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APPLICATION OF THE MAXIMUM LIKELIHOOD SAMPLING MATHEMATICAL MODEL TO REDUCE COSTS IN PSYCHO-FUNCTIONAL DIAGNOSTICS OF ATHLETES' CONDITIONS IN YOUTH SPORTS

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Acyclic non-standard sports (including hockey) are characterized by the multifactorial nature of competitive activities with a lack of decision-making time; the complex biomechanical structure of movements distinguished by many dynamic stereotypes; the variability of their motor component; and high demands on the reserves of all energy supply systems of the body. This paper discusses the applicability of an algorithm for completing the missing indicators of the psycho-functional state based on young hockey players using adjustment factors found by the maximum similarity sampling method. The use of the algorithm allows the calculation of missing indicators without their direct diagnosis will significantly refine the need to change scheduled training and competitive activities. The study into the psycho-functional state of athletes can result in the timely adjustment of training and competitive plans and the individualization of educational and training, which is essential in sports training.

Keywords: cost reduction; youth sports; mathematical modeling; psycho-functional diagnostics; maximum similarity sampling.

Introduction

Understanding the importance of individual features of athletes provides for their successful adaptation to training and competitive loads by choosing different strategies, which is vital in choosing the most effective training regimes.

There is solid accumulated experience in determining indicators of the psychological and physiological fitness of athletes. Complex methods for assessing athletes' functional state and functional fitness have been developed, taking into account age, sports specialization, and training stage. Methods for correcting the athletes' functional state can be chosen based on the results of studying, in particular, age peculiarities.

A complete checkup of the psychological and functional state of an athlete requires measuring more than 150 indicators, which is time and resource consuming. A full cycle of examining one athlete generally takes about 3–3.5 hours.

In addition to the costs, it is not always possible to conduct a complete checkup due to the high workload of athletes with training and competitive activities, especially in team sports. In youth sports, an athlete's daily routine includes not only training activities, but also compulsory education. A large number of competitions involve traveling outside the place of residence further reducing time for diagnostics.

Therefore, some indicators are omitted during a complete checkup, which significantly compromises the quality of the analysis and potentially resulting in incorrect ratings of young athletes and inappropriate training methods and programs.

1. Identification of Correlation Dependencies

A complete checkup of young athletes consists of eight groups:
– “Morphology”.
– “Psychological fitness”.
– “Functional state of the cardiovascular system”.
– “Mental state (current)”.
– “Functional state of the central nervous system (CNS) (sensorimotor system)”.
– “Functional state of autonomic regulation”.
– “Psychomotor abilities”.
– “Physical and technical fitness”.

The first group “Morphology” measures chronological age, biological age, height, weight, body mass index, absolute value of the muscle component, absolute value of the fat component, absolute value of the bone component, muscle mass as a percentage of body weight, fat mass as a percentage of body weight, and bone tissue as a percentage of body weight.

The second group of indicators “Psychological fitness” measures lability, thinking type, mental stability, frustration tolerance, self-control, volitional activity, perseverance, willpower, competitive emotional stability, motivational sphere, self-regulation, stability, and distraction tolerance.

The third group “Functional state of the cardiovascular system” measures is determined by: rheovasography (stroke output, cardiac output, blood pressure (average), total peripheral resistance index, stroke index, cardiac index, ejection fraction, specific general peripheral resistance index, blood flow stiffness, venous vascular resistance index), echocardiography (EchoCG) and dopplerography (internal diameter of the aortic valve ring, ascending aorta diameter, anteroposterior size of the left atrium, left atrium volume, end-diastolic size of the left ventricle, left ventricular ejection fraction, relative thickness of the left ventricle wall, left ventricular myocardial mass, interventricular septal thickness, left ventricular end-systolic size, left ventricular contractility function, left ventricular end-systolic volume, left ventricular myocardial mass index, left ventricular posterior wall thickness), basal size of the right ventricle, pulmonary artery in the valve ring area, pulmonary artery/aortic diameter ratio, right atrium, right atrium length, right atrium width, right atrium volume, heart rate at rest, systolic blood pressure (resting), diastolic blood pressure (resting), pulse pressure, maximum minute respiratory volume (exercising), maximum heart rate (exercising), maximum working capacity, aerobic threshold pulse, anaerobic metabolic threshold pulse, lactate (lactate blood content (2nd minute of recovery after maximum exercise)), anaerobic glycolysis capacity (number of steps), heart rate (3rd-4th minutes of recovery after maximum exercise), systolic blood pressure (3–4 min), and diastolic blood pressure (3–4 min).

The fourth group “Mental state (current)” is represented by the total deviation from the autogenic norm, stress indicator, anxiety, and dynamic attention.

The fifth group “Functional state of the central nervous system (sensorimotor system)” includes the functional level of the system, response stability, functionality level, and average functionality level.

The sixth group “Functional state of autonomic regulation” is determined by variation range, resting stress index, very low-frequency waves, total spectrum power, orthostatic test stress index, reactivity coefficient of the parasympathetic system in response to orthostasis “K30:15”, heart rate at rest, orthostatic test heart rate, regulation type, and regulation type level.

The seventh group “Psychomotor abilities” includes the average simple visual motor reaction (SVMR) time, accuracy of SVMR (number of errors), average time of choice reaction, accuracy of choice reaction (number of errors), average time of moving object reaction, accuracy of moving object reaction (number of accurate reactions), average time of interference reaction, accuracy of interference (number of errors), average time of discrimination reaction, accuracy of discrimination reaction (number of errors), number of guesses in SVMR (number of times), reaction time (lower limbs), initial frequency (tapping test-upper limbs), average frequency (tapping test-upper limbs), dominant hand strength, non-dominant hand strength, vertical jump (cm), vertical jump (5 times, cm), average frequency (tapping test, 15s), coordination abilities, sensorimotor coordination of the dominant arm (static form, %), sensorimotor coordination of the dominant arm (dynamic form, %), voluntary regulation of the dominant arm (static form, %), voluntary regulation of the dominant arm (dynamic form, %), voluntary regulation of dominant arm muscular efforts (%), sensorimotor coordination of the non-dominant arm (static form, %), sensorimotor coordination of the non-dominant arm (dynamic form), voluntary regulation of the non-dominant arm (static form, %), voluntary regulation of the non-dominant arm (dynamic form, %), voluntary regulation of non-dominant arm muscular efforts (%), static stability (%), and statokinetic stability (%).

The eighth group “Physical and technical fitness” is represented by: general physical performance, 30m run, 4x9m shuttle run, complex agility test, flexion-extension of arms while lying face down (push up), flexion-extension of arms while hanging on a high bar (pull up), standing long jump, flexion-extension of the torso from a prone position (bench press) frequency for 30 or 60s, bending forward from a standing position, special physical fitness, 30m face forward skating, 30m backward skating, no-dribble “Slalom”, no-dribble “Pocket”, 4x or 6x 9m shuttle skating, average time per segment, technical fitness, “Turns 1”, “Turns 2”, Dribble “Turns 1”, the difference between “dribble” and “no-dribble” (Turns 1), dribble “Turns 2”, the difference between “dribble” and “no-dribble” (Turns 2), dribble “Slalom”, the difference between “dribble” and “no-dribble” (Slalom), dribble “Pocket”, the difference between “dribble” and “no-dribble” (Pocket), accuracy speed shots, number of perfect shots, test completion time, “Forehand or backhand shot accuracy” (forehand, forehand score, forehand test completion time, backhand, backhand score, backhand test completion time, total score per test), “Pass technique control test” (number of perfect shots, test completion time), “Forehand and backhand hook pass while running” test (forehand per 10 pucks, number of perfect shots, backhand per 10 pucks, number of perfect shots).

Multicollinearity matrices were constructed separately for each group to study correlation dependencies within each group. The correlation dependence is considered high if coefficient is greater than 0.8 or less than -0.8, and low if the coefficient is in the range from -0.2 to 0.2.

The following conclusions were made for “Morphology”: the game role binary indicator has a very weak inverse relationship with all the characteristics, i.e. for attacking players the linear relationship with all characteristics is inverse; the bone tissue percentage/ body weight indicator does not correlate significantly with any indicator of the group.

“Psychological fitness” has no high correlation indicators, almost no indicators correlate with each other; visual-figurative and abstract-symbolic thinking have the highest indicator.

“Functional state of the cardiovascular system” has no correlation with other indicators: lactate (lactate blood content (2nd minute of recovery after maximum load)), anaerobic glycolysis capacity (number of load steps), systolic blood pressure (3–4 min) as a percentage of the initial indicator, diastolic blood pressure (3–4 min) as a percentage of the initial indicator. The only high correlation is between the maximum heart rate (exercising) and the pulse threshold of anaerobic metabolism.

“Mental state (current)” has a correlation between anxiety and stress indicators which is close to high, while the dynamic attention indicator does not correlate with any other indicator.

“Functional state of the central nervous system (sensorimotor system)” has high correlations between all indicators.

“Functional state of autonomic regulation” has average correlations between almost all indicators.

“Psychomotor abilities” has no correlation with other indicators for sensorimotor coordination (static form, %), voluntary regulation (static form, %), voluntary regulation (dynamic form, %), voluntary regulation of muscular efforts (%), sensorimotor coordination (static form, %), sensorimotor coordination (dynamic form, %), statokinetic stability (%).

“Physical and technical readiness” does not correlate with other indicators for “Turns 1” (time difference between “dribble” and “no-dribble” tests), “Forehand and backhand hook pass while running” (test completion time).

This study determines the degree of influence of individual indicators of the athletes’ functional and psychological state on “Physical and technical fitness”. We calculated correlation dependencies between this and all other groups. The results are presented in Table 1. The indicators of “Functional state of autonomic regulation” maximally affect the indicators of “Physical and technical fitness”, while the correlations with “Psychomotor abilities” and “Mental state (current)” were weak. The weak relationship between the level of psychomotor abilities and “Physical and technical fitness” allows us to conclude that the influence of individual characteristics is high in the physical potential of a hockey player.

We calculated separately correlation between blocks of athletes by the year of birth. The results are presented in Table 2.

The highest correlation coefficients are observed in the data of athletes born in 2009. The correlation between the performance of athletes of different ages indirectly allows us to assume that sports selection events are essential in hockey. At the time of the checkup, the players born in 2009 were 14 years, i.e. the players selected by this time already stand a good chance of further staying on the team.

The correlation analysis confirmed the usability of the maximum similarity sampling

Table 1

Correlates between all other groups and "Physical and technical fitness"

	"Physical and technical fitness"
"Morphology"	0.7178
"Psychological fitness"	0.7063
"Functional state of the cardiovascular system"	0.6229
"Mental state (current)"	0.2350
"Functional state of the central nervous system (sensorimotor system)"	0.7655
"Functional state of autonomic regulation"	0.9068
"Psychomotor abilities"	0.2782

Table 2

Correlation between blocks of athletes by the year of birth of hockey players

	2006	2007	2008	2009	2010
2006	1				
2007	0.899	1			
2008	0.874	0.884	1		
2009	0.916	0.921	0.892	1	
2010	0.886	0.896	0.871	0.912	1

model to complete missing values and reduce the need for a complete diagnostics saving time and money.

2. Algorithm for Completing Empty Values Using the Maximum Similarity Sampling Model

Let us formalize the problem statement for using the maximum similarity sampling model to find the missing indicators.

1. A table line with the indicators of the psycho-functional state of an individual athlete will be considered as a series of indicators and denoted by Y, which is the initial series of indicators (for the line to complete the missing value), and X_i, which is the remaining series of indicators (for all remaining lines), where i is the athlete's serial number in the data table.

2. Each individual element of the initial series of indicators will be denoted by y_j, and the remaining series of indicators by x_{ij}, where j is the serial number of the indicator.

3. $\tilde{X}_i$ is the series of indicators as similar as possible to the initial Y

4. $\tilde{y}_j$ is the missing indicator in the initial series of indicators Y

5. $\tilde{x}_{ij}$ is the indicator of the most similar series $\tilde{X}_i$ corresponding to the missing indicator $\tilde{y}_j$ in the initial series of indicators Y.

The algorithm for completing the empty values uses the maximum similarity sample.

1. Select a series of indicators Y and determine an empty value of the indicator $\tilde{y}_j$ to be completed.

2. Determine all series of indicators X_i with completed corresponding indicators $\tilde{y}_j$, denote such series of indicators by $\check{X}_i$.

3. Determine correlation coefficients for Y and each $\check{X}_i$ by formula (1):

$$r_{Y\check{X}_i} = \frac{n \cdot \sum x_{ij} y_j - (\sum x_{ij}) \cdot (\sum y_j)}{\sqrt{[n \cdot \sum x_{ij}{}^2 - (\sum x_{ij})^2] \cdot [n \cdot \sum y_j{}^2 - (\sum y_j)^2]}} \quad (1)$$

4. Select the maximum from the resulting array of correlation coefficients.

5. The series of indicators corresponding to the maximum correlation coefficient is $\tilde{X}_i$.

6. Construct the approximation equations for $\tilde{X}_i$ and initial Y (2):

$$\hat{Y} = \alpha_1 \tilde{X}_i + \alpha_0 I \quad (2)$$

where I is a unit vector, $\hat{Y}$ is the approximated value of the initial series of indicators, and α_0, α_1 are the approximation coefficients with the following value (3):

$$\sigma^2 = \Sigma(\tilde{X}_i - \hat{Y})^2 \to min \quad (3)$$

that is, the square of the standard deviations of the model values from real ones should be minimal. The values of the coefficients are found using the least squares method.

7. Substitute $\tilde{x}_{ij}$ into the approximation equation and find the corresponding $\tilde{y}_j$.

The algorithm is repeated after each $\tilde{y}_j$ is found.

Conclusion

Adolescence and youth are a tough age for athletes of acyclic non-standard sports due to the increasing psychological and physical stress and the peculiarities of puberty. During this period, under the influence of hormonal changes, there is a significant increase in selection competition for team and individual sports. Therefore it is important to promptly monitor and diagnose changes in the functional and mental state of young athletes. Due to the high number of indicators, such diagnostics are labor-intensive in terms of time, human resources, and equipment. The algorithm for completing unknown data is based on diagnosed data, which will allow athletes to be less frequently distracted from competitive and training activities and reduce the cost of the diagnostics.

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ПРИМЕНЕНИЕ МАТЕМАТИЧЕСКОЙ МОДЕЛИ ВЫБОРКИ МАКСИМАЛЬНОГО ПОДОБИЯ ДЛЯ СНИЖЕНИЯ ЗАТРАТ НА ПСИХО-ФУНКЦИОНАЛЬНУЮ ДИАГНОСТИКУ СОСТОЯНИЯ СПОРТСМЕНОВ В ДЕТСКО-ЮНОШЕСКОМ СПОРТЕ

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Ациклические нестандартные виды спорта (в том числе и хоккей) характеризуются: мультифакторным характером соревновательной деятельности в условиях дефицита времени принятия решения; сложностью биомеханической структуры движений, отличительной особенностью которых является, с одной стороны, наличие большого числа динамических стереотипов, с другой – вариативность их моторного компонента; высокими требованиями к резервам всех систем энергообеспечения организма. В статье рассмотрена применимость алгоритма заполнения отсутствующих показателей психо-функционального состояния с помощью корректирующих коэффициентов, найденных по методу выборки максимального подобия. Применение предложенного алгоритма, позволит принимать решения о тех или иных показателях спортсмена без непосредственного диагностирования показателя (например, для принятия решения в условиях неопределенности показателя), что значительно повысит качество реагирования на необходимость изменений планов тренировочной и соревновательной деятельности. На основании результатов исследования психо-функционального состояния спортсменов возможен своевременная коррекция планов тренировочной и соревновательной деятельности, индивидуализация учебно-тренировочного процесса, что является одной из важнейших задач в спортивной подготовке.

Ключевые слова: снижение затрат; детско-юношеский спорт; математическое моделирование; психо-функциональная диагностика; выборка максимального подобия.

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