ANALYSIS OF SELECTION INDICATORS OF BADMINTON PLAYERS BY THE DELPHI METHOD AND ANALYTIC HIERARCHY PROCESS

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ABSTRACT

This study aims to clarify the selection standard of potential badminton players and construct an evaluation model of badminton players. Through literature review and the Delphi Method, this study validated the selection indicators of badminton team players: body type, physical qualities, physical functions, psychological qualities, and intelligence level, including a total of 17 detailed indicators. The researcher then interviewed badminton coaches and applied Analytic Hierarchy process (AHP) to determine the importance of the indicators of potential badminton players for badminton coaches. A selection model of badminton players was constructed. The results can serve as reference for badminton coaches' scientific and objective selection of players.

KEYWORDS

Delphi Method, Analytic Hierarchy process, Selection model

1. INTRODUCTION

Badminton is a technique-oriented sport, and badminton racquets are important keys. Striking a ball with force requires elegant and delicate techniques, which must be constructed and delivered through precise basic skills, powerful strength, and coordination [1, 2]. Badminton is a sport with complicated skills. Selection and training of players should be based on precise and reasonable scientific methods [3-5]. Horng [6] and Chi [7] suggested that when selecting badminton talents, there should be systematic, planned, and organized cultivation of objectives, in order to screen potential badminton players and enhance training performance. How to find excellent badminton talents by scientific and efficient methods is an important issue in badminton development in Taiwan.

This study aims to clarify the selection indicators of potential badminton players in order to establish a selection model for badminton players. Through literature review, the Delphi Method, and AHP, this study validates the important selection indicators of badminton players. The findings are expected to enhance selection precision, and serve as scientific and objective reference for badminton coaches. The research purposes are as follows:

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1. To clarify the evaluation standard of the selection of badminton talents.
2. To analyze importance of selection indicators of badminton players.
3. To construct a scientific and objective selection model for badminton players.

2. LITERATURE REVIEW

2.1. Selection of sports talents

Talent selection is the first step of sports training. In order to result in excellent sports performance, besides scientific training, natural talents of sports should be discovered as early as possible. By training from childhood, excellent players will demonstrate better results [5-7]. Selection of athletes is originated from the Olympic Games in Amsterdam, the Netherlands, in 1928. At the time, the host reorganized the athletes' basic information, such as height, weight, date of birth, etc. According to the statistical results of sports scientific researchers, the potential talents were selected based on the characteristics and requirements of different sports items, and a selection model was constructed [8]. This breakthrough immediately enhances the level of the game, as it not only saves labor, materials, and time, but also allows coaches to establish athletes' regular training plans according to the differences of sports. Hence, sports training will be more effective. Selection of sports talents in Taiwan was originated from the 1950s, and in the 1980s, scientific selection was developed; however, research on scientific selection was not conducted until later. Based on literature regarding the selection of athletes in Taiwan, scientific selection was based on "figure, genes, family health history, pathological examination, physical function, and basic physical competence" [5-8]. Hsu [9] indicated that scientific selection of sports talents should include figures and body type, physical function, physical conditions, analysis of sports techniques, creative movement, psychological quality, and intellectual capability. By scientific theory, and through observation, testing, and judgment, young people in excellent condition are selected for systematic and organized training.

Since badminton is based on complicated techniques, how to find more talents through scientific and efficient selection is an important issue for the development of badminton. Regarding scientific selection of sports talents, Chi [7] suggested (1) investigation; (2) survey; (3) experiment; (4) experience; Chou [8] indicated selection by (1) genes; (2) instruments; (3) body types; (4) mental and intellectual functions. According to Chou [8], Bacon [10, 11] and Hellebrandt [12] , selection is based on 5 steps: (1) health examination; (2) test of indicators; (3) comparison of peak of growth and duration; (4) trace of measurement; 5) general decisions.

2.2. Delphi Method

The Delphi Method is also called expert survey, and its problem is distribution to experts to inquire about their opinions. All experts' opinions are then retrieved and categorized into general opinions [13, 14]. The experts obtain feedback of the general opinions, their views are collected again. The opinions are then revised and reorganized. Thus, decisions with more consistent prediction results are progressively obtained.

The method is universal, thus, experts do not have direct discussion or horizontal contact. By repeated inquiry, generation, and revision, the experts finally reach a consensus [15].

The Delphi Method can be adopted to solve complicated problems, such as prediction of population, operation, demand, and education. In addition, it can be used for assessment, decision-making, management communication, and planning. Application of the Delphi Method is based on the following 5 rules [16-18]:

1. Anonymity: all experts and scholars express their opinions individually, they are strictly anonymous, and their identity is confidential.
2. Iteration: the host collects and announces the participants' opinions. After several rounds, participants can revise their original judgment by reviewing others' data.
3. Controlled feedback: participants are invited to respond to the designed questionnaire, and have total measurement on collective judgment.
4. Statistical group response: general judgment of all participants' opinions usually depends on median, dispersion, and frequency distribution.
5. Expert consensus: the Delphi Method aims to lead to experts' common consensus to have final results.

2.3. Analytic Hierarchy Process

AHP is a theory developed by Thomas L. Saaty at the University of Pittsburgh, U.S.A. in 1971. By 1980, AHP became more complete [19-23]. It can be used to solve complicated decisions and factors in uncertain situations, and resolve issues with several criteria, thus, it deals with decision-making.

The content of AHP is to systematically develop a hierarchy of problems. Through pairwise comparison, it determines the relative weights between elements, and develops rankings of the plans as reference to select the best plan [19, 20]. The purpose of AHP is to systemize complicated problems and reorganize related data, thoughts, and intuitive judgments, through logic and a hierarchical structure. For decision makers, the hierarchical structure helps understand the issues, and complicated and non-structural situations are divided into different parts, thus, hierarchical order is established. The values are based on the importance of variables, as determined through subjective judgment. After a series of judgments and statistics, the ranking of variables is established to result in decision makers' conclusions [23-25].

3. RESEARCH METHOD AND PROCESS

3.1. Research Method

This study aims to explore the selection indicators of badminton players, as well as the importance of the indicators, in order to establish a new selection decision-making model of badminton players by AHP as reference for badminton coaches to cultivate players. By literature review, this study generalized the selection indicators, and developed an evaluation framework and criteria to select badminton players. The selection model was divided into three levels: objective level, major criteria level, and sub-criteria level. The primary framework was based on repeated questionnaire survey, conducted through the Delphi Method. Finally, this study obtained a complete assessment framework with experts' and scholars' consistent opinions (Figure 1). The hierarchical framework includes three levels, the first level is research purpose; the second level is major criteria, including body type, physical quality, physical function, psychological quality, and intelligence level, and the third level is sub-criteria, including 17 items.

Objective	Major criteria	Sub-criteria
Selection of badminton players	Body type	• Height • Figure • Length of arm
	Physical quality	• Speed • Reaction • Bounce • Muscular endurance • Flexibility
	Physical function	• Cardiopulmonary function • Body fat • Eyesight
	Psychological quality	• Active • High concentration • Emotion management
	Intelligence level	• Intelligence assessment • Strategy comprehension and application • Immediate reaction

Figure 1. Hierarchical framework of selection indicators of badminton players

By hierarchical analysis, complicated problems are simplified from top to bottom; and any selection that cannot be presented is quantified in order to easily understand it, develop the ranking of assessment, and enhance decision-making quality. After designing a "questionnaire of hierarchical analysis of weights for the selection indicators of badminton players", this study invites experts and scholars with practical experience in sports circles, and related academic fields, to clarify and validate the weights of the indicators. Huizingh and Vrolijk proposed 9 phases of hierarchical analysis [26], as shown in Figure 2. Phase 7: Comparison of criteria pairwise is shown, as follows [19-23]:

1. Construction of Pairwise Comparison Matrix:

It assumes that there are elements $A_1, A_2, A_3, A_4 \ldots A_n$ at a certain level. The weights of elements are $W_1, W_2, W_3 \ldots W_n$ to construct Pairwise Comparison Matrix. The relative importance of pair A_i and A_j is as shown by a_{ij}. The Pairwise Comparison Matrix of elements W_n, $A_1, A_2, A_3, A_4 \ldots A_n$ is A=$\lfloor a_{ij} \rfloor$. When weights $W_1, W_2, W_3 \ldots W_n$ are known, the Pairwise Comparison Matrix A=$\lfloor a_{ij} \rfloor$ can be shown by Eq. 1.

$$A=\lfloor a_{ij} \rfloor=\begin{bmatrix} W_1/W_1 & W_1/W_2 & \ldots & W_1/Wn \\ W_2/W_1 & W_2/W_2 & \ldots & W_2/W_n \\ . & . & \ldots & . \\ W_n/W_1 & W_n/W_2 & \ldots & W_n/W_n \end{bmatrix} \quad (1)$$

$a_{ij} = W_i / W_j$, $a_{ji} = W_j / W_i$, i, j=1, 2, …n.

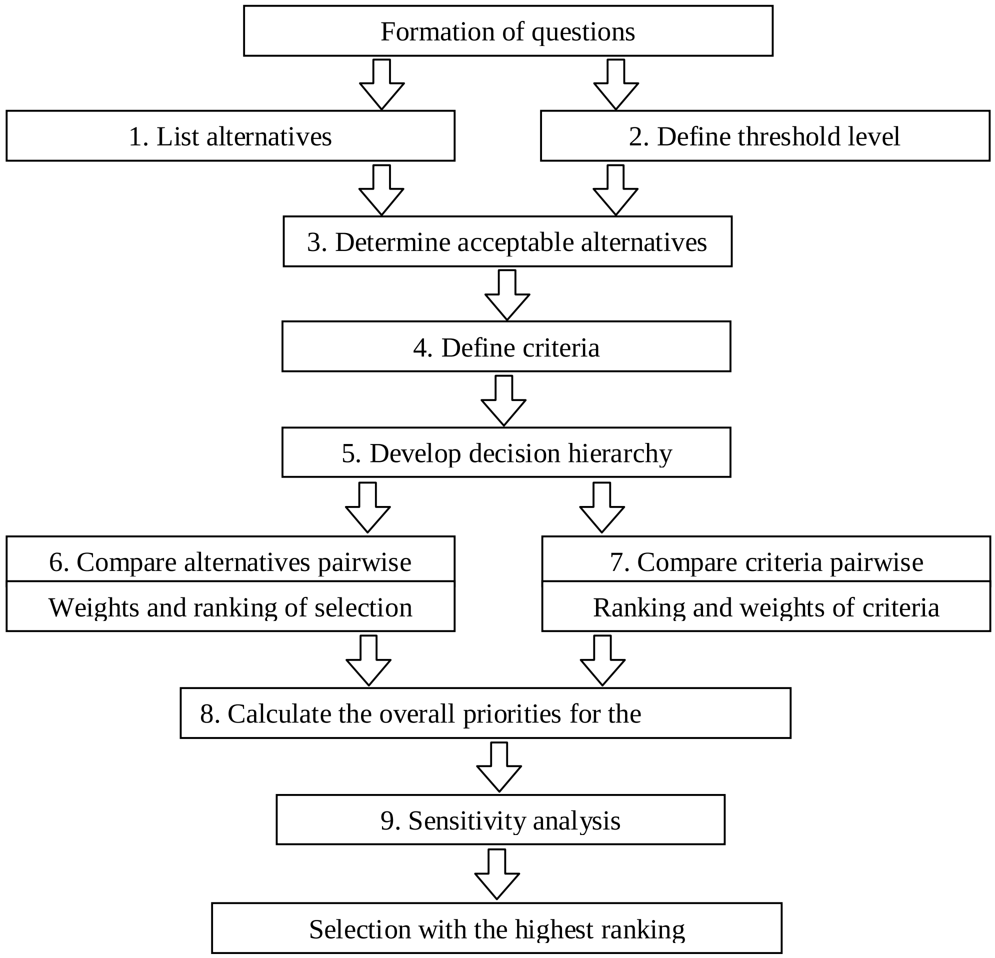

Figure 2. Nine phases of AHP

2. Acquisition of maximum eigen vector and eigenvalue:

According to the Pairwise Comparison Matrix, we obtain the corresponding eigen vector of the maximum eigenvalue or priority vector and weight distribution. Vector $\overline{W}$ of multiplication between Pairwise Comparison Matrix A and weights of indicators is as shown by Eq. 2:

$$\overline{W} = (W_1,\ W_2,\ W_3, \ldots\ldots W_n)^T$$

$$A\overline{W} = \begin{bmatrix} W_1/W_1 & W_1/W_2 & \ldots. & W_1/W_n \\ W_2/W_1 & W_2/W_2 & \ldots. & W_2/W_n \\ . & . & \ldots. & . \\ W_n/W_1 & W_n/W_2 & \ldots. & W_n/W_n \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ . \\ W_n \end{bmatrix} = \lambda \begin{bmatrix} W_1 \\ W_2 \\ . \\ W_n \end{bmatrix} \tag{2}$$

According to Eq. 2, multiplication between Pairwise Comparison Matrix A and $\overline{W}$ is equal to multiplication between λ and $\overline{W}$; $A\overline{W} = \lambda\ \overline{W}$. λ is the eigenvalue of A. It is the corresponding eigen vector of the eigenvalue of Pairwise Matrix A. In pairwise comparison, since a_{ij} is acquired by subjective judgment, it is different from the actual W_i / W_j and it becomes $a_{ij} \approx W_i / W_j$. When a_{ij} changes slightly, the eigenvalue will also change. When the eigenvalue is not equal to λ, λ is the major eigenvalue and is close to the eigenvalue of the theoretical weight. Thus, $\lambda_{\max}$ replaces λ, as shown in Eq. 3

$$A\overline{W} = \lambda_{\max} \times \overline{W} \tag{3}$$

Calculation of maximum eigenvalue $\lambda_{\max}$ is as shown below. Pairwise Comparison Matrix A multiplied eigen vector $\overline{W}$ will be new vector $\overline{W}$, as shown in Eqs. 4 and 5.

$$A\overline{W} = \overline{W}' \tag{4}$$

$$\begin{bmatrix} W_1/W_1 & W_1/W_2 & .... & W_1/W_n \\ W_2/W_1 & W_2/W_2 & .... & W_2/W_n \\ . & . & .... & . \\ W_n/W_1 & W_n/W_2 & .... & W_n/W_n \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ . \\ W_n \end{bmatrix} = \begin{bmatrix} W_{1'} \\ W_{2'} \\ . \\ W_{n'} \end{bmatrix} \tag{5}$$

Vectors obtained are divided by the original vector, and the mean of the total is $\lambda_{\max}$, as shown in Eq. 6.

$$\lambda_{\max} = \frac{1}{n}\left(\frac{W_1}{W_1} + \frac{W_2}{W_2} + ... + \frac{W_n'}{W_n}\right) \tag{6}$$

3. Consistency testing:

It is difficult to require subjects' consistency in pairwise comparison; thus, we must conduct consistency testing to obtain Consistency Index (C.I.) in order to determine if the Pairwise Comparison Matrix of the subjects' responses is a consistency matrix. According to the suggestion of Saaty [21, 22], when C.I.=0, it means that the assessment is consistent; and C.I. ≤ 0.1 is an acceptable error. Hence, consistency is validated, as shown in Eq. 7.

$$\text{C.I.} = \frac{\lambda_{\max} - \lambda}{n-1} \tag{7}$$

According to the Positive Reciprocal matrix developed by scale 1~9; C.I. with different hierarchical numbers is Random Index (R.I.) [21, 22]. The ratio of C.I. and R.I. of a matrix with the same number of hierarchy is called C.R.(Consistence Radio), as shown in Eq. 8. Saaty [21, 22] suggested that when C.R.≤ 0.1, consistency is acceptable.

$$\text{C.R.} = \frac{C.I.}{R.I.} \tag{8}$$

3.2. Subjects

This study treats sports team coaches in Taiwan as questionnaire subjects (a total of 16), including 4 university and college experts and scholars, 3 badminton coaches of senior high school, 3 badminton team coaches of junior high school, 2 badminton coaches of elementary school, and 4 professional badminton coaches (Table 1):

Table 1. Number and percentage of experts

Category of experts	Number of experts	Percentage
Badminton team coaches of university	4	25%
Badminton coaches of senior high school	3	18.75%
Badminton team coaches of junior high school	3	18.75%
Badminton coaches of elementary school	2	12.5%
Professional badminton coaches	4	25%
Total	16	100%

4. RESEARCH RESULTS AND DISCUSSION

4.1. Consistency testing

This study examined the weights of the selection indicators of badminton players by AHP. It determined current badminton coaches' tendency to select talents. The pair comparisons of AHP must satisfy the relationship of priority and intensity. However, in the processes, some factors might cause errors, and consistency testing should be conducted. Thus, Satty [21, 22] suggested testing the consistency of the Pairwise Comparison Matrix by Consistence Index and Consistence Ratio (Table 4-1). In this study, there are 16 questionnaire subjects, including 16 questionnaires retrieved. However, 2 questionnaires failed to pass consistency testing. The results of consistency testing are as shown in Table 2.

Table 2. Result of consistency test

Objective	Major criteria	C.I.	C.R.	Sub-criteria	C.I.	C.R.
Selection of badminton players	Body type	0.0635	0.0567	Height Figure Length of arm	0.0197	0.0339
	Physical quality			Speed Reaction Bounce Muscular endurance Flexibility	0.0431	0.0385
	Physical function			Cardiopulmonary function Body fat Eyesight	0.0566	0.0977
	Psychological quality			Active High concentration Emotion management	0.0343	0.0591
	Intelligence level			Intelligence assessment Strategy comprehension and application Immediate reaction	0.0200	0.0344

4.2. Analysis of weights

4.2.1. Weights of major criteria

Major criteria include five dimensions. Calculation by Pairwise Comparison Matrix in Table 3 can lead to the weights of the 5 dimensions of the major criteria (Table 4). In the major criteria, the order of importance of the dimensions is, as follows: physical quality (0.335), body type (0.216), physical function (0.197), intelligence level (0.146), and psychological quality (0.107). Importance of these 5 dimensions is significantly different. The physical quality of current players is more important for professional coaches. The effects of "intelligence level" and "psychological quality" in the selection are insignificant. Individuals' physical quality, body type, and physical function are more important.

Table 3. Pairwise Comparison Matrix of major criteria

	Body type	Physical quality	Physical function	Psychological quality	Intelligence level
Body type	1.000	1.034	1.168	1.715	1.140
Physical quality	0.967	1.000	3.072	4.143	1.539
Physical function	0.856	0.326	1.000	1.905	2.267
Psychological quality	0.583	0.241	0.525	1.000	0.949
Intelligence level	0.877	0.650	0.441	1.053	1.000

Table 4. Weights of major criteria

	Body type	Physical quality	Physical function	Psychologica l quality	Intelligence level	weights
Body type	0.233	0.318	0.188	0.175	0.165	0.216
Physical quality	0.226	0.308	0.495	0.422	0.223	0.335
Physical function	0.200	0.100	0.161	0.194	0.329	0.197
Psychological quality	0.136	0.074	0.085	0.102	0.138	0.107
Intelligence level	0.205	0.200	0.071	0.107	0.145	0.146

4.2.2. Weights of sub-criteria

(1) Body type

The sub-criterion includes 3 items. Calculation by Pairwise Comparison Matrix in Table 5 can result in the weights of the sub-criteria (Table 6). Ranking of importance is shown, as follows: height (0.454), figure (0.326), and length of arm (0.220).

Table 5. Pairwise Comparison Matrix of sub-criteria of body type

	Height	Figure	Length of arm
Height	1.000	1.706	1.705
Figure	0.586	1.000	1.809
Length of arm	0.587	0.553	1.000

Table 6. Sub-criteria weight of body type

	Height	Figure	Length of arm	weights
Height	0.460	0.524	0.378	0.454
Figure	0.270	0.307	0.401	0.326
Length of arm	0.270	0.170	0.222	0.220

(2) Physical quality

The sub-criterion includes 5 items. Calculation by Pairwise Comparison Matrix of Table 7 can result in the weights of the sub-criteria (Table 8). Ranking of importance is shown, as follows: reaction (0.283), speed (0.230), flexibility (0.182), bounce (0.153), and muscular endurance (0.151).

Table 7. Sub-criteria Pairwise Comparison Matrix of physical quality

	Speed	Reaction	Bounce	Muscular endurance	Flexibility
Speed	1.000	1.392	0.962	1.190	1.352
Reaction	0.719	1.000	2.714	1.619	1.171
Bounce	1.040	0.368	1.000	1.171	0.971
Muscular endurance	0.840	0.618	0.854	1.000	0.891
Flexibility	0.739	0.854	1.029	1.122	1.000

Table 8. Sub-criteria weights of physical quality

	Speed	Reaction	Bounce	Muscular endurance	Flexibility	weights
Speed	0.231	0.329	0.147	0.195	0.251	0.230
Reaction	0.166	0.236	0.414	0.265	0.217	0.283
Bounce	0.240	0.087	0.152	0.192	0.180	0.153
Muscular endurance	0.194	0.146	0.130	0.164	0.165	0.151
Flexibility	0.170	0.202	0.157	0.184	0.186	0.182

(3) Physical function

The sub-criterion includes 3 items. Calculation by Pairwise Comparison Matrix in Table 9 can result in the weights of the sub-criteria (Table 10). Ranking of importance is as follows: cardiopulmonary function (0.693), body fat (0.186), and eyesight (0.121).

Table 9. Sub-criteria Pairwise Comparison Matrix of physical function

	Cardiopulmonary function	Body fat	Eyesight
Cardiopulmonary function	1.000	5.510	4.367
Body fat	0.181	1.000	2.143
Eyesight	0.229	0.467	1.000

Table 10. Sub-criteria weights of physical function

	Cardiopulmonary function	Body fat	Eyesight	weights
Cardiopulmonary function	0.709	0.790	0.582	0.693
Body fat	0.129	0.143	0.285	0.186
Eyesight	0.162	0.067	0.133	0.121

(4) Psychological quality

The sub-criterion includes 3 items. Calculation by Pairwise Comparison Matrix in Table 11 can result in the weights of the sub-criteria (Table 12). Ranking of importance is as follows: high concentration (0.444), active (0.319), and emotion management (0.237).

Table 11. Sub-criteria Pairwise Comparison Matrix of psychological quality

	Active	High concentration	Emotion management
Active	1.000	0.925	1.043
High concentration	1.081	1.000	2.467
Emotion management	0.958	0.405	1.000

Table 12. Sub-criteria weights of psychological quality

	Active	High concentration	Emotion management	weights
Active	0.329	0.397	0.231	0.319
High concentration	0.356	0.429	0.547	0.444
Emotion management	0.315	0.174	0.222	0.237

(5) Intelligence level

The sub-criterion includes 3 items. Calculation by Pairwise Comparison Matrix in Table 13 can result in the weights of the sub-criteria (Table 14). Ranking of importance is, as follows: strategy comprehension and application (0.465), intelligence assessment (0.336), and immediate reaction (0.199).

Table 13. Sub-criteria Pairwise Comparison Matrix of intelligence level

	Intelligence assessment	Strategy comprehension and application	Immediate reaction
Intelligence assessment	1.000	0.878	1.394
Strategy comprehension and application	1.139	1.000	2.886
Immediate reaction	0.718	0.347	1.000

Table 14. Sub-criteria weight of intelligence level

	Intelligence assessment	Strategy comprehension and application	Immediate reaction	weights
Intelligence assessment	0.350	0.395	0.264	0.336
Strategy comprehension and application	0.399	0.449	0.547	0.465
Immediate reaction	0.251	0.156	0.189	0.199

4.2.3. Weights and ranking of all criteria

After the calculation of hierarchical analysis, we can obtain the weights of criteria (Table 15). Ranking of the Top 10 is cardiopulmonary function (0.136), height (0.098), reaction (0.095), speed (0.077), figure (0.070), strategy comprehension and application (0.068), flexibility (0.061), bounce (0.051), muscular endurance (0.051), and intelligence assessment (0.049). The total weight of the 10 indicators is 75.6%. Indicators that are less important: eyesight, emotion management, immediate reaction, active, body fat, high concentration, and length of arm. The total weight of the 7 indicators is only 24.4%.

Table 15. Weights and ranking of selection indicators of badminton players

Objective	Major criteria	Weights	Sub-criteria	Hierarchical weights	Overall weights	Overall ranking
Selection of Badminton players	Body type	0.216	Height	0.454	0.09801	2
			Figure	0.326	0.07037	5
			Length of arm	0.220	0.04760	11
	Physical quality	0.335	Speed	0.230	0.07712	4
			Reaction	0.283	0.09480	3
			Bounce	0.153	0.05119	8
			Muscular endurance	0.151	0.05066	9
			Flexibility	0.182	0.06094	7
	Physical function	0.197	Cardiopulmonary function	0.693	0.13645	1
			Body fat	0.186	0.03656	13
			Eyesight	0.121	0.02377	17
	Psychological quality	0.107	Active	0.319	0.03411	14
			High concentration	0.444	0.04745	12
			Emotion management	0.237	0.02534	16
	Intelligence level	0.146	Intelligence assessment	0.336	0.04897	10
			Strategy comprehension and application	0.465	0.06770	6
			Immediate reaction	0.199	0.02895	15

5. CONCLUSIONS

Scientific selection of badminton players is a complicated and important issue for many badminton coaches in Taiwan. Therefore, by literature review, the Delphi method, and AHP, this study analyzed and constructed a selection model, and determined the indicators and weights of badminton coaches' selection. The proposed a selection model of badminton players can serve as scientific and objective reference for badminton coaches. The selection framework contains 5 dimensions: (1) body type; (2) physical quality; (3) physical function; (4) psychological quality; (5) intelligence level, including 17 items. The top 10 indicators are cardiopulmonary function, height, reaction, speed, figure, strategy comprehension and application, flexibility, bounce, muscular endurance, and intelligence. Importance of the ten indicators achieves 75.6%.

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