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A possible relationship between school performance and motor skills: a neural network approach

Uma possível relação entre desempenho escolar e habilidades motoras: uma abordagem de rede neural

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Abstract – The aim of this study was to answer the question whether a relationship exists between school grades reflecting humanistic, synthesis, ecological, and physical skills and motor skills (speed and power) in middle school adolescents. The following tests were used for the evaluation of the particular motor skills: plate tapping test for the measurement of upper limb speed, Fleishman test for the measurement of lower limb speed, medicine ball throwing for the evaluation of upper limb power, and standing broad jump for lower limb power testing. The data were analyzed using a neural network approach. The results indicated that the school grades of middle school adolescents can be used to predict motor power. In this case, the linear correlation coefficient (*r*) between the actual and predicted data exceeded the level of $r = 0.9$. In particular, a strong statistical impact of ecological, synthesis and physical skills on power performance was established. In contrast, a weaker correlation was observed with motor speed performance ($r < 0.6$). More attention should be paid to the possible relationship between school grades and motor skills in children and adolescents. This information is important, particularly for the selection of youngsters with advanced motor skills at an early age.

Key words: Adolescent; Educational score; Psychomotor performance; Neural networks.

Resumo – *O objetivo deste estudo foi pesquisar uma resposta à questão se existe uma relação entre as notas escolares que refletem as habilidades humanística, síntese, ecológica e habilidades físicas, e melhores competências em termos de velocidade motora e de potência, em alunos do ensino médio. A testagem das habilidades específicas envolveram: teste de toque na placa para a medição da velocidade de membros superiores e teste de Fleishman para medir a velocidade dos membros inferiores. A medida da potência dos membros superiores foi feita por meio do lançamento da medicine ball e, a potência de membros inferiores por meio do teste de impulsão horizontal. Os resultados foram analisados utilizando a rede neural. Com base nos resultados obtidos foi indicado que as notas escolares em adolescentes do ensino médio podem ser usadas para estimar a potência motora. Neste caso, o coeficiente de correlação linear (r) entre os dados reais e os estimados excedeu o nível de r = 0,9. Em especial, foi estabelecido forte impacto estatístico entre os resultados em áreas ecológica, síntese e habilidades físicas. Paralelamente, os resultados de velocidade motora não indicaram forte correlação desse tipo (r <0,6). Sugere-se que maior atenção deve ser dada para as possíveis relações entre desempenho escolar e habilidades motoras em crianças e adolescentes. Essa informação é importante, particularmente na seleção de jovens com habilidades motoras avançadas em idade precoce.*

Palavras-chave: *Adolescente; Desempenho psicomotor; Escolaridade; Redes neurais.*

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INTRODUCTION

School performance and physical activity are independent determinants of a child's health. A positive association between physical activity and cognitive health in younger subjects has been well documented. A recent systematic review[1] investigated the relationship between academic achievement and involvement in physical education, physical activity and sport programs, which provides a broad list of studies documenting this relationship. Recent research results, echoed in the media, also suggest that such activity may have a positive impact on learning and memory in older subjects. For example, it is now fairly well recognized that exercise has beneficial effects on the brain and cognition, i.e. physical activity is associated with the maintenance of cognitive function in adults[2] and offers some protection against Alzheimer's disease[3].

Despite a large number of publications investigating the possible influence of physical activity on learning performance, a short review of subjects stored in leading education, behavioral and physical activity journals testifies much less scientific attention on the reverse relation, i.e., different determinants (including school education) and their effects on physical activity. Particularly the question of a possible influence of diet/nutrition, parents or socioeconomic environment on physical activity has been taken into account as explanatory variables[4-7].

With respect to the influence of school performance on motor skills among children, according to Klasen[8], a large number of children with learning difficulties also present problems with physical movement. Moreover, Kourtessis et al.[9] provided a brief review of various studies similar to the study of Klasen[8], which indicated that a high percentage of the children who were claimed to have learning problems also had motor difficulties. Equally important is the study of O'Hare and Khalid [10], in which the authors suggested that most children with motor difficulties also have problems with writing and reading.

Despite the large number of studies designed to investigate different factors that influence or are important for motor skills in children, few of them have evaluated the relationship between school performance and physical movement. Therefore, the main objective of the present study was to establish a possible relationship between school grades and selected motor skills in middle school adolescents. For this purpose, a brand-new computational technique was adopted, the artificial neural network approach. This approach is an unconventional statistical method not typically used in this type of research, which is based on classical tests such as *t*-test, chi-square test, Pearson's or Spearman's correlation, and more advanced analysis of variance (ANOVA/MANOVA) and logistic regression. We proposed cybernetic optics in psychomotricity studies giving a new light and inference possibilities on the questions considered. Since the description of the statistical tool chosen is not within the objective of this study, we only provide the required brief information about the computational methodology and encourage the reader to consult the source reference.

METHODOLOGICAL PROCEDURES

Participants

The participants were 147 middle school adolescents (78 first-grade and 69 second-grade students; 73 boys and 74 girls aged 16 and 17 years, respectively). Final school grades after the second semester of core classes, i.e., native language (Polish), mathematics, biology, and physical education, were taken into account according to their representation of humanistic, synthesis, ecological, and physical skills. The parents gave permission for their children to participate in the physical activities, which were necessary to test the objectives of the study. The study was approved by the Bioethics Committee of Opole (Permit No. 151/13.12.2007).

Procedure

Motor skills were assessed in two test blocks:

- Speed was assessed by two methods: plate tapping and the Fleishman test. The first is used to measure upper limb movement speed and coordination. In this test, two yellow discs are placed on a table with their centers 60 cm apart and a rectangle is placed equidistant between the two discs. The non-preferred hand is placed on the rectangle and the participant moves the preferred hand back and forth between the discs over the hand in the middle as quickly as possible[11]. The Fleishman test is a balance test that is performed in the sitting position on a chair. The participant raises his/her leg and transfers it from one side of the T bar to the other over an obstacle that rises above the board[11].
- Power was evaluated by medicine ball throwing and the standing broad jump test. Medicine ball throwing is a straight arm standing throw that uses both arms in a javelin style. One foot is placed 50 cm behind the other, the ball is taken back, with the hands holding the ball high, the

shoulders are stretched, and the chest is stretched out[11]. Standing broad jump is a distance test. The participant stands at the edge of a sandpit and then leaps forward as far as possible. The distance jumped is measured from the edge of the sandpit to the nearest point of contact in the sandpit[11].

All physical exercises in the two blocks were completed simultaneously.

Instrument

A neural network (NN) analysis was conducted based on the classification model[11]. The final school grades in the selected core classes were assumed to be the explanatory variables (inputs), whereas the categorical motor skills data (separately for the speed and power tests) were used as the response (target) variable. The main idea of NN regression was to predict the response variables based on a set of assumed explanatory variables.

The simulation run consisted of 500 iterations to achieve the equilibrium distribution. For prediction, the first 100 iterations were rejected as the so-called burn-in steps. The NN learning process was monitored based on control parameters, the so-called rejection rate, together with several numerical and graphical so-called hyperparameters found within the software[12].

RESULTS

No satisfactory results were obtained when modeling motor speed skills based on final grades in the core classes. Although highly exceptional control parameters were obtained during the NN learning process, the linear correlation coefficient *r* between observed and expected outcomes did not exceed the level of 0.6. The distribution of the ordered motor speed skills (actual and predicted) in school adolescents is shown in Figure 1.

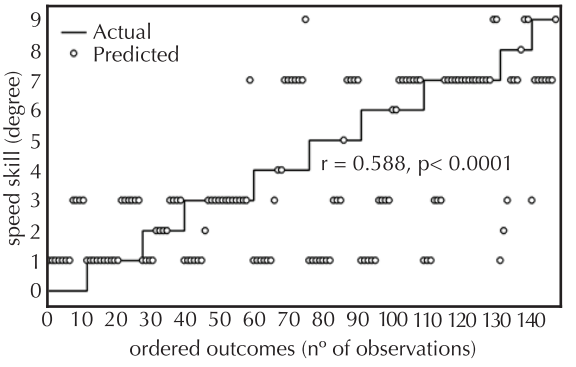

Figure 1. Motor speed skills (actual and predicted data).

A similar number of adolescents in each step of the speed skills can be seen in the plot of Figure 1. The most predictable degrees are 1, 3, and 7, whereas the other predictions are fairly dispersed. Therefore, motor speed skills was excluded from further analysis. Surprisingly, school grades of middle school adolescents were better predictors of motor power skills ($r > 0.9$) (for details, see Figure 2).

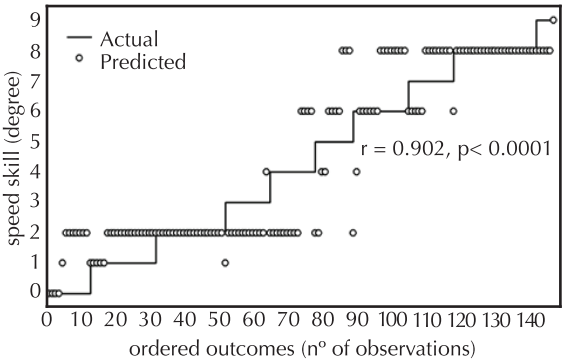

Figure 2. Motor power skills (actual and predicted data).

The *r* estimate and the plot shown in Figure 2 provide evidence that power skills can be anticipated by the observed school grades obtained in the core classes.

The simulated predictions based on the NN model of power performance are graphically illustrated in Figures 3 and 4. The simulations of power performance in first-grade and second-grade students are shown in Figure 3.

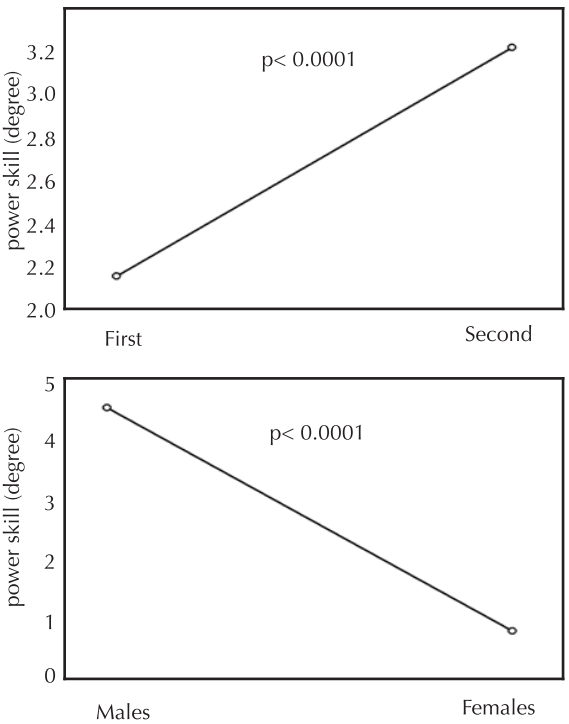

Figure 3. Power performance in middle school adolescents obtained for 1st and 2nd grade students (top panel) and boys and girls (bottom panel) (predicted data).

The results shown in Figure 3 indicate that power was about 10% higher in older adolescents

than in younger ones, with a statistically significant difference between groups. In addition, as can be seen in the plot girls were physically weaker (approximately one-third) than boys. The difference between genders was statistically significant and the predicted means are fairly distant (see Figure 3).

As can be seen in Figure 4, power performance did not vary significantly across school grades (according to Poland's education system: from 1 = worst grade to 6 = best grade) (for details, see the plot in Figure 4 and the *p*-value estimate). Therefore, the native language reflecting humanistic skills did not affect motor power skills in adolescents.

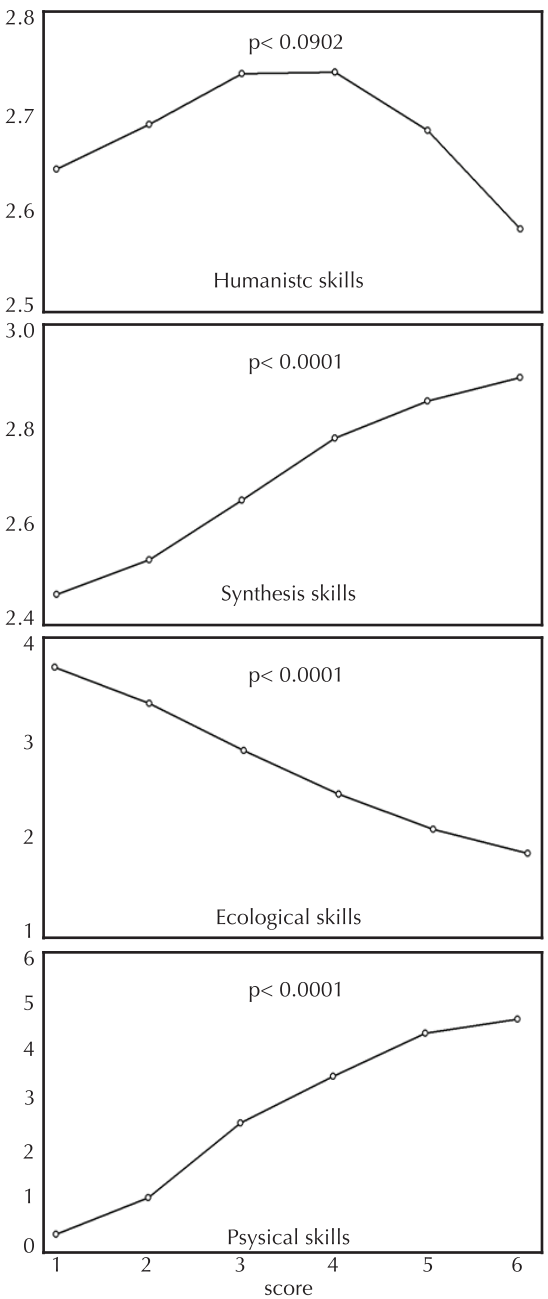

Figure 4. Power performance versus skills in middle school adolescents (predicted data).

However, synthesis skills in adolescents are more likely to have an influence on power performance (the predicted trend is positive, i.e., the higher the school grade in synthesis disciplines, the higher the power performance). Although the differences between means were statistically significant, they did not change rapidly. An opposite trend was observed for the ecological skills of adolescents. The model indicates more drastic changes, i.e., adolescents with the lowest ecological score present an approximately twice as high power as adolescents with the highest score. The model shown in Figure 4 also indicates a marked increase of power performance in adolescents with the highest physical education scores. Skills ranges from nearly 0 to almost 50% across the physical education scale axis and it is also strongly statistically significant (see Figure 4, *p*-value estimates).

DISCUSSION

Schools have been recognized as a key societal institution to promote physical activity in adolescents. However, effective changes in physical activity behavior require the identification of causal relationships. Usually, behavioral hypotheses are based on dietary, economic or ecological models that explain nutritional[13], socioeconomic[14], and environmental characteristics[15], factors that can influence physical activity. However, regular motor activity during childhood and adolescence is associated with improvement in numerous physiological and psychological variables[16,17].

To reduce this negative influence of schools, in the present study we propose a possible interrelation between school grades and physical performance. In addition to the influence of age and gender of the adolescents, a strong statistical impact of core educational skills (i.e., synthesis, ecological, and physical skills represented by mathematics, biology and physical education, respectively) on power performance (assessed by medicine ball throwing and standing broad jump) was observed. The NN model developed here did not reveal a significant role of the native language (humanistic skills) in the motor activity analyzed. Furthermore, motor speed skills were not represented sufficiently by the educational skills analyzed. Furthermore, motor speed performance was not associated with the educational skills. Since the present results are not easily interpreted, they provoke a discussion about the actual association between education and physical activity (cause-effect relationship) and require scientific verification or constructive criticism.

CONCLUSIONS

The present results obtained with the advanced statistical tool developed here suggest a strong interference of the brain (school grades) on the selected types of motor skills. In particular, potential statistical relationships with ecological, concise and physical skills were established. In contrast, the results obtained for motor speed skills did not indicate such strong correlation. More attention should be paid to the possible impact of school grades on motor skills in children and adolescents. The NN approach seems to be a useful and irreplaceable statistical tool for data prediction studies.

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