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# Study on Quality Indicator System of Rhythmic Gymnasts in Analytic Hierarchy Process

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**Abstract:** The rhythmic gymnastics (RG) is a sport item with the direct aim of winning as well as a good ornamental value. The scientific selection by the rhythmic gymnasts is necessary for the success, and also the beginning for the scientific training of the gymnasts in their special training stage. According to RG characteristics and the physical characteristics of the gymnasts, also in combination with the investigations & interviews to the coaches who have years of training experience in RG, the experts & scholars on RG study & teaching in universities, and by referring to relevant documents, this paper established the quality indicator system in analytic hierarchy process (AHP). We summarized and selected several indicators obviously influencing the RG training and divided them into the three types of factors: physical factors, flexibility & strength factors, and speed & dexterity factors, according to which 12 specific indicators, their weights and comprehensive evaluation coefficients. Based on these indicators, we established the quality indicator system of the gymnasts, and developed corresponding software system, providing scientific theoretical basis & practical application basis for the selection & evaluation of the gymnasts.

## 1. Introduction

As a novel and highly rhythmic female sport item, the rhythmic gymnastics (RG) is based on rhythm, cadence and natural movements. The RG does not show the beauty of health from sports, but also integrates the essence of ballet, folk dance, gymnastics, sports acrobatics, martial arts, acrobatics, drama, etc. In addition to training the gymnasts' strength, dexterity, rhythm and other qualities, a complete set of all-around exercising methods with thought, expressions, hierarchies, structure and difficulty is also created, forming the beauty of RG.

In recent years, the Chinese RG has made great progress in the world-class events and many excellent achievements been obtained; however, the Chinese gymnasts' personal skills are still not as good as those of excellent foreign gymnasts in the RG events, so attentions will have to be paid to the selection of the gymnasts in the cultivation of high-quality gymnasts. The RG is a sport item pursuing beauty and the perfect performance of all of its movements, setting high requirements to all aspects of physical quality. The selection of the gymnasts is a complicated and meticulous task, and we are focusing on the scientific selection according to the gymnast selection experience of experts & coaches in China and foreign countries, and in combination with the actual status in China. During the process, to determine the quality indicator system of the gymnasts becomes the key link for the scientific selection and evaluation of the gymnasts.

Therefore, we introduced the analytic hierarchy process combining qualitative analysis & quantitative analysis to determine the indicator system for the gymnast selection and evaluation, as



well as the weights of all indicators. According to the established quality indicator system for the gymnasts, we designed corresponding software system which has produced a good practical effect.

## 2. Relevant Studies

The analytic hierarchy process (AHP) was proposed by Saaty, an American operational researcher in mid 1970s, which is a comprehensive decision-making method for multiple aims, with the combination of qualitative analysis and quantitative analysis [4]. Wang Jing et al are the first ones who have applied such type of process in the field relevant to the RG, but mainly focusing on the analysis of physical quality itself [1].

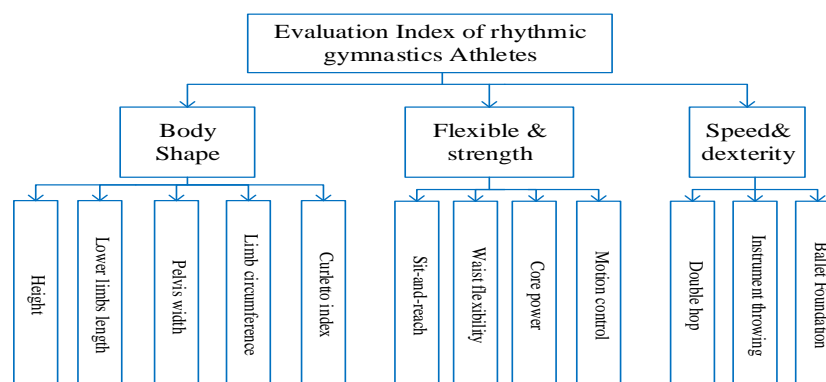
The selection & evaluation of the gymnasts are mainly based on the coaches and experience, or on statistical analysis. For the standards for the selection of the gymnasts, Camargo et al proposed a process based on the development of sports science & expert knowledge [2][3]; however, the process analyzes mainly the comparison of different items and persons, with a lack in quantitative and objective properties relatively. From the physical quality characteristics of the gymnasts, Cao Juan et al applied the AHP on the training, selection and other processes for the gymnasts [5][6][7], but the relevant studies lack analyses on the sport item characteristics, the physical quality indicators are not targeted and the statistical methods are also comparatively simple.

In summary, the studies on the gymnast selection are mostly focused on body shape, physical quality, psychological quality and various capacities, which are mainly qualitative studies summarizing the experience of coaches and experts; however, the quantitative studies on the quality indicator system of the gymnasts are relatively fewer, and the quality indicator system needs to be more scientific and reasonable. The thesis proposes a model based on the AHP, which considers the RG characteristics and is integrated with the practical experience & statistical data, so the model establishes a scientific and quantitative quality indicator system for the gymnasts.

## 3. Hierarchical Structure Model

The quality indicators of a gymnast cover several aspects including physical factors, flexibility & strength factors, and speed & dexterity factors. According to experts' investigation & relevant analysis, and in combination with RG characteristics, it is confirmed that the analysis factors in the study compromise three types: physical factors, flexibility & strength factors, and speed & dexterity factors

The physical factors are five contents, including height, dimensions and the Quetelet Index; the flexibility & strength factors are four ones, including the sit-and-reach, the waist flexibility, the core strength and single movement control; and the speed & dexterity factors are made up of three aspects, including double-foot jump, the one-on-one apparatus throwing, and the ballet basics. The indicator system is shown in Figure 1. All factors will be introduced in details below.



**Figure 1.** Quality indicator system of gymnasts

(1) Physical factors. The body shape is significant for the gymnast selection, including the factors like height, limb dimension, etc. Generally, these factors are not likely to change, but they can

obviously influence RG training, and all technical movements in RG have clear requirements to the body shape; generally, some movements cannot be completed if the requirements are not met. ①The height and some length indicators are the indicators reflecting the skeletal development and the longitudinal body development, so the height is one of the important indicators. ②Narrow pelvis is not only good for a gymnast to exert her speed, strength and other skills in the upper limbs, but also good for her development in running & jumping capabilities. Smaller hips and light lower body mean flexible movement, agile movement, less strength use and beautiful shape. Therefore, the pelvis width is an important indicator for measuring the body shape of a gymnast. ③The length of lower limbs is also an important indicator of the body shape. The length is greatly influenced by acquired factors; considering the influence of movements to the body shape, it is significant to measure the lower limbs. ④The dimensions of the limbs reflect the development of muscles & fat of a person, and the muscle elasticity & strength to some extent; the dimensions of the limbs depend on the size of the cross section of muscles, and are important indicators to measure the physical quality of a gymnast. ⑤The Quetelet Index was proposed by Quetelet named “Father of Human Body Measurement”, and the index is named with his name later. In paleoanthropology and human body development evaluation, it is widely used as an ancient and famous index. The index represents the weight per cm of height, which is obtained by the proportion between the weight and the height, and serves as relative weight or the weight of specific length for reflecting the dimensions, width, thickness and mass tissue density of a human body; the index is an important indicator reflecting the uniformness of the development of a gymnast.

(2) Flexibility & strength factors. An RG student must have good flexibility & strength to complete high-quality, graceful and delicate movements. The flexibility of a student is the necessary condition for embodying the maximum movement range and doing delicate movements; graceful movements in the air requiring good jumping ability, and good explosive power is the guarantee for completing a whole set of movements (e.g. leaps) easily. ①The sit-and-reach test can be used to measure the possible movement ranges of the torso, the waist, the hip and other joints in the static status, and the test reflects mainly the extensibility and the elasticity of the joints, ligaments and muscles in these parts, as well as the development of the flexibility of the body. ②The flexibility of the waist is significant to the graceful expression of the body movements of a gymnast. ③The core muscle group has the functions including stabilizing the center of gravity and transmitting force, is the main link for the overall force generation, and the pivot for the movement & force exertion of the upper & lower limbs. Strong core force can stabilize and support the body posture in the movement, the movement skills and the special technical movements ④The single movement control reflects the body control capability & movement completion capability of a gymnast, which is very important for the combination of a series of movements.

(3) Speed & dexterity factors. In the aspect of speed & dexterity factors, the RG students must have the dexterity & explosive power required by movements to complete movement sequence efficiently. The RG requires that a certain number of difficult movements in limited time, and the connection between movements, so as to complete a movement sequence in a consistent manner. The examinations on the speed & dexterity are indispensable. ①Double-foot jump is a movement of successive jumps by thrusting against the ground with the soles of double feet, which is a test for the explosive power & dexterity of a gymnast. ②The one-on-one apparatus throwing: in the RG event, the throwing & catching of apparatus is an important and difficult link for completing the whole movement sequence, and is the key for obtaining good result in the event. ③The ballet basics. The RG has certain requirements to the aesthetic judgment of gymnasts, the ballet (and other relevant types of dance) basics can help the gymnasts to complete the graceful movements better.

#### 4. Hierarchical Computation Model

After establishing the hierarchical structure, the subordination between the higher and lower hierarchies is confirmed, and the element in the higher hierarchy dominates the one in the lower. Now it is required to give corresponding weights to the elements according to their relative importance to

the criteria in the higher hierarchy. In the AHP, the weights are exported by building a judgment matrix for comparing, analyzing and judging the importance between any two indicators. Each judgment matrix is for the comparison between two elements in the same hierarchy relative to the single criterion in the higher hierarchy, so 4 judgment matrixes need to be built according to the model above. The comparison is completed by issuing questionnaires for gathering the comments of 16 experts. The questionnaire adopts 7-fractile relative importance proportional scaling, the values in the judgment matrixes confirmed by the experts are input to the C Language AHP Program for finally calculating the largest eigenvalue of each matrix, the eigenvector corresponding to the largest eigenvalue and the consistency ratio; if the consistency ratio (CR) < 0.1, it can be considered that the consistency of the judgment matrix is satisfying, the smaller the CR value, the better, by which it can be confirmed that the weights of all indicators are reasonable.

The calculation formula of CR is:

$$CR = \frac{\left( \frac{\lambda_{max} - n}{n - 1} \right)}{RI}$$

$\lambda_{max}$  the largest eigenvalue of the matrix,  $n$  is the matrix order, and  $RI$  is the average random CR of the matrixes.

We firstly establish the judgment matrix of Hierarchy B to Hierarchy A, as shown in Table 1, the weights of the physical factors, the flexibility & strength factors, and the speed & dexterity factors for the evaluation of a gymnast according to the experts' rating. According to the analysis, it can be found that the rating of the speed & dexterity is most important for a gymnast, the one for the flexibility & strength is less important, and the weight (rating) of the physical factors is the least. The calculated CR is 0.00, smaller than 0.10, proving that the mutual importance comparison of the indicators is logically consistent, and the AHP precondition is reliable.

**Table 1. Judgment matrix of hierarchy B to hierarchy A.**

Evaluation Indicator System	Physical factors	Flexibility & strength	Speed & dexterity	W	CR
Physical factors	1.0000	0.3333	0.1429	0.0810	0.0000 CR < 0.1
Flexibility & strength	3.0000	1.0000	0.2000	0.1884	
Speed & dexterity	7.0000	5.0000	1.0000	0.7306	

Next is the calculation of the judgment matrix of the indicator hierarchy to the criterion hierarchy, i.e. analyzing the influence weights of the specific indicators of the physical factors, the flexibility & strength factors, and the speed & dexterity factors to the three types of factors. The body shape indicators are firstly analyzed, including the 5 characteristics of height, length of lower limbs, pelvis width, dimensions of limbs, and the Quetelet Index. By collecting the experts' ratings, the judgment matrix obtained is shown in Table 2. According to analysis, we know that the dimensions of limbs and the Quetelet Index are relatively important measuring indexes for a gymnast. The calculated CR = 0.074, proving that the importance comparison of the indicators is logically consistent.

**Table 2. Judgment matrix of hierarchy C to hierarchy B1.**

Body shape	Height	Dimensions of limbs	Pelvis width	Quetelet Index	Length of lower limbs	W	Consistency check
Height	1.0000	0.2500	0.3333	0.1429	0.3333	0.0502	0.0061 <0.1
Dimensions of limbs	4.0000	1.0000	1.0000	0.2000	0.5000	0.1262	
Pelvis width	3.0000	1.0000	1.0000	0.3333	1.0000	0.1516	
Quetelet Index	7.0000	5.0000	3.0000	1.0000	4.0000	0.5075	
Length of lower limbs	3.0000	2.0000	1.0000	0.2500	1.0000	0.1644	

Hierarchy B2 is for the flexibility & strength, which is measured by 4 indicators including sit-and-reach, flexibility of waist, core force, single movement control. According to the experts' ratings, the judgment matrix of Hierarchy C to Hierarchy B2 obtained is shown in Table 3. It can be seen that the movement control and the flexibility of waist are important in flexibility & strength aspects respectively. CR = 0 proves that the importance comparison of the indicators is logically consistent.

**Table 3. Judgment matrix of hierarchy C to hierarchy B2.**

Flexibility & strength	Movement control	Flexibility of waist	Sit-and-reach	Core force	W	Consistency check
Movement control	1.0000	2.0000	7.0000	5.0000	0.5276	CR=0.0075 CR<0.10
Flexibility of waist	0.5000	1.0000	4.0000	4.0000	0.3068	
Sit-and-reach	0.1429	0.2500	1.0000	1.0000	0.0793	
Core force	0.2000	0.2500	1.0000	1.0000	0.0863	

Hierarchy B3 is for the speed & dexterity, according to the weights in Table 1, we know that the hierarchy is most important. According to the experts' ratings, the judgment matrix of Hierarchy C to Hierarchy B3 obtained is shown in Table 4. By analyzing the weights of all indicators, it can be seen that the most important factors are the two profession-related skills of one-on-one apparatus throwing and ballet basics. The calculated CR = 0.0043, proving that the indicator judgment is logically consistent.

**Table 4. Judgment matrix of hierarchy C to hierarchy B3.**

Speed & dexterity	One-on-one apparatus throwing	Double-foot jump	Ballet basics	W	CR
One-on-one apparatus throwing	1.0000	5.0000	0.5000	0.3522	0.0043 CR < 0.1
Double-foot jump	0.2000	1.0000	0.2000	0.0887	
Ballet basics	2.0000	5.0000	1.0000	0.5591	

According to the judgment matrixes above, we ordered comprehensively all of the 12 indicators measuring the quality of a gymnast, and the result is shown in Table 5. From the overall order of the hierarchies, the speed & dexterity factors, particularly the professional qualities including the one-on-one apparatus throwing and the ballet basics, are important in the quality indicator system of a gymnast; in addition, the important indicators also include the movement control measuring the flexibility of a gymnast, and the core force reflecting force. According the order of the indicators and their corresponding weights, we can establish the quality indicator system of rhythmic gymnasts in the AHP. The calculation formula is:

$$S = \sum_{i=1}^{12} c_i * W_i$$

In the formula, S is the total score of a gymnast,  $c_i$  is the score in Item i, and W is the weight of Item i.

**Table 5. Calculation result of overall order of hierarchies.**

Target hierarchy scheme	Weight of indicator	Order of weights
Height	0.0041	12
Dimensions of limbs	0.0102	11
Pelvis width	0.0123	10
Quetelet Index	0.0411	6
Length of lower limbs	0.0133	9
Movement control	0.0994	3
Flexibility of waist	0.0578	5
Sit-and-reach	0.0149	8
Core force	0.0163	7
One-on-one apparatus throwing	0.2573	2
Double-foot jump	0.0648	4
Ballet basics	0.4085	1

## 5. Implementation of Quality Indicator Evaluation System of Rhythmic Gymnasts

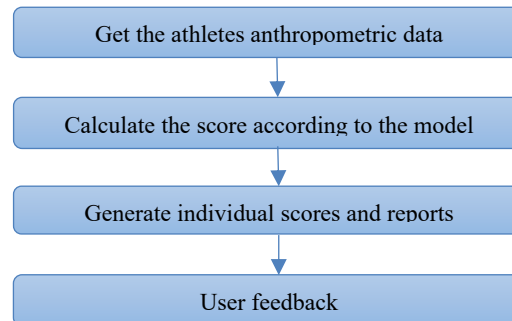
According to the quality indicator system established above, we designed and implemented a Quality Indicator Evaluation System of Rhythmic Gymnasts for recording the relevant test data of a gymnast, generating corresponding reports, to provide practical application basis for the selection & self-evaluation of gymnasts. The system establishes a data model based on AHP with the relevant test data of the gymnasts, and calculates the indicators in the test with software, for providing physical test reports and capability analysis for individuals.

The Quality Indicator Evaluation System of Rhythmic Gymnasts aims mainly at the daily test, as well as the selection & evaluation processes of the gymnasts, it can manage and analyze the test data of the gymnasts' indicators, to generate corresponding reports and targeted schemes, guiding the



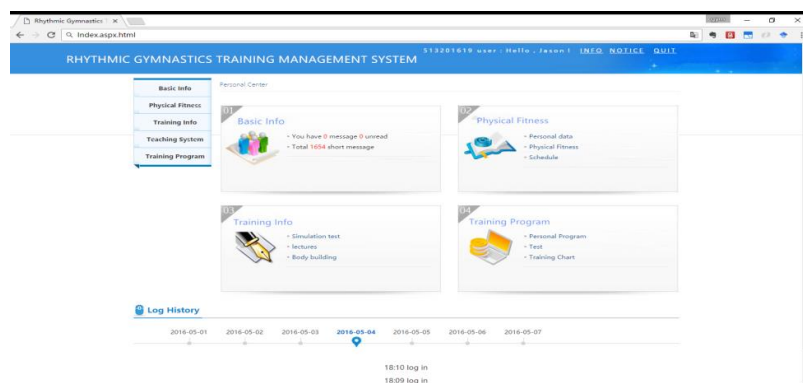
gymnast selection. Based on the model established by us, the overall evaluation performance of the gymnasts can be obtained, achieving scientific evaluation.

The overall flow chart of the system is shown in Figure 2:



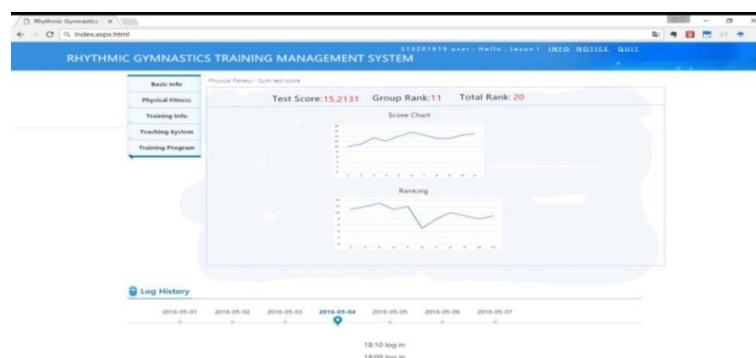
**Figure 2.** Flow chart of quality indicator evaluation system of rhythmic gymnasts

The following contents are the illustration & explanation of the Quality Indicator Evaluation System of Rhythmic Gymnasts. After logging in the system, a gymnast can enter the user interface with the functions of basic gymnast information maintenance, physical quality status, test requirements, test rating indicators, personal test report export, etc. The corresponding interface implementation effect is shown in Figure 3 below.



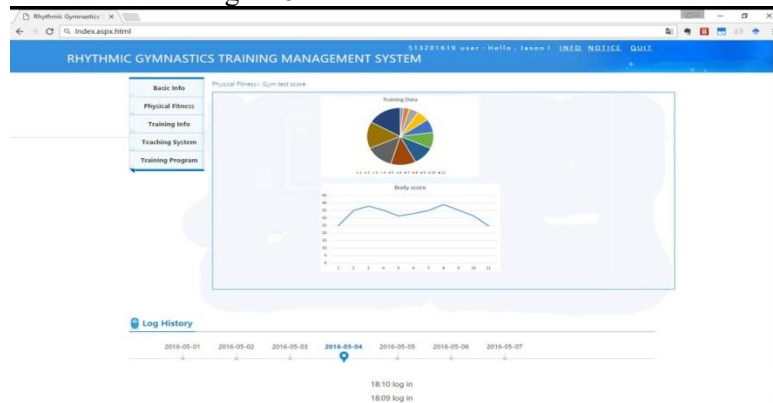
**Figure 3.** Main interface for gymnast user

The Quality Indicator Evaluation System of Rhythmic Gymnasts analyzes mainly the scores of a gymnast's 12 indicators, for establishing evaluation model. The data analysis results can be shown in the corresponding data statistics visualization method. From a gymnast's physical quality, test requirements and test status, the test data for all of the indicators of the gymnast, as well as the details & historical development curves of the indicators; the user interface implementation effect is shown in Figure 4.



**Figure 4.** Interface of indicator status development curve

A coach can also view the corresponding data of gymnasts, and select good ones according to their conditions and test results. After completing the data of physical quality tests, a coach can visually see the distribution of the scores of the physical quality evaluations of the gymnasts, and the user interface implementation effect is shown in Figure 5.



**Figure 5.** Interface for coach viewing physical quality status of gymnasts

The application of the whole system can meet the functional demands of the quality evaluation of the gymnasts; the gymnasts can obtain their evaluation indicators & specific scores from their basic information & relevant training information, according to the algorithm of the calculation model. Meanwhile, a coach can know the status of his/her gymnasts, summarize the teaching experience, and reduce the time for data arrangement, boosting the development of RG; by analyzing relevant data, the current overall quality status of the gymnasts can be known, providing theoretical basis for the relevant experts, so that they can summarize experience from the data results, making the training methods more consistent with the development direction & rules of RG.

## 6. Conclusion

The quality evaluation of the gymnasts is a systematic engineering, and the important content in gymnast selection & training. It is both a theoretical issue and a practical issue how to evaluate the gymnasts' quality. We rely on the subjective evaluations of the gymnasts and coaches for too long, lacking quantitative scientific indicators. Therefore, it is an important precondition for scientific selection & evaluation to establish a reasonable quality indicator system in a scientific way. The thesis establishes the quality indicator system in AHP, determines the indicator rating table, and implements the corresponding quality indicator evaluation system; the indicator system obtained is scientific to some extent and very practical; it is expected that the system can provide reference basis for the scientific evaluation in the gymnast selection & training in the new era.

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