, VULETA D, HARASIN D, Coll Antropol, 35 (2011) 335 — 17. LESKOSEK B, STREL J, KOVAC M, Coll Antropol, 34 (2010) 63 — 18. LE GALL F, CARLING C, WILLIAMS M, REILLY T, J Sci Med Sport, 13 (2010) 90. DOI: 10.1016/j.jsams.2008.07.004 — 19. VRANES HS, GALL V, JUKIC M, VRANES Z, Coll Antropol, 36 2012) 549 — 20. JURESA V, MUSIL V, TIJAK MK, Coll Antropol, 36 (2012) 47.

N. Zenić

University of Split, Faculty of Kinesiology, Teslina 6, 21000 Split, Croatia
e-mail: natasazenic@yahoo.com

NELINEARNE ZAVISNOSTI IZMEĐU ANTROPOMETRIJSKIH VARIJABLI I VARIJABLI TJELESNOG FITNESA U NETRENIRANIH DJEČAKA PUBERTETSKOG UZRASTA

S A Ž E T A K

Dosadašnja istraživanja koja su uglavnom analizirale sportaše i trenirane ispitanika, aktualizirala su nelinearne regresije i predstavile ih kao iskorak u definiranju prave prirode zavisnosti između antropometrijskih varijabli i varijabli različitih tjelesnih sposobnosti (fitnes varijable). U ovom radu analizirali smo 1176 netreniranih dječaka uzrasta od 14 do 16 godina i testirali ih na setu antropometrijskih prediktora (visina, težina, kožni nabor tricepsa, opseg nadlaktice i indeks tjelesne mase – BMI), te pet fitnes kriterija kojima je procijenjena repetitivna snaga, aerobna izdržljivost, statička snaga, eksplozivna snaga i koordinacija. Linearni ($y = a + bx$) i nelinearni ($y = a + bx + cx^2$) modeli regresija izračunavani su paralelno. BMI se pokazao kao najznačajniji prediktor fitnes kriterija. Premda je izračunavanje i interpretacija nelinearnih regresija značajno kompliciranija u usporedbi s linearnim regresijskim modelima, varijanca kriterija u nekim slučajevima bolje je opisana putem nelinearnih regresijskih modela. Štoviše, u nekim slučajevima, interpretacija linearnih modela dovodi do značajne interpretacijske pogreške. Ovo se najviše odnosi na činjenicu da linearni model implicira kontinuiranu zavisnost između prediktora i kriterija, a to vrlo često nije slučaj. Nelinearni modeli s druge strane pronalaze točku prijeloma u regresijskoj krivulji i omogućavaju jasnu interpretaciju prave prirode zavisnosti među varijablama.