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RELATIONSHIPS BETWEEN MUSCULAR STRENGTH, ANTHROPOMETRIC CHARACTERISTICS AND MOTOR ABILITIES IN CHILDREN 11-12 YEARS OF AGE

RAZMERJE MED MIŠIČNO MOČJO, ANTROPOMETRIČNIMI LASTNOSTMI IN GIBALNIMI SPOSOBNOSTMI OTROK, STARIH 11-12 LET

Abstract

To gain deeper insight into the integral anthropological status of children 11-12 years of age, the 11-test and measure battery, assessing anthropological status, was applied on a sample of 1058 primary school fourth-graders (540 boys and 518 girls). In the study three variables measuring muscular strength were criterion variables, whereas four anthropometric and four motor variables were the predictor variables. Canonical correlation analysis revealed that in the subsample of boys the two pairs of canonical factors were determined. Boys performed better in the tests of explosive leg power and isometric arm strength endurance if they had lower values of body mass, subcutaneous fat, and body voluminosity, and better gross body co-ordination and aerobic endurance. According to the second canonical factor boys performed better in the trunk strength endurance of a dynamic type test if they had better scores in the movement frequency and hamstrings flexibility tests. In the subsample of girls the statistically significant association existed only in the first pair of canonical factors. Girls performed well in the strength/power tests if they had lower values of body mass and subcutaneous fat and better scores in the movement frequency, gross body coordination, flexibility and aerobic endurance tests.

Key words: strength/power, anthropometric characteristics, motor abilities, children

Izvleček

Za ugotavljanje celovitega antropološkega statusa otrok, starih 11-12 let smo uporabili merilno baterijo z 11 testi. V študiji je sodelovalo 1058 osnovnošolcev iz četrtih razredov (540 dečkov, 518 deklic). Uporabili smo tri kriterijske spremenljivke mišične moči ter osem prediktorskih spremenljivk (štiri antropometrične in štiri gibalne spremenljivke). Kanonična korelacijska analiza je pokazala, da sta v podvzorcu dečkov značilna dva para kanoničnih dejavnikov. Dečki, ki so imeli nižje vrednosti telesne mase, podkožnega maščevja in voluminoznosti telesa kot tudi boljšo koordinacijo vsega telesa in aerobno vzdržljivost, so dosegli boljše rezultate pri testih eksplozivne moči nog in izometrične mišične vzdržljivosti rok. Glede na drug kanonični dejavnik so imeli dečki boljše rezultate mišične vzdržljivosti trupa pri dinamičnem testu, če so se bolje odrezali pri frekvenci gibanja in testih gibljivosti podkolenskih vezi. Pri podvzorcu deklic je statistično pomembna povezava obstajala le med prvim parom kanoničnih dejavnikov. Deklice so se dobro odrezale pri testih moči/sile, če so imele manjše vrednosti telesne mase in podkožnega maščevja ter so dosegle boljše rezultate pri frekvenci gibanja, koordinaciji vsega telesa, gibljivosti in testih aerobne vzdržljivosti.

Ključne besede: moč/sila, antropometrične značilnosti, gibalne sposobnosti, otroci

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Introduction

Among the paramount diversity of issues pertaining to the domain of the desired integral anthropological development of children 11-12 years of age, relations among muscular strength, anthropometric characteristics and other relevant motor abilities seem to deserve special attention, not only because they have not been thoroughly investigated yet, but because it is generally considered that muscular strength is the most crucial human motor ability which makes each and every motor activity in everyday life, sport or physical education (PE) possible.

One can hardly imagine any human motion structure consisting of exclusively one movement/motion that is not under the strong influence of complex mechanisms which regulate the duration of excitation in the motor zones of the central nervous system. These are on the one hand responsible for variability in the dimensions of muscular endurance of a dynamic type (repetitive strength) and isometric muscular endurance (static strength), while the excitation intensity regulation mechanisms are on the other hand responsible for the variability in the dimensions of explosive strength or power. This primarily concerns the mechanisms that have been in the previous research studies referred to as the power regulators, responsible for explosive motor unit activation, and the endurance regulators, responsible for duration of motor unit activity (Metikoš, Gredelj, & Momirović, 1979).

Several factors of muscular strength have been established so far in literature. According to the action type criterion or type of manifestation they have been identified as the explosive strength or power, which is commonly defined as an ability of an individual to exert maximal force (energy) in one quick movement at the fastest possible rate; additionally, muscular endurance of a dynamic type (repetitive strength), which is defined as an ability of an individual to repeatedly perform a series of separated simple movements - motions; and muscular endurance of a static type (static strength), as an ability of an individual to maintain isometric muscle contraction at a particular level. Certain authors (e.g., Kurelić, Momirović, Stojanović, Šturm, Radojević, & Viskić-Štalec, 1975) have named the listed strength factors the primary strength factors. In terms of physics they have connected isometric strength endurance with the notion of force, explosive strength or power with the notion of energy and muscular endurance of a dynamic type with the notion of strength.

The practice of PE teaching, as represented in the curriculum, pays considerable attention to developing strength/power in elementary school children. Structure of the 11-test and measure battery confirms the aforementioned – as much as three variables assess developmental levels of the primary strength/power (explosive strength or power, isometric muscular endurance, strength endurance/static strength), muscular endurance of a dynamic type/repetitive strength), in addition to one variable which at a time assesses frequency of movements, gross body co-ordination, flexibility and aerobic endurance, whereas four variables measure anthropometric attributes (body height, body weight, forearm circumference, upper arm - triceps skinfold). The use of the battery of standard instruments is prescribed in the school system of Croatia. In relation to such focus of PE work a need emerges to investigate if this development of strength/power involves or impacts parallel development of other relevant motor abilities.

It is well known (Blašković, 1977; Bonacin, Katić, Zagorac, & Mraković, 1995; Malacko, 2002; Pejčić, Malacko, & Tončev 1987; Tokić & Prskalo 1999; Viskić-Štalec & Mejovšek 1975) that in one motor activity one somatotype may directly hinder the realisation of a kinetic programme, whereas in any other situation the same somatotype may be extremely favourable. The theory and

practice of PE are continuously faced with the above-mentioned problem in the pursuit to fulfil the main purpose of promoting above all harmonious physical development of children and the youth, which should help them in physical proficiency and in building awareness and the habits of healthy, active life-styles (Findak, 1999; Milanović, 1999): how to find and maintain an optimal ratio and relationships between these types of power, other relevant components of motor or physical fitness (or abilities), and adequate morphological characteristics to provide children of the age in question with optimal developmental anthropological integrity?

The aim of the present study was therefore to determine relations between the group of variables assessing strength (the group of criterion variables) on the one hand, and the group of anthropometric variables and other relevant motor variables on the other, as the group of predictor variables, in the primary school boys and girls 11-12 years of age, i.e. the fourth-graders in the Croatian primary schools. The rationale for such a research design lies, on the one hand, in the need to verify the influence of typical contents of regular PE school programmes on the harmonious development of morphological characteristics and motor abilities, and, on the other hand, in a potential of expected findings to be implemented in economic and sensible procedures of optimal sport orientation and selection as well as in sport and/or PE planning, programming, monitoring and control, and also in procedures of efficient monitoring of development of relevant and desirable anthropological attributes by means of a common and verified battery of measuring instruments within the school system.

Method

Participants

On a sample of 1058 Croatian primary school fourth-graders (540 boys and 518 girls), aged 11-12 years, from the Rijeka County, the 11-test and measure battery was applied. This battery is a standard evaluation measure used commonly in the Croatian school system.

Instruments

The following variables were used to assess muscular strength/power: explosive strength (power) – standing (broad - long) jump (MSLJ), muscular endurance of a dynamic type (repetitive strength) – sit-ups (MSU) and isometric muscular endurance (static strength) - bent-arm hang (MBAH). These formed the criterion group of variables.

The group of predictor variables consisted of the following anthropometric measures: body height (ABH), body weight (ABW), forearm girth (circumference) (AFC) and triceps skinfold (AUAS). Measures of other relevant motor abilities were: rate of movement performance (movement frequency) – hand-tapping (MHT), gross body co-ordination - polygon (obstacle course) backwards (MPB), flexibility – straddle seat-and-reach (MSR) and aerobic endurance - 3-min run (F3R). Standard test procedures and decimal measure units were applied.

Procedure

Participants were tested using the 11-test and measure battery. The morphological status was measured first, followed by anthropometric characteristics, motor and functional abilities. Group

testing took place twice, initial condition in September and October 2001 and terminal condition a year later.

Statistical method of canonical correlation analysis was used to determine the connections between the two multidimensional anthropological systems of manifest variables (Malacko & Popović, 2001).

The starting point was a presumption that these two multidimensional anthropological systems were in a linear association. Therefore, the connection between the criterion and predictor groups of variables was calculated first by means of the cross-correlation matrix for each sex separately, and then, by solving the characteristic equations, the eigenvalues of these equations were obtained (λ). The statistical significance of the coefficient of canonical correlation (Rc^2) was tested by means of the Bartlett's χ^2-test at the level of p = .01, which explained linear combinations among the pairs of the canonical factors in groups of variables. The squares of canonical correlations (Rc^2) were also computed, which provided an explanation for the common variance of the pairs of the canonical factors in two groups of variables.

Results

The analysis of the cross-correlations matrix between the criterion variables of strength/power and the predictor anthropometric-motor variables in the subsample of boys (see Table 1) showed statistically significant correlations of pairs (marked with *) in most of the applied variables, with the exception of body height.

Table 1: Cross-correlations between the criterion and predictor variables - boys

Variables	ABH	ABW	AFC	AUAS	MHT	MSR	MBAH	F3R
MSLJ	.01	-.19*	-.17*	-.33*	.01	-.42*	.00	.25*
MSU	.05	-.10*	-.12*	-.14*	.24*	-.17*	.12*	.31*
MBAH	-.02	-.28*	-.28*	-.36*	.07	-.42*	.12*	.21*

Legend:
MSLJ - standing long jump
MSU - sit-ups
MBAH - bent-arm hang
ABH - body height
ABW - body weight
AFC - forearm circumference
AUAS - upper arm skinfold
MHT - hand-tapping
MPB - polygon (obstacle course) backwards
MSR - straddle seat-and-reach
F3R- three-min run

In the determination of connections between the strength/power and anthropometric-motor dimensions (see Table 2) the highest eigenvalue was assigned to the first canonical factor (λ=.52). The statistical significance (p) of the canonical correlation coefficients (Rc) and common variance (Rc^2) was tested by means of the Bartlett's Chi-square test (χ^2). The statistically significant association of the two pairs of canonical factors was determined at the p = .01 level. The canonical correlation coefficients of the first and the second pair of canonical factors are .63 and .31, respectively.

Table 2: Eigenvalue (λ), canonical correlation (Rc), coefficient of determination (Rc^2), Bartlett's test (x2) and its significance (p) - boys

λ	Rc	Rc^2	χ^2	p
.52	.63	.39	341.97	.00*
.87	.31	.09	71.63	.00*

The canonical factor structure matrices of the criterion variables of strength/power (see Table 3) and the predictor group of anthropometric and other motor variables (see Table 4) display statistically significant correlations among all manifest variables and isolated canonical factors in both spaces.

Table 3: The structure of canonical factors of criterion variables - boys

Variables	*CAN-1*	*CAN-2*
MSLJ	.77*	-.27
MSU	.51	.82*
MBAH	.82*	-.17

Legend:
MSLJ – standing broad - long jump
MSU - sit-ups
MBAH - bent-arm hang

Table 4: The structure of canonical factors of predictor variables - boys

Variables	CAN-1	CAN-2
ABH	.00	.17*
ABW	-.46*	.12
AFC	-.45*	.03
AUAS	-.65*	.26
MHT	.18	.70*
MPB	-.78*	.33
MSR	.17	.30*
F3R	.52*	.48

Legend:
ABH - body height
ABW - body weight
AFC - forearm circumference
AUAS - upper arm skinfold
MHT - hand-tapping
MPB - polygon (obstacle course) backwards
MSR - straddle seat-and-reach
F3R- three-min run

In the space of strength/power the first canonical factor can be interpreted as the canonical factor of explosive leg strength (power) and isometric arm muscular endurance, whereas the second factor can be interpreted as the trunk muscular endurance of a dynamic type. The first canonical factor in the anthropometric-motor space can be interpreted as the canonical factor of physical development (voluminosity with fat tissue), gross body co-ordination, and aerobic endurance and the second one as the canonical factor of movement frequency and hamstrings flexibility.

The analysis of the matrix of cross-correlations in the subsample of girls (see Table 5) between the group of criterion variables of strength/power and the group of predictor anthropometric and motor variables showed also statistically significant correlations of pairs (marked with *) in most of the applied variables at the level up to .05 (p<.05), with the exception of body height and forearm circumference.

Table 5: Cross-correlations between the criterion and predictor variables – girls

Variables	ABH	ABW	AFC	AUAS	MHT	MPB	MSR	F3R
MSLJ	-.01	-.07	.04	-.32*	.15*	.07	.13*	.32*
MSU	-.04	-.04	.01	-.19*	.18*	.00	.13*	.21*
MBAH	-.08	-.17*	-.02	-.36*	.14*	.09*	.01	.31*

Legend:
MSLJ - standing long jump
MSU - sit-ups
MBAH - bent-arm hang
ABH - body height
ABW - body weight
AFC - forearm circumference
AUAS - upper arm skinfold
MHT - hand-tapping
MPB - polygon (obstacle course) backwards
MSR - straddle seat-and-reach
F3R- three-min run

In the determination of associations between the space of strength/power and anthropometric-motor dimensions (see Table 6) the highest eigenvalue was assigned to the first canonical factor (λ=.64). It was also determined that statistically significant correlation existed only in the first pair of canonical factors at the p = .01 (p<.01) level and that it equalled .56 (Rc=.56).

Table 6: Eigenvalue (λ), canonical correlation (Rc), coefficient of determination (Rc2), Barlett's test (x)2 and its significance (p) – girls

λX	Rc	Rc^2	χ^2	P
.64	.56	.31	221.09	.00*

The canonical factor structure matrices of the criterion variables of strength/power (see Table 7) and the predictor group of anthropometric and motor variables, except for the variable forearm circumference (see Table 8), display statistically significant correlations among all manifest variables and the isolated canonical factors in both spaces.

Table 7: The structure of canonical factor of criterion variable - girls

Variables	CAN-1
MSLJ	.79*
MSU	.54*
MBAH	.82*

Legend:
MSLJ - standing long jump
MSU - sit-ups
MBAH - bent-arm hang

In the space of strength/power the isolated canonical factor can be interpreted as the canonical factor of general strength/power, due to the fact that it is determined by the following variables:

isometric arm muscular endurance, explosive leg strength (power) and trunk muscular endurance of a dynamic type.

Table 8: The structure of canonical factors of predictor variables – girls

Variables	CAN-1
ABH	-.11*
ABW	-.26*
AFC	.01
AUAS	-.75*
MHT	.35*
MPB	.16*
MSR	.18*
F3R	.69*

Legend:
ABH - body height
ABW - body weight
AFC - forearm circumference
AUAS - upper arm skinfold
MHT - hand-tapping
MPB - polygon (obstacle course) backwards
MSR - straddle seat-and-reach
F3R- three-min run

The canonical factor in the anthropometric-motor space can be interpreted as an integral canonical factor of somatic and motor development, because it is defined by the anthropometrical variables: longitudinal skeletal dimensionality, body weight and fat tissue as well as by the motor variables: movement frequency, gross body co-ordination, flexibility and aerobic endurance.

Discussion

According to the first pair of canonical factors boys accomplish better results in the explosive leg strength (power) and isometric arm muscular endurance tests if they have lower values of body weight and body voluminosity, better gross body co-ordination and aerobic endurance. And vice versa, they accomplish poorer results in the explosive leg strength (power) and isometric arm muscular endurance tests if they have enhanced values of body mass and body voluminosity, poorer gross body co-ordination and aerobic endurance. The second pair of canonical factors demonstrates that boys perform better in the trunk muscular endurance of a dynamic type test if they have better scores in the movement frequency and hamstrings flexibility tests. And contrary, they are less successful in the trunk muscular endurance of a dynamic type test if their scores in the movement frequency and hamstrings flexibility tests are inferior.

Girls perform well in the strength/power tests if they have lower values of body mass and body voluminosity on the one hand, and better scores in the movement frequency, gross body co-ordination, flexibility and aerobic endurance tests on the other. And vice versa, their performance in the strength/power tests is poorer if they have enhanced values of body mass and body voluminosity and poorer scores in the movement frequency, gross body, flexibility and aerobic endurance tests.

The findings are objectified by the validated battery of measuring instruments, commonly and obligatorily applied in the Croatian schools, which conceptually covers the most important morphological characteristics and motor abilities of children. The measured data were processed by the canonical correlation analysis, and a relatively high level of statistical significance of the pair of canonical factor mutual relations was recorded.

In general, the research has met the expectations. Its findings demonstrated that the applied PE teaching contents, stipulated in the PE curriculum, the purpose of which was the development of strength/power, speed, flexibility, gross body co-ordination and aerobic endurance, were adequate in terms of pupils' age (ontogenetic development), developmental levels of their abilities ("sensitive periods" of particular abilities) and their genetic potential (endogenous factors). As such, they contributed significantly to the desired harmonious morphological and motor development of boys and girls, the fourth-graders from the Rijeka County schools. The findings also confirmed that it is justified to keep all three variables of the general strength/power (explosive strength (power), muscular endurance of a dynamic type, isometric muscular endurance) in the battery of assessment tests, because they demonstrated statistically significant correlations with almost all the applied morphological and motor variables.

The obtained results can be applied in the sport practice as well, especially when designing economical and sensible procedures for sport orientation and selection, in planning training programmes, and in development and control (assessment) of relevant motor abilities, particularly in power sports. It is well known that in power sports athletes should simultaneously develop the correlated anthropological characteristics as well. The analogy holds true for other sports as well – strength and power should be developed in accordance with otherwise predominant motor abilities.

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