

MOTOR SKILLS DEVELOPMENT: OPTIMIZATION OF TEACHING BOYS AGED 14

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Abstract

The study objective is to substantiate the modes of alternation of physical exercises and rest intervals in the process of teaching series of tasks aimed at motor skills development in boys aged 14 years.

Materials and methods. The participants in the study were 40 boys aged 14. The children and their parents were fully informed about all the features of the study and gave their consent to participate in the experiment. To achieve the objective set, the following research methods were used: study and analysis of scientific and methodological literature; pedagogical observation, timing of training tasks; pedagogical experiment, methods of mathematical statistics, methods of mathematical experiment planning.

Results. The results of the analysis of variance and regression models show that the optimal mode of performing series of training tasks is within the range of 6-12 exercise repetitions with rest intervals of 60-120 seconds. In the proposed matrix of factorial design, the selected step of factor variation is sufficient to study the impact of different modes of physical exercises on the effectiveness of teaching children and adolescents.

Conclusions. A 2² type experiment made it possible to examine the multifactorial structure of the process of teaching boys aged 14, using the program of algorithmic instructions, to specify the optimal balance between factors for their use when teaching physical exercises during physical education classes.

The best options for teaching series of tasks to boys aged 14 during physical education classes are: series 1 — 12 repetitions, rest interval of 120 s; series 2 — 12 repetitions, rest interval of 60 s; series 3 — 6 repetitions, rest interval of 60 s; series 4 — 12 repetitions, rest interval of 60 s; series 5 — 12 repetitions, rest interval of 120 s; series 6 — 6 repetitions, rest interval of 60 s.

Keywords: boys, motor skills, training tasks, modes of exercises, factorial experiment.

Introduction

Current studies focus on discovering regularities of motor skills development in children and adolescents (Wright, 1999; Khudolii & Ivashchenko, 2014; Ivashchenko, 2016) as a basis for professional excellence of physical education teachers (Rink, Jones, Kirby, Mitchell and Douthett, 2007).

The research papers by Chernenko (2015), Ivashchenko, Iermakov, Khudolii, Yermakova, Ciešlicka and Harkusha (2018), Ivashchenko (2017) ascertained that the effectiveness of motor skills development is influenced by the modes of alternation of exercise repetitions and rest intervals. According to Samuel, Zavdy, Levav, Reuveny, Katz and Dubnov-Raz (2017), Balaban

(2018), physical activity can both stimulate and negatively affect cognitive activity and motor skills development in children. Regression analysis performed on the basis of a full 2^k type factorial experiment data is an effective method for defining optimal modes of alternation of physical exercises and rest intervals during physical education classes (Ivashchenko, 2016).

In their papers, Khudolii & Ivashchenko (2014), Lopatiev, Ivashchenko, Khudolii, Pjanylo, Chernenko and Yermakova (2017) substantiated the concept of pedagogical experiment in studying the process of building motor skills and developing learning models. The researchers ascertained the effectiveness of factorial designs for studying the regularities of teaching children and adolescents. The papers by Acher, Arca and Sanmarti (2007), Chatzipanteli, Digelidis, Karatzoglidis and Dean (2016) point to the importance of modeling in

Table 1. Press headstand and handstand training program

Informative frame (what is performed)	Operational frame (how it is performed)	Control frame (proceed to training the next exercise)
First series of training tasks – exercises for developing motor abilities		
From stoop standing position, with the back against stall bars, proceed to arch hang	Performed by jumping off both feet, hold the position for 3-4 seconds	If the student performs the exercise correctly three times in a row, proceed to the next exercise
In prone position, bend arms and knees (5 times in 5-6 seconds)	Performed with maximum amplitude	If the student performs the exercise for 5-6 seconds, proceed to the next exercise
Second series of training tasks – starting and ending positions		
From squatting position, lean forward, put the head down on mat on the marking and evenly shift the body weight to the head and arms	Hold the position for 3-4 seconds	If the student performs the exercise correctly three times in a row, proceed to the next exercise
Third series of training tasks – actions without which the exercise performance is impossible		
From squatting position, return to starting position to perform a headstand and handstand. Straighten the legs, transition to a headstand and handstand with bent legs	Transition to headstand and handstand should be done by straightening the legs	If the student performs the exercise correctly three times in a row, proceed to the next exercise
Fourth series of training tasks – teaching to control movement time and muscular effort		
In kneeling position, bending and straightening of the arms (5 times)	Bend the arms simultaneously with straightening the legs. Perform in 5 seconds	If the student performs the exercise for 5-6 seconds, proceed to the next exercise
Bending and straightening of the arms in stoop standing position (5 times)	Plant the hands on the floor a step's length away from the toes. Perform in 5 seconds	If the student performs the exercise for 5-6 seconds, proceed to the next exercise
From normal standing position, lean forward, touch the floor with the palms and, walking slowly on the hands, adopt a prone position and return to starting position in the same way	Do not bend knees when performing the exercise. Perform in 6 seconds	If the student performs the exercise for 5-6 seconds, proceed to the next exercise
Fifth series of training tasks – separate parts of the target exercise and preliminary exercises		
From squatting position, return to starting position to perform a headstand and handstand. Straighten the legs, transition to a headstand and handstand with bent legs	Straighten the back and hold balance with bent legs for 3-4 seconds	If the student performs the exercise correctly three times in a row, proceed to the next exercise
Perform a headstand and handstand, back and legs against the wall, with assistance	Focus on the exercise technique	If the student performs the exercise correctly three times in a row, proceed to the next exercise
Sixth series of training tasks – performing the whole exercise		
Perform a headstand and handstand, back and legs against the wall, without assistance	Hold the headstand and handstand for 3-4 seconds	If the student performs the exercise correctly three times in a row, proceed to the next exercise
Headstand and handstand without assistance	Hold the headstand and handstand for 3-4 seconds	Correct performance of the series at the third attempt

children's cognitive activity. According to García-Moya, Moreno and Jiménez-Iglesias (2012), Wang, Karns, and Meredith (2003), the use of factorial designs in studies involving adolescents and children helps to obtain objective information about the dynamics of physical development. The validity of using a full 2^k type factorial experiment is confirmed by the data of Correa, Grima, and Tort-Martorell (2009, 2012), Kapkan, Khudolii and Bartik (2018, 2019).

An important element in building motor skills is pedagogical control of motor abilities development and the dynamics of proficiency level in physical exercises

(Khudolii, & Iermakov, 2011; Ivashchenko, 2016). Discriminant analysis is an effective method for assessing schoolchildren's state. It allows to classify schoolchildren by the level of motor skills development (Cantell, Smyth, & Ahonen, 2003; Donovan, Mercier, & Phillips, 2015), as well as to determine the informative value of a test battery for assessing the impact of physical training on the basic motor competences (Herrmann, Gerlach, & Seelig, 2016; Ivashchenko, 2016; Kapkan, Khudolii, & Bartik, 2018).

Thus, physical exercises modes in the process of acquisition of series of training tasks within programmed

learning remain underexplored. The problem of control over schoolchildren's learning process needs further research.

The study objective is to substantiate the modes of alternation of physical exercises and rest intervals in the process of teaching series of tasks aimed at motor skills development in boys aged 14 years.

Materials and methods

Study participants

The participants in the study were 40 boys aged 14. The children and their parents were fully informed about all the features of the study and gave their consent to participate in the experiment.

Study organization

To achieve the objective set, the following research methods were used: study and analysis of scientific and methodological literature; pedagogical observation, timing of training tasks; pedagogical experiment, methods of mathematical statistics, methods of mathematical experiment planning.

During the learning process, the study used a method of algorithmic instructions. The press headstand and handstand training program included training tasks given in Table 1. The student could proceed to the next exercise only after a correct performance of the previous exercise on three consecutive attempts. The number of repetitions needed to teach exercises in each series of training tasks was recorded. The level of proficiency in the physical exercises performance was determined by the alternative method: "performed" or "failed". A technically correct performance of the exercise gave the students "1" point; a failure to perform the exercise gave them "0" entered in the protocol.

To achieve the objective set, the study examined the effect of different variants of exercises, specifically: the number of repetitions (x_1) and rest intervals (x_2) on mastering a press headstand technique. The boys aged 14 were divided into four groups according to the experiment plan. The differences between the groups in the lesson plan resulted from the factorial experiment conditions presented in Table 2. The bottom and top levels of the factors were chosen based on the data provided by Khudolii and Ivashchenko (2014), Ivashchenko (2016), Chernenko (2015), and were limited to the lesson framework.

Statistical analysis

The paper used the methods of analyzing the results of mathematical experiment planning of a full 2^k type

Table 2. 2^2 type factorial design

Variants of exercises	Modes of training	
	Repetition number	Rest interval
1	6-	60-
2	12+	60-
3	6-	120+
4	12+	120+

factorial experiment (Khudolii & Ivashchenko, 2014; Ivashchenko, 2016). The study materials were processed by the IBM SPSS 20 statistical analysis software.

The study protocol was approved by the Ethical Committee of the University. In addition, the children and their parents or legal guardians were fully informed about all the features of the study, and a signed informed-consent document was obtained from all the parents.

Study results

Table 3 shows the results of analysis of a full 2^2 type factorial experiment.

The analysis of regression equations allowed us to conclude that:

- in the first series of training tasks, the most influential factor is the duration of rest interval (x_2), the second most influential factor is the relationship between the number of repetitions and rest intervals (x_1x_2), the third – the number of repetitions (x_1). To improve the effectiveness of training, it is necessary to increase the number of repetitions from 6 to 12 times and increase rest intervals (x_2) from 60 to 120 seconds.
- in the second series of training tasks, the most influential factor is the number of repetitions (x_1), the duration of rest interval (x_2) and the relationship between the number of repetitions and rest interval (x_1x_2) are far less influential. To improve the effectiveness of training, it is necessary to increase the number of repetitions from 6 to 12 times and reduce the rest interval from 120 to 60 seconds.
- in the third series of training tasks, the most influential factor is the duration of rest interval (x_2), the second most influential factor is the relationship between the number of repetitions and rest interval (x_1x_2), the third – the number of repetitions (x_1). To improve the effectiveness of training, it is necessary to reduce the number of repetitions from 12 to 6 times and reduce the rest interval from 120 to 60 seconds.
- in the fourth series of training tasks, the most influential factor is the duration of rest interval (x_2), the second most influential factor is the

Table 3. Results of analysis of a full 2² type factorial experiment. Boys aged 14

Series of training tasks	Regression equations	Percentage contribution to achievement of target indicator		
		x_1	x_2	x_1x_2
1	$Y = 6.925 + 1.475x_1 + 1.875x_2 + 1.725x_1x_2$	25	40	34
2	$Y = 9.075 + 2.225x_1$	93	3	2
3	$Y = 13.9 - 1.15x_2 - 1.05x_1x_2$	12	47	39
4	$Y = 13.6 + 0.85x_1 + 2.2x_2 - 1.15x_1x_2$	10	70	19
5	$Y = 9.35 + 1.55x_2 + 1.4x_1x_2$	2	53	44
6	$Y = 8.425 - 1.075x_1 - 2.775x_1x_2$	13	0	86

relationship between the number of repetitions and rest interval (x_1x_2), the third – the number of repetitions (x_1). To improve the effectiveness of training, it is necessary to increase the number of repetitions from 6 to 12 times and reduce the rest interval from 120 to 60 seconds.

- in the fifth series of training tasks, the most influential factor is the duration of rest interval (x_2), the relationship between the number of repetitions and rest interval (x_1x_2) and the number of repetitions (x_1) are less influential. To improve the effectiveness of training, it is necessary to increase the number of repetitions from 6 to 12 times and the rest interval (x_2) from 60 to 120 seconds.
- in the sixth series of training tasks, the most influential factor is the relationship between the number of repetitions and rest interval (x_1x_2), the second most influential factor is the number of repetitions (x_1). To improve the effectiveness of training, it is necessary to reduce the number of repetitions from 12 to 6 times and reduce the rest interval from 120 to 60 seconds.

The analysis of variance shows:

- in the first series of training tasks, the learning process is most influenced by the second factor (x_2), the percentage contribution is 40 %, as well as by the relationship between both factors (x_1x_2), the percentage contribution is 34 %, and the first factor (x_1), the percentage contribution is 25 %;
- in the second series of training tasks, the learning process is most influenced by the first factor (x_1), the percentage contribution is 93 %, the second factor (x_2), the percentage contribution is 3 %, and the relationship between both factors (x_1x_2), the percentage contribution is 2 %;
- in the third series of training tasks, the learning process is most influenced by the second factor (x_2), the percentage contribution is 47 %, as well as by the relationship between both

factors (x_1x_2), the percentage contribution is 39 %, and the first factor (x_1), the percentage contribution is 12 %;

- in the fourth series of training tasks, the learning process is most influenced by the second factor (x_2), the percentage contribution is 70 %, as well as by the relationship between both factors (x_1x_2), the percentage contribution is 19 %, and the first factor (x_1), the percentage contribution is 10 %;
- in the fifth series of training tasks, the learning process is most influenced by the second factor (x_2), the percentage contribution is 53 %, as well as by the relationship between both factors (x_1x_2), the percentage contribution is 44 %, the first factor (x_1), the percentage contribution is 20 %;
- in the sixth series of training tasks, the learning process is most influenced by the relationship between both factors (x_1x_2), the percentage contribution is 86 %, the first factor (x_1), the percentage contribution is 13 %.

Consequently, the best options for teaching series of tasks to boys aged 14 are:

- series 1 — 12 repetitions, rest interval of 120 s;
- series 2 — 12 repetitions, rest interval of 60 s;
- series 3 — 6 repetitions, rest interval of 60 s;
- series 4 — 12 repetitions, rest interval of 60 s;
- series 5 — 12 repetitions, rest interval of 120 s;
- series 6 — 6 repetitions, rest interval of 60 s.

Discussion

The study assumed that the effectiveness of acquisition of series of training tasks depends on the mode of alternation of exercises and rest intervals. The results of the analysis of variance and regression models show that the optimal mode of performing series of training tasks is within the range of 6-12 exercise repetitions with rest intervals of 60-120 seconds. In the proposed matrix of factorial design, the selected step of factor

variation is sufficient to study the impact of different modes of physical exercises on the effectiveness of teaching children and adolescents (Table 2).

The findings enhance and supplement the data obtained by Khudolii, and Ivashchenko (2014), Ivashchenko (2016) on the effectiveness of using factorial designs when studying children's and adolescents' learning process and motor abilities development; Kapkan's (2015) data on the possibility of improving the effectiveness of the learning process based on the analysis of regression models and calculation of modes of alternation of physical exercises and rest intervals in the process of motor skills development in schoolchildren aged 14-15 during physical education classes. The findings confirm Ivashchenko's (2016) data showing that a full factorial experiment method makes it possible to mathematically describe the process in some local area of the factorial space around the point with the coordinates of the n -dimensional space and to verify the regression model; allows to evaluate the effectiveness and reliability of a 2^2 type factorial design in determining the effects of different modes of training on the change in children's functional state and ability to learn movements.

According to García-Moya, Moreno, and Jiménez-Iglesias (2012), Wang, Karns, and Meredith (2003), the use of factorial designs in studies involving adolescents and children increases the objectivity of evaluation of their development indicators. The effectiveness of using a full 2^k type factorial experiment, the objectivity of data obtained through factorial designs are confirmed by the data of Correa et al. (2009, 2012), Ivashchenko, Khudolii, Iermakov, Chernenko, and Honcharenko (2018).

The data obtained supplement the studies by Chernenko (2015), Ivashchenko, Abdulkhalikova, and Cieślicka (2017), Ivashchenko, Khudolii, Iermakov, and Harkusha (2017) that found that the control over the learning process is more effective if the modes of teaching are defined based on regression models.

Conclusions

A 2^2 type experiment made it possible to study the multifactorial structure of the process of teaching boys aged 14, using the program of algorithmic instructions, to specify the optimal balance between factors for their use when teaching physical exercises during physical education classes.

The best options for teaching series of tasks to boys aged 14 during physical education classes are:

- series 1 — 12 repetitions, rest interval of 120 s;
- series 2 — 12 repetitions, rest interval of 60 s;
- series 3 — 6 repetitions, rest interval of 60 s;
- series 4 — 12 repetitions, rest interval of 60 s;
- series 5 — 12 repetitions, rest interval of 120 s;

series 6 — 6 repetitions, rest interval of 60 s.

The prospect for further exploration is to study the regularities of teaching physical exercises to boys aged 15.

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Conflict of Interest

The authors state that there is no conflict of interest.

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ФОРМУВАННЯ РУХОВИХ НАВИЧОК: ОПТИМІЗАЦІЯ РЕЖИМУ НАВЧАННЯ ХЛОПЦІВ 14 РОКІВ

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Мета дослідження — обґрунтувати режими чергування виконання фізичних вправ та інтервалів відпочинку у процесі навчання серій завдань спрямованих на формування рухових навичок у хлопців 14 років.

Матеріали і методи. Учасниками дослідження були 40 хлопчиків у віці 14 років. Діти та їхні батьки були повністю поінформовані про всі особливості дослідження та погодилися взяти участь в експерименті. Для досягнення поставленої мети були використані такі методи дослідження: вивчення та аналіз наукової та методичної літератури; педагогічне спостереження, хронометраж виконання навчальних завдань; педагогічний експеримент, методи математичної статистики, методи математичного планування експерименту.

Результати. Результати дисперсійного аналізу та регресійних моделей свідчать, що в діапазоні 6-12 повторень вправи з інтервалами відпочинку 60-120 с знаходиться оптимальний режим виконання серій навчальних завдань. У запропонованій матриці плану факторного експерименту вибраний крок ва-

рювання факторів є достатнім для вивчення впливу різних режимів виконання фізичних вправ на ефективність навчання дітей і підлітків.

Висновки. Експеримент типу 2² надав змогу дослідити багатофакторну структуру процесу навчання хлопців 14 років за програмою алгоритмічних розпоряджень, уточнити оптимальні співвідношення факторів для їх використання у період навчання фізичних вправ під час уроків фізичної культури.

Оптимальними варіантами умов навчання серіям завдань хлопців 14 років на уроках фізичної культури є: 1 серія — 12 повторень, інтервал відпочинку 120 с; 2 серія — 12 повторень, інтервал відпочинку 60 с; 3 серія — 6 повторень, інтервал відпочинку 60 с; 4 серія — 12 повторень, інтервал відпочинку 60 с; 5 серія — 12 повторень, інтервал відпочинку 120 с; 6 серія — 6 повторень, інтервал відпочинку 60 с.

Ключові слова: хлопці, рухові навички, навчальні завдання, режими виконання вправ, факторний експеримент.

ФОРМИРОВАНИЕ ДВИГАТЕЛЬНЫХ НАВЫКОВ: ОПТИМИЗАЦИЯ РЕЖИМА ОБУЧЕНИЯ РЕБЯТ 14 ЛЕТ

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Цель исследования — обосновать режимы чередования выполнения физических упражнений и интервалов отдыха в процессе обучения серий заданных направленных на формирование двигательных навыков у ребят 14 лет.

Материалы и методы. Участниками исследования были 40 мальчиков в возрасте 14 лет. Дети и их родители были полностью информированы обо всех особенностях исследования и согласились принять участие в эксперименте. Для достижения

поставленной цели были использованы следующие методы исследования: изучение и анализ научной и методической литературы; педагогическое наблюдение, хронометрирование выполнения учебных заданий; педагогический эксперимент, методы математической статистики, методы математического планирования эксперимента.

Результаты. Результаты дисперсионного анализа и регрессионных моделей свидетельствуют, что в диапазоне 6–12 повторений упражнения с интерва-

лами отдыха 60-120 с находится оптимальный режим выполнения серий учебных заданий. В предлагаемой матрице плана факторного эксперимента выбранный шаг варьирования факторов является достаточным для изучения влияния различных режимов выполнения физических упражнений на эффективность обучения детей и подростков.

Выводы. Эксперимент типа 2² предоставил возможность исследовать многофакторную структуру процесса обучения ребят 14 лет по программе алгоритмических предписаний, уточнить оптимальные соотношения факторов для их использования в период обучения физических упражнений на уроках физической культуры.

Оптимальными вариантами условий обучения сериям заданий ребят 14 лет на уроках физической культуры являются: 1 серия — 12 повторений, интервал отдыха 120 с; 2 серия — 12 повторений, интервал отдыха 60 с; 3 серия — 6 повторений, интервал отдыха 60 с; 4 серия — 12 повторений, интервал отдыха 60 с; 5 серия — 12 повторений, интервал отдыха 120 с; 6 серия — 6 повторений, интервал отдыха 60 с.

Ключевые слова: ребята, двигательные навыки, учебные задания, режимы выполнения упражнений, факторный эксперимент.

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