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# Integration of Coordination into the Morphological-Motor System in Male Children Aged 7–11 Years

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

*The study objective was to analyze the integration of psychomotor coordination into other dimensions evaluated. Four morphologic variables (stature, body mass, forearm circumference and triceps skinfold) and 7 motor variables (hand tapping, standing jump, sit-ups, forward bow, bent arm hang, 3-min run and polygon backward) were assessed in a sample of 2205 male children (subdivided into 4 groups) aged 7–11 years, elementary school first- to fourth-graders from the Primorje – Gorski Kotar County, Republic of Croatia. Relations between the set of morphologic-motor variables and the coordination variable (of backward polygon) as a criterion were analyzed Data were processed by use of regression analysis. Study results clearly indicated the values of the criterion variable (coordination) to rise and the criterion prediction using the set of variables to improve with age. Explosive strength, movement frequency and static strength were the best positive criterion predictors, whereas body weight at age 7–10, and skeletal longitudinality and subcutaneous adipose tissue at age 10–11 were the best negative criterion predictors. Also, developmental characteristics of coordination were found to be a major determinant on programming the work in kinesiologic education of elementary school children.*

***Key words:*** *boys, morphologic-motor status, motor coordination, relations*

## Introduction

The theory of integrated development points out that all human abilities and characteristics in the process of development are inter-related. This has been scientifically demonstrated, especially in the studies of relations among particular dimensions of the psychosomatic status[1,2].

Thorough understanding of developmental patterns is required for efficient actions to provide quality support to the development of biomotor characteristics of a child. Therefore, a specially programmed kinesiologic education compared with standard kinesiologic education results in significantly better effects on the development of almost all relevant motor abilities as well as on aerobic endurance and strength and flexibility factors in particular[3,4]. These are accompanied by adipose tissue reduction and muscle mass increase, with moderate skeleton development[5,6].

The ability of performing complex movement, known as psychomotor coordination, is one of the substantial determinants of the development of the body as a whole. Although coordination is to a considerable extent a congenital ability, its development is being reproduced over a longer period of life, mostly at age 7–9, as previously described[7]. The reason for the development of coordination to terminate later than the development of most other motor abilities lies in the fact that coordination is the most complex motor ability that is being saturated through its relations with all others. This means that, for example, the abilities of speed, strength, flexibility and endurance have to develop to a certain degree to be gradually integrated into the ability of performing the most complex movements, i.e. coordination. However, the development of coordination also requires a minimum of persistent morphologic system characteristics, e.g., development of the skeleton, ligaments and musculature, which ultimately leads to the integration of coordination into the morphologic system of the anthropologic framework. Thus, the two processes take place in parallel and/or alternately, i.e. the process of coordination integration into the motor system and the process of motor system integration into the morphologic system. The role of school as an institution in these pro-

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cesses is to provide, through appropriate general and differential programs of kinesiologic education, an active support to the development of morphologic-motor and functional systems as an integral segment of the child's body as a whole[7–9].

The nature of coordination is complex and depends on a number of cortical and subcortical centers, whereby lower centers regulate elementary actions, e.g., well measured movement in a motor structure, how to include and exclude particular muscle groups, etc., whereas higher centers will integrate, coordinate and regulate the work of lower centers. Ismail and Gruber[1] found coordination to significantly correlate with intelligence and school test results. Ismail and El-Naggar[10] point to the presence of successive and simultaneous processes, including both cerebral hemispheres, on performing motor coordination tasks. The evidence for the left or right cerebral hemisphere predominance mostly derive from patients with brain diseases and lesions[11], and it is quite difficult to find a reasonable explanation for this observation. However, Ruben et al.[12] found the white and grey matter to be more abundant in the right and left hemisphere, respectively. They also believe that verbal analytical functions are supported by an organization implying a process or transfer within the hemispheric regions, whereas spatial functions are supported by an organization implying transregional transfer. Thus, psychomotor coordination is to a considerable extent saturated by cognitive factors, whereas operationally it can simply be defined as the ability to integrate different movements into a unique structure.

Development of coordination is a complex process and the basic task of kinesiologic education in elementary school. Because of its complexity, coordination cannot be explained simply as a sum of particular less complex motor abilities, but by suprasummation relationships of all relevant anthropologic characteristics with which the psychomotor coordination is tightly associated during the process of development.

Therefore, the objective of this study was to assess the effects of growth and development on the relations of morphologic characteristics and motor abilities with coordination in elementary school first- to fourth-graders. In this way, changes in the structure of coordination in the area of morphologic-motor variables according to age were analyzed. Results of the study may influence the planning and reprogramming of the procedures, methods and contents of the activities in kinesiologic education intended for elementary school children.

## Subjects and Methods

*Sample*

The study sample included 2,205 male first- to fourth-graders aged 7–11 years from elementary schools in the Primorje – Gorski Kotar County, Republic of Croatia. The sample was subdivided into four groups as follows: first graders (N=566), second-graders (N=560), third-graders (N=651) and fourth-graders (N=518). All children were free from apparent aberrations and able to follow the standard program of elementary school activities.

*Measurements*

A standard battery of 11 variables currently used in the educational system of the Republic of Croatia were employed to assess the morphologic, motor and functional status of the children. Based on this test battery, a set of 10 predictor variables was formed, including 4 variables for the assessment of morphologic factors (skeleton longitudinality, body mass and volume, and adipose tissue) and 6 variables for the assessment of basic motor abilities (strength factors, speed, endurance and flexibility), and one criterion variable for the assessment of psychomotor coordination.

The morphologic variables included stature (mm), body mass (kg), forearm circumference (mm) and triceps skinfold (1/10 mm). The measures were taken according to the international biological program[13].

The motor variables included:

- hand tapping (taps/min) to estimate psychomotor speed (the task was to touch, within 15 s, both panels on the tapping board alternately by finger as quickly as possible, the result being the number of cycles, where each cycle represented touching of both round panels),
- standing jump (cm) to estimate the explosive strength of the jump type (the task was to jump from the spot forward as far as possible, the result being recorded in cm),
- sit-ups (per min) to estimate the repetitive strength of the body (the task was to make as many lifts of the body as possible from the supine position with legs at 90°),
- forward bow (cm) to estimate flexibility (from the sitting position on the floor, where the legs were extended at angle of 45°, the subject had to lean forward as deep as possible, so that the tips of the fingers of the clasped hands glided along a meter on the floor, the result being the distance from the original touch, i.e. from zero to the ultimate touch recorded in centimeters),
- bent arm hang (s) to estimate the static strength of the arms (the task was to endure as long as possible hanging by arms with the chin above the bar, the result being recorded in s), and
- 3-minute run (m) to estimate aerobic endurance (the task was to run as far as possible in 3 min, the result being recorded in m).

The criterion variable was the result obtained on coordination test:

- polygon backward (s) to estimate coordination in resolving a complex motor task (the task was to cover a 10-m distance at the »go« signal by walking backward on all fours, passing across a low box and through the frame of the box, the results being recorded in tenths of a second).

*Statistics*

On data analysis, metric characteristics, basic statistical parameters and multivariate methods were used. Data related to standard linear regression analysis using the least square model were employed. This method of analysis allows for the relationships between the parameters of morphologic and motor factor assessment as predictors and the parameter of coordination assessment as a criterion to determine.

The basic variable parameters (X±SD), partial regression coefficients (β), coefficient of the predictor correlation with the criterion, i.e. multiple correlation (ρ), and significance of regression coefficients and multiple correlation according to groups are presented in tables. Pooled results of four regression analyses are shown.

Although the study was carried out in transverse samples, the results could also be interpreted through parameter changes as a function of time, primarily because the samples were representative of the respective population and included a large number of subjects.

## Results

The basic parameters of the morphologic measures and motor tests are presented in Table 1. Of morphologic measures, body height showed a steady increase from first to fourth grade, being more pronounced between second and third grade, when it was about 6 cm. The rise in body height was paralleled by the increase in body mass and volume, and to a lesser extent in adipose tissue.

The male first- to fourth-graders showed a continuous development of all factors of strength and aerobic endurance as well as of psychomotor speed, whereas intensified development of coordination and flexibility was recorded from first to third grade, showing a declining tendency thereafter. Of motor abilities, the greatest relative changes occurred in static and repetitive strength, psychomotor speed, explosive strength, coordination, aerobic endurance and flexibility.

Regression analysis yielded significance at a level of 0.001 (Table 2), indicating the set of variables employed to be a valid predictor of psychomotor coordination in male children aged 7–11. Therefore, psychomotor coordination cannot be observed apart from other biomotor abilities and characteristics. The more so, this implies that the procedures intended for the development of coordination should be widely included in the kinesiologic education of male children, thus to ensure a complete and integral action on the development of the children's relevant abilities and characteristics.

Multiple correlations were on an increase from first to third grade, pointing to intensified processes of the psychomotor coordination integration into the system of other biomotor dimensions at this age. In fourth-graders, these processes were observed to stagnate, probably because the children's physical activity was inadequate to support their further complete biomotor development.

Characteristic integration of coordination into the morphologic system was recorded in all study children. In first-graders, excessive mean body weight had an unfavorable effect, and muscle mass a favorable effect on the criterion, whereas in fourth-graders excessive body height and adipose tissue were the factors interfering with the performance of complex movement structures.

In the motor area, tests for assessment of strength, especially explosive strength and to a lesser extent repetitive strength, hand tapping test for assessment of psychomotor speed assessment, and flexibility were reg-

**TABLE 1**
STATISTICAL PARAMETERS OF MORPHOLOGIC AND MOTOR VARIABLES FOR ELEMENTARY SCHOOL FIRST- TO FOURTH-GRADE BOYS

| Variable | 1. grade (N=566) | 2. grade (N=560) | 3. grade (N=561) | 4. grade (N=518) |
|---|---|---|---|---|
| | X±SD | X±SD | X±SD | X±SD |
| Stature (cm) | 128.82±6.36 | 133.51±6.47 | 139.72±6.21 | 144.38±8.99 |
| Body mass (kg) | 27.94±5.24 | 31.30±6.45 | 35.53±7.50 | 38.82±8.16 |
| Forearm circumference (cm) | 19.01±1.75 | 19.48±1.96 | 20.24±1.95 | 20.77±2.50 |
| Triceps skinfold (mm) | 10.30±3.92 | 9.78±3.59 | 10.36±4.57 | 10.60±3.91 |
| Hand tapping (f) | 17.89±3.40 | 21.45±3.85 | 22.92±4.53 | 24.78±3.94 |
| Standing jump (cm) | 118.50±20.9 | 130.65±20.6 | 142.50±21.4 | 151.55±23.1 |
| Sit-ups (per min) | 22.83±6.38 | 29.10±7.50 | 31.04±8.11 | 33.12±7.69 |
| Forward bow (cm) | 36.69±8.41 | 39.46±8.29 | 44.64±11.6 | 44.91±11.4 |
| Bent arm hang (s) | 16.70±16.7 | 21.01±14.0 | 26.33±21.3 | 28.95±20.2 |
| 3-min run (m) | 467.29±79.8 | 507.34±78.9 | 545.99±92.2 | 583.8±105.0 |
| Polygon backward (s)# | 22.73±6.25 | 20.05±6.40 | 18.27±6.41 | 17.86±4.81 |

#variable with the opposite metric orientation

**TABLE 2**
REGRESSION COEFFICIENTS (β) AND MULTIPLE CORRELATION (ρ) OF POLYGON BACKWARD VARIABLE IN MORPHOLOGIC-MOTOR AREA FOR ELEMENTARY SCHOOL FIRST- TO FOURTH-GRADE BOYS

| Variable | 1. grade (N=566) | 2. grade (N=560) | 3. grade (N=561) | 4. grade (N=518) |
|---|---|---|---|---|
| | β | β | β | β |
| Stature (cm) | –0.04 | 0.05 | –0.02 | 0.22*** |
| Body mass (kg) | 0.28*** | 0.15** | 0.23** | –0.03 |
| Forearm circumference (cm) | –0.18** | 0.02 | 0.10 | 0.03 |
| Triceps skinfold (mm) | 0.02 | 0.11** | –0.07 | 0.15** |
| Hand tapping (f) | –0.10* | –0.26*** | –0.10** | –0.06 |
| Standing jump (cm) | –0.19*** | –0.26*** | –0.27*** | –0.07 |
| Sit-ups (per min) | –0.11* | –0.16*** | –0.19*** | –0.13** |
| Forward bow (cm) | –0.13** | –0.09** | –0.12*** | 0.01 |
| Bent arm hang (s) | –0.03 | –0.02 | –0.09* | –0.18*** |
| 3-min run (m) | –0.04 | 0.09* | –0.03 | –0.11* |
| ρ | 0.40 | 0.57*** | 0.66*** | 0.48*** |

*p<0.05, **p<0.01, ***p<0.001

ularly recorded as good positive criterion predictors from first to fourth grade. In fourth grade, static strength of relative type and/or muscular endurance were the best positive predictors. The impact of repetitive and explosive strength on the criterion increased from first to third grade, whereas in case of psychomotor speed this impact rose from first to second grade, to decline thereafter.

Accordingly, from the first to third grade, psychomotor coordination was found to be predominantly determined by movement energy regulation, this to a considerably greater extent by the intensity of energy mobilization than by its duration. Thus, the development of coordination is accompanied by the continuous development of explosive, repetitive and static strength, and of psychomotor speed in terms of movement frequency on the one hand and formation of optimal morphologic structure for the performance of complex movement structures on the other hand.

## Discussion

The process of integration of the anthropologic status subsegments into a harmonious unit proceeds through a number of developmental stages. The structure of coordination also undergoes modifications in parallel with the development of particular morphologic characteristics and motor abilities.

In first-grade boys, explosive strength utilization predominates in performing complex motor tasks (coordination), whereas flexibility, repetitive strength and psychomotor speed are used to a lesser extent, whereby an under-average total body mass and above-average mean muscle mass favor the performance of complex movements.

In second-grade boys, a significant parallel development of all strength factors, psychomotor strength and coordination occurs, which is manifested by their high mutual determination. Now, explosive strength and psychomotor speed as well as repetitive speed and to a lesser extent flexibility are predominantly and equally used in performing complex motor tasks, while the rate of movement performance is reduced by the increased use of aerobic endurance.

In third-graders, further development of the repetitive and static strength modifies the criterion structure, thus the abilities of explosive and repetitive strength being much more used, along with flexibility and static strength, than psychomotor speed in performing complex motor tasks. In third-grade boys, the repetitive strength of the trunk is highly influenced by the movement frequency, i.e. there is an integration of the strength and speed.

To put it simply, two mechanisms and/or types of regulation, i.e. those for the regulation of strength and of speed, are responsible for coordination. It is evident that the regulation of excitation intensity, i.e. explosive strength relative to psychomotor speed, has a considerably greater impact on the achievement of coordination in elementary school first- to third-graders.

Once a satisfactory level of psychomotor speed has been achieved, its further development will have no major impact on coordination improvement, however, this effect will now be predominantly elicited by explosive and repetitive strength in third-graders, and by static and repetitive strength in fourth-graders.

In fourth-grade boys, significant integration of coordination into the morphologic system occurs, with body height and adipose tissue exerting an unfavorable effect on the criterion. Concerning these morphologic characteristics, these boys will now predominantly use static

strength, then repetitive strength and aerobic endurance on performing complex motor tasks. In this way, performance of the backward polygon test is being switched from a higher to a lower level of central nervous system regulation, whereby all those abilities used as the basic ones in the previous stages of development are being partially integrated through muscular endurance, repetitive strength and aerobic endurance.

The information on the structure and development of coordination obtained in the study are of paramount importance for the correct programming of kinesiologic education of elementary school first- to fourth-graders. If coordination is defined as the ability to solve complex motor tasks, as already done in this study, then it is at the same time the ability that predominantly determines motor functioning. Thus, the activities focused on the development of this ability gain additional importance, especially at this particular age. The sequence of inclusion and exclusion of particular predictor variables in criterion prediction will be dictated by the choice of transformation procedures directed primarily to those anthropologic features which significantly determine the development of coordination at a particular stage of development, and secondarily to the maintenance of the achieved level of development of those anthropologic characteristics which were fundamental for the development of coordination in the previous stage.

Kinesiology operators should be primarily used to influence the development of minimal persistence of morphologic characteristics in terms of muscular mass increase, joint reinforcement and joint mobility increase, and influencing the explosive strength, flexibility, repetitive strength and psychomotor speed. Repetitive and static strength as well aerobic endurance should be influenced upon in parallel and then to a greater extent once a satisfactory level of the morphologic characteristics and motor abilities has been achieved. All this should be set to a minimal level for the complex movements to be best performed in terms of information and energy involved. The possibilities of influencing individual motor abilities are limited by their developmental curves, which are evident in the study results presented. The development of coordination, i.e. the ability to solve complex motor tasks, is especially intensive at the age of 7 to 9 years. Coordination is a basis for the manifestation of other motor abilities, especially psychomotor speed and explosive strength, the intensive development of which is also completed by this age. This points to the need of designing and conducting high-quality programs of kinesiologic education, which will completely and simultaneously influence the development of speed, explosive strength and coordination, along with other basic motor abilities in elementary school first- to fourth-graders.

An appropriate morphologic-motor structure is necessary for the tasks of coordination to successfully accomplish. Regression coefficients clearly show which morphologic characteristics and motor abilities bear major burden on performing the tasks of coordination in a particular age group. A movement should be properly measured, i.e. of appropriate strength, speed, amplitude and muscle tone (contraction – relaxation) to be efficient in terms of motor routine. That is why the interactive effects of coordination primarily refer to particular motor manifestations in terms of their facilitated performance, and vice versa the effects of these motor manifestations to the performance of coordination tasks. Therefore, kinesiologic education should focus on influencing the morphologic-motor structure, in other words, on qualitative changes in the morphologic-motor functioning in children.

The information obtained in the study could find application in the process of learning particular motor skills (programs) belonging to a specific kinesiologic activity (sport). The basic motor abilities and skills have a crucial role in the early phases of the motor learning process[14]. There are various theories on what is of relevance in designing a motor program[15,16]. Task duration and structure definitely are the characteristics that influence the motor program design. When a child is being acquiring a motor program (motor knowledge or skill), he/she starts doing it at a cortical level. Through mastering the program, the process will proceed at a subcortical level[1,17,18]. This imposes the need of concrete research into the biomotor structure of the relevant motor knowledge-programs for particular kinesiologic activities and of identifying the process of their formation[19,20].

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## INTEGRACIJA KOORDINACIJE U MORFOLOŠKO-MOTORIČKI SUSTAV KOD DJEČAKA OD 7–11 GODINE

### S A Ž E T A K

Svrha rada bila je analiza integracije psihomotorne koordinacije u ostale procijenjene dimenzije. Na ukupnom uzorku od 2205 djece muškog spola (sastavljenog od 4 subuzorka), polaznika prvog do četvrtog razreda osnovnih škola Primorsko-goranske Županije Republike Hrvatske, starosne dobi 7–11 godina, primjenjene su 4 morfološke i 7 motoričkih varijabli. Za svaki razred analizirane su relacije skupa morfološko-motoričkih varijabli s koordinacijskom varijablom-poligon natraške kao kriterijem. Podaci su obrađeni regresijskom analizom. Rezultati su jasno pokazali kako ovisno o starosnoj dobi rastu vrijednosti kriterijske varijable i kako je predikcija kriterija primijenjenim skupom varijabli sve bolja. Najbolji prediktori kriterija su eksplozivna snaga, frekvencija pokreta, repetitivna i statička snaga u pozitivnom smislu, a težina tijela od 7–10 godine i longitudinalnost skeleta i potkožno masno tkivo od 10. do 11. godine u negativnom smislu. Istaknuto je, da su utvrđene razvojne karakteristike koordinacije bitna odrednica programiranja rada u kineziološkoj edukaciji učenika osnovne škole.