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Key Determinants of Athletic Success: A Fuzzy AHP Approach

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ABSTRACT

Athletic success is influenced by multiple factors, requiring a structured approach to identify and prioritize the key contributors to success. The Fuzzy Analytical Hierarchy Process (AHP) method provides a systematic decision-making framework to evaluate these factors by incorporating expert judgment and handling uncertainty in pairwise comparisons. This study employs the fuzzy AHP method to assess and rank the factors influencing an athlete's successful in sports. Two experts, both lecturers from the Faculty of Sports Science and Recreation at UiTM Perlis, were involved in the evaluation due to their extensive experience and achievements in sports, making them suitable decision-makers for this study. Based on the findings, the factor of facilities plays a crucial role in sports performance, with a normalized weight of 0.4658, while coaching is identified as the most critical sub-factor, receiving a normalized weight of 0.2399. These results demonstrate that Fuzzy AHP effectively handles uncertainty and subjective judgments, providing valuable insights for athletes, coaches, and sports management in optimizing training and resource allocation.

1. INTRODUCTION

An athlete is a person who is trained or skilled in sports, physical activities, or competitive games that require strength, agility, endurance, or coordination. Athletes can participate in various sports, ranging from individual events like running and swimming to team sports like football and basketball. They undergo rigorous training to improve their performance and often compete at different levels, from amateur to professional and even international competitions like the Olympics.

Achieving success as an athlete requires a combination of various factors, including natural talent, physical fitness, technical skills, discipline, access to sports facilities and psychological strength. These

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factors may influence the overall performance of an athlete and determine their ability to compete at higher levels (Kubiak, 2012). However, prioritizing these factors can be complex, as they often involve subjective judgments and uncertainties. This is because each type of sport requires a different level of emphasis on each factor, whereby each athlete may respond differently to these factors. Additionally, factors such as psychological strength and talent are difficult to measure objectively, making the decision-making process more challenging. The influence of external elements, particularly access to training facilities, further adds to the complexity of analysing the most important factors for athletic success.

Once complexity and ambiguity situation occur in the process of analysing or evaluation, one of the most common approaches will be applied is the fuzzy Analytic Hierarchy Process (Fuzzy AHP). This method was integrated based on the classical Analytic Hierarchy Process (AHP) by Van Laarhoven and Pedrycz (1983). They extended the traditional AHP by incorporating fuzzy logic to handle uncertainty and imprecision in decision-making. Their approach used fuzzy numbers to represent pairwise comparisons, making AHP more suitable for real-world problems with vague or subjective judgments.

Specifically, this study aims to identify the key factors and sub-factors that contribute to athletic success, rank the main factors using the fuzzy AHP method, and further rank the sub-factors accordingly. This study focuses on four primary factors that athletes should consider in achieving success, which are discipline, facilities, talent, and psychology. The analysis will be conducted based on the sub-factors associated with each of these main factors. It is hoped that this study will provide valuable insights for athletes by highlighting the most critical factors for success. Additionally, it will offer significant contributions to the Ministry of Youth and Sports by providing a structured analysis to guide sports development programs and talent management strategies.

This paper is organized as follows. In Section 2, some literature reviews are provided on the fuzzy AHP and the factors that related to athletic success. The methodology used for the study is provided in Section 3. Next, the results and discussion are presented in Section 4 and finally in Section 5, the conclusion is drawn.

2. LITERATURE REVIEW

This section outlines the theories behind fuzzy AHP and the factors considered in this study.

2.1 Fuzzy analytical hierarchy process

The Fuzzy AHP is an extension of the traditional AHP that incorporates fuzzy logic to handle uncertainty and imprecision in decision-making. Basically, the fuzzy AHP method relies on data collected through questionnaires or interviews, typically from experts with relevant knowledge in the field. These experts provide valuable insights that shape the decision-making process. As Saaty and Ozdemir (2015) highlight, fuzzy AHP is based more on expert opinions than on strict statistical analysis. This means that the number of experts involved matters less than their level of expertise in the subject.

One of the strengths of fuzzy AHP is its ability to handle pairwise comparisons, which help structure complex decisions by ranking different factors in a hierarchical way (Zabihi et al., 2020). Since AHP captures human judgment, which is often complicated to handle, it has frequently been selected to be applied in solving the multi-criteria decision-making (MCDM) problems.

As for now, researchers have applied fuzzy AHP in many areas. Some examples include selecting contractors (Rashid et al., 2020), identifying groundwater potential zones in Bangladesh (Sresto et al., 2021), assessing land conflict risks (Peng et al., 2021), choosing effective strategies for COVID-19 prevention (Idris et al., 2023), evaluating nasyid competitions (Aziz et al., 2023), and selecting the best student award (Aziz et al., 2023). More recently, in 2024, there is a study that has explored how Fuzzy SERVQUAL methods can be integrated into Fuzzy AHP to measure service quality and satisfaction in

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educational programs (Aulia et al., 2024). In summary, based on the significant number of studies, Fuzzy AHP has proven to be consistently relevant in real-world applications.

2.2 Factors influencing athletes' success

There are many factors that can influence an athlete's success. In this study, four key factors are considered, which are the athlete's discipline, natural talent, available facilities, and psychological aspects. A literature revies has been conducted to explore these factors.

2.2.1 Discipline

According to Denison et al. (2017), discipline is one of the most important criteria that athletes should consider. Discipline is essential in any sport because it builds an athlete's attitude, helping them stay focused and achieve their goals without distractions. It also provides athletes with a set of rules that they can implement in their daily lives, allowing them to live efficiently and effectively. When athletes develop discipline, they can make small sacrifices for a better future. One crucial aspect of discipline is understanding and adhering to rules. Rules provide structure and guidelines that help athletes stay focused on their goals (Graham & Burns, 2020). By following the rules of their sport, athletes learn to channel their efforts toward specific objectives.

Another crucial factor in an athlete's discipline is good time management (Macquet & Skalej, 2015). Athletes who manage their time well can balance training, competitions, and personal life more effectively. They need to plan their daily schedule by setting time for training, rest, proper meals, and recovery sessions. However, they often face challenges such as a tight training schedule and academic responsibilities. Therefore, using a schedule or a to-do list can help them organize their activities better. Good time management not only improves performance in sports but also helps build a more responsible character.

2.2.2 Facilities

The important facilities for athletes include training venues, sports equipment, and quality coaches. A suitable venue with basic facilities such as fields, courts, tracks, or swimming pools that meet international standards is crucial to ensure effective training (Nacar et al., 2013). In addition, extra facilities like changing rooms, rest areas, and physiotherapy spaces are also needed to maintain the comfort and well-being of athletes. A good venue not only provides a comfortable training space but also helps improve an athlete's performance in competitions by offering a safe and conducive environment for practice and competition at both national and international levels.

Besides that, sports equipment is also very important in helping an athlete succeed (Diejomaoh et al., 2015). High-quality and suitable equipment for each sport can improve performance and reduce the risk of injuries. For example, running shoes designed for better support help protect the feet, while lightweight and durable badminton rackets allow players to control their movements more effectively. Regular maintenance of equipment is also essential to ensure it remains in good condition and safe to use.

A good coach is also an important element in an athlete's success. Coaches help athletes improve their skills, techniques, and performance by providing technical knowledge, strategic guidance, and structured training. They not only understand the technical aspects of the sport but can also adjust training sessions according to the athlete's level and needs (Suyudi, 2023). In addition, experienced coaches can provide motivation, develop discipline, and guide athletes in both mental and physical aspects to ensure they are always in their best condition for training and competitions.

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2.2.3 Talent

Talent in sport refers to an individual's natural ability or potential to excel in a specific sport, which can be seen in their technical skills and physical attributes (such as strength, speed, and endurance). It is often a combination of genetic traits, such as strength, speed, and agility, along with mental attributes like determination, focus, and resilience. However, talent alone is not enough for success, it must be developed through consistent training, proper coaching, and a supportive environment. According to Wilson et al. (2017), players with natural talent, combined with greater skill and balance, were more likely to perform better when given proper training. Additionally, athletes with great talent often show a quick ability to learn new techniques, adapt to different game situations, and perform at a high level under pressure.

2.2.4. Psychology

Psychology helps athletes set meaningful goals and maintain motivation throughout their training and competition journey (Bulent et al., 2017). Every athlete needs strong psychological well-being in their life. There are three key psychological factors that athletes should consider, with the first being motivation. Ibrahim et al. (2016) states that motivation provides athletes with the determination and focus needed to achieve their goals. Whether aiming to win a championship, break a personal record, or qualify for the Olympics, motivation keeps athletes focused on their objectives. It helps them maintain a clear vision of what they want to accomplish and drives their efforts toward success.

The second factor is mental rehabilitation, which involves mental training to prepare an athlete's mind for peak performance, both mentally and physically. Covassin et al. (2015) highlights that mental attributes such as confidence, focus, self-belief, and motivation are crucial for success in sports. These factors can help athletes reach higher levels of performance when combined with physical talent. Lastly, goal setting plays a crucial role in providing athletes with clear direction and focus. Baker et al. (2003) explains that setting specific goals, such as improving performance, winning an award, or reaching a particular ranking, help athletes channel their efforts, prioritize training, and align their actions with their objectives.

3. RESEARCH METHODOLOGY

The methodology of the study is designed as illustrated in the following Fig. 1.

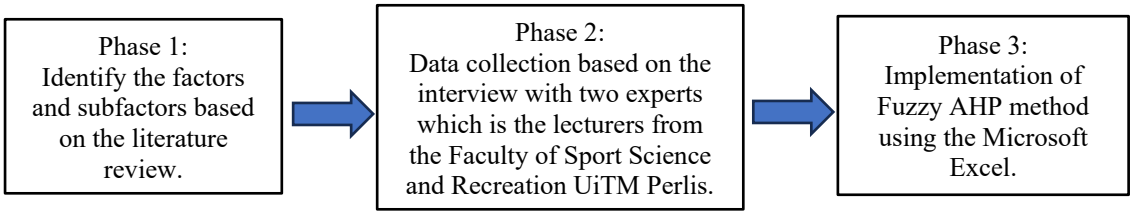

Fig. 1. Research methodology phases

The detail description is given as follows.

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3.1 Phase 1: Identify the criteria and sub-criteria based on the literature review

As discussed in Subsection 2.2, the main factors (criteria) and their corresponding sub-factors (sub-criteria) influencing athletes' success were identified from past studies. These elements, which have been elaborated in the literature review, are summarized in Table 1 for clarity.

Table 1. Factors and sub-factors of athletes' success

Factor	Sub-factors
	Time -management
Discipline	Attitude
	Rules
	Equipment
Facilities	Sport facilities
	Coaching
	Skill
Talent	Fitness
	Physical
	Motivation
Psychology	Mental rehab
	Goal setting

3.2 Phase 2: Data collection

The data collection process involves conducting interviews with experts in the field. In this study, the experts consist of two lecturers from the Faculty of Sport Science and Recreation, UiTM Perlis, who have extensive experience and notable achievements in sports. These experts provide valuable insights based on their expertise in athletic performance, coaching, and sports management. The interviews were conducted using a structured questionnaire that consisted of two sections: a demographic section (collecting information such as name, position, and qualification) and the main questionnaire. Section A contained questions comparing each main factor to determine effective ways of achieving success as an athlete, while Section B involved questions comparing the sub-factors in relation to each main factor.

3.3 Phase 3: Implementation of Fuzzy AHP

In this study, Fuzzy AHP is implemented using Microsoft Excel, which offers a practical and accessible approach for analyzing complex multi-criteria decision-making problems without the need for specialized software. The following section presents a step-by-step guide to the implementation process in Excel.

Step 1: Construct the pairwise comparison matrix (PCM)

In constructing the pairwise comparison matrix (PCM), the Saaty scale (1 to 9) is used, according to the following Table 2.

Table 2. Linguistic variable for pairwise comparison of each criterion

Scale	Reciprocal	Linguistic Variables
1	1	Equally Important
2	1/2	Equally to weakly important
3	1/3	Weakly important
4	1/4	Weakly to fairly important
5	1/5	Strongly Important
6	1/6	Fairly to strongly important
7	1/7	Strongly Important
8	1/8	Strongly to absolutely important
9	1/9	Absolutely Important

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In Microsoft Excel, these values are entered in a matrix format using separate column for lower, middle and upper fuzzy numbers, which based on the judgement provided by the experts. The general form of the PCM is given as follows.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix}$$

where $a_{11}, a_{12}, \ldots, a_{nn}$ represent the input or values assigned by the experts based on a scale of 1 to 9. These values correspond to linguistic variables, as shown in the Table 2. It is important to note that $a_{ji} = 1/a_{ij}$ and $a_{ii} = 1$ for every $i, j = 1,2,3,\ldots,n$. In other words, if the preferences value p_{ij} appears in the upper triangle of the matrix, then its reciprocal $a_{ji} = 1/a_{ij}$ must be in the lower triangle, and vice versa. As the result, the PCM denoted as matrix *A*, which is always positive and symmetric (Bozanic & Pamucar, 2013).

Step 2: Calculate the largest eigenvalue

Before obtaining the largest eigenvalue denoted as $\lambda_{\max}$, it is necessary to determine the priority vector, which is obtained by averaging the rows of the normalized PCM. Then, the weighted sum values are computed by multiplying the values in the PCM with the priority vector. From that, the values of *W* are then determined using the following Eq. (1).

$$W = \frac{weighted\ sum\ value}{criteria\ weight} \tag{1}$$

Hence, $\lambda_{\max}$ is obtained by averaging the values in *W*.

Step 3: Compute the Consistency Ratio (CR)

The value of the CR is used to verify the consistency of judgements, where it must be 0.1 or lower (Saaty, 1980). Otherwise, PCM should be revised, or data collection should be reconducted. The formula for CR is determined using Eqs (2) and (3).

$$CR = \frac{Consistency\ index\ (CI)}{Random\ consistency\ index\ (RI)} \tag{2}$$

where

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{3}$$

Here, *n* denotes the total number of factors. The random consistency index (RI), which depends on the number of factors, is provided in Table 3 (Saaty, 1980).

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Table 3. Random consistency index

Number of factors, *n*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ratio Index, *RI*	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

Step 4: Performed the fuzzy pairwise comparison matrix

Next, the entries in the PCM based on the interview are converted into their corresponding triangular fuzzy numbers (TFNs) of (l,m,u) as shown in Table 4.

Table 4. Linguistic variable for the fuzzy pairwise comparison of each criterion

Classical Saaty' Scale	**Triangular Fuzzy Number**	**Triangular Fuzzy Reciprocal Number**	**Linguistic Variables**
1	(1, 1, 1)	(1, 1, 1)	Equally Important
2	(1, 2, 3)	(1/3, 1/2, 1)	Weakly Important
3	(2, 3, 4)	(1/4, 1/3, 1/2)	Fairly Important
4	(3, 4, 5)	(1/5, 1/4, 1/3)	Strongly Important
5	(4, 5, 6)	(1/6, 1/5, 1/4)	Absolutely Important
6	(5, 6, 7)	(1/7, 1/6, 1/5)	
7	(6, 7, 8)	(1/8, 1/7, 1/6)	Intermittent Values
8	(7, 8, 9)	(1/9, 1/8, 1/7)	
9	(9, 9, 9)	(1/9, 1/9, 1/9)	

Thus, the PCM becomes a fuzzy PCM, $\tilde{A} = (l,m,u)$ as follows.

$$\tilde{A} = \begin{bmatrix} (1,1,1) & \tilde{A}_{12} & \cdots & \tilde{A}_{1n} \\ \tilde{A}_{21} & (1,1,1) & \cdots & \tilde{A}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{A}_{n1} & \tilde{A}_{n2} & \cdots & (1,1,1) \end{bmatrix}$$

Since there were two experts, each expert's preference had to be averaged and calculated using the Eq. (4).

$$Average\left(l_{ij}, m_{ij}, u_{ij}\right) = \frac{\sum_{k=1}^{k}\left(l_{nn}^{k}, m_{nn}^{k}, u_{nn}^{k}\right)}{k} \tag{4}$$

where k represents the number of experts.

Step 5: Calculate the geometric mean

The fuzzy geometric mean $\tilde{r}_i$ for each factor i is determined using the following Eq. (5).

$$\tilde{r}_i = \left(\tilde{a}_{i1} \times \tilde{a}_{i2} \times \ldots \times \tilde{a}_{in}\right)^{\frac{1}{n}} \tag{5}$$

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Then, the vector summation of the geometric mean and its reciprocal is computed by employing the following Eqs. (6) and (7) respectively.

$$\text{Vector summation} = \sum_{i=1}^{n} \tilde{r}_i = \left(\sum l_{r_i}, \sum m_{r_i}, \sum u_{r_i} \right) \tag{6}$$

$$\text{Reciprocal} = \left(\sum_{i=1}^{n} \tilde{r}_i \right)^{-1} = \left(\frac{1}{\sum u_{r_i}}, \frac{1}{\sum m_{r_i}}, \frac{1}{\sum l_{r_i}} \right) \tag{7}$$

Next, the fuzzy weight of the vector $\tilde{w}_i$ is obtained by multiplying the geometric mean $\tilde{r}_i$ with the reciprocal obtained in Eq. (7) with in ascending order. The formula of the fuzzy weight is given by the Eq. (8).

$$\tilde{w}_i = \tilde{r}_i \times \left(\sum_{i=1}^{n} \tilde{r}_i \right)^{-1} \tag{8}$$

Then defuzzification of the $\tilde{w}_i$ is calculated using Eq. (9).

$$w_i = \frac{l_i + m_i + u_i}{3} \tag{9}$$

Step 7: Ranking of the factor

The ranking and selection of decisions are conducted based on the normalized non-fuzzy weights. The factors are arranged in descending order, with the highest value representing the most significant factor. The ranking is determined using the following Eq. (10).

$$Z_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{10}$$

The factor with the highest normalized weight is considered the most important. All steps are repeated to all sub-factors that influence factors for athletes' success. Meanwhile, to calculate the normalization of sub-factor, the weight of sub-factor must be multiplied with the weight of factors to form global weight using the Eq. (11).

$$\text{Global Weight} = \text{Weight of Factor} \times \text{Weight of Sub-factor} \tag{11}$$

4. RESULT AND DISCUSSION

This section presents and discusses the analysis of the factors and sub-factors that contribute to athletes' success. The results are presented in Table 5 as follows.

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Table 5. Fuzzy weight, non-fuzzy weight, and normalized weight of all factors

Factor	Fuzzy Weight	Non-Fuzzy Weight	Normalized Weight	Rank
Discipline	(0.1495, 0.2565, 0.4040)	0.2700	0.2539	2
Facilities	(0.3223, 0.4733, 0.6903)	0.4953	0.4658	1
Talent	(0.1444, 0.2242, 0.3738)	0.2475	0.2327	3
Psychology	(0.0327, 0.0460, 0.0729)	0.0505	0.0475	4

According to Table 5, the fuzzy AHP method identifies facilities as the primary factor for making successful athletes, with a normalized weight of 0.4658. The subsequent factor is discipline, with a normalized weight of 0.2539, followed by talent with a normalized weight of 0.2327, and psychology with a normalized weight of 0.0475. The experts agreed that these facilities play a crucial role in enabling athletes to enhance their skills, improve their physical fitness, and practice under optimal conditions. High-quality facilities offer athletes a suitable environment for training. Having safe facilities allows athletes to focus on their performance without unnecessary concern for their well-being. State-of-the-art facilities can provide athletes with an edge by offering cutting-edge technology and equipment. For example, advanced sports science laboratories can assess athlete's physical attributes, monitor their performance, and provide data-driven insights to enhance training methods. Specialized facilities like swimming pools with wave machines or running tracks with force plates can aid in specific training needs.

On the other hand, discipline takes the second spot, emphasizing the vital role of commitment, work ethic, and adherence to training and competition routines. Athletes who maintain a focused and dedicated approach, follow structured regimens, and exhibit self-control and determination are more likely to achieve consistent performance, skill development, and long-term goals. Talent is ranked third, recognizing the significance of natural ability, skill, and aptitude in sports. Athletes with inherent attributes and physical capabilities possess a competitive edge, which serves as a foundation for further growth through training, practice, and skill refinement. Finally, psychology holds the fourth position, highlighting the importance of the mental aspect of sports. Sports psychology helps athletes cultivate a resilient mindset, motivation, focus, and confidence. Mental strength and psychological well-being are crucial for consistent performance, handling pressure, and overcoming challenges.

Subsequently, the rank of the sub-factors is presented in the following Table 6.

Table 6. Fuzzy weight, non-fuzzy weight, and normalized weight of all sub-factors

Factor	Weight of Factor	Sub-factor	Weight of Sub-factor	Weight of Factor × Weight of Sub-factor	Normalized Weight of Sub-factor	Rank
Discipline	0.2539	Time-Management	0.2535	0.0644	0.0644	8
		Attitude	0.2887	0.0733	0.0733	6
		Rules	0.4578	0.1162	0.1163	4
Facilities	0.4658	Equipment	0.2162	0.1007	0.1007	5
		Sport Facilities	0.2689	0.1253	0.1253	3
		Coaching	0.5149	0.2398	0.2399	1
Talent	0.2327	Skill	0.1030	0.0240	0.0240	10
		Fitness	0.2938	0.0684	0.0684	7

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Psychology	0.0475	Physical	0.6031	0.1403	0.1404	2
		Motivation	0.3514	0.0167	0.0167	11
		Mental Rehab	0.0728	0.0035	0.0035	12
		Goal setting	0.5757	0.0273	0.0273	9

Table 6 presents the ranking of sub-factors contributing to an athlete's success. Coaching is identified as the most important factor with a normalized weight of 0.2399, followed by physical attributes (0.1404), sport facilities (0.1253), rules (0.31163), equipment (0.1007), attitude (0.0733), fitness (0.0684), time management (0.0644), goal setting (0.0273), skill (0.0240), motivation (0.0167), and mental rehabilitation (0.0035).

Coaching plays a vital role in athlete development, providing guidance, technical expertise, and mentorship to enhance performance. Physical attributes, including endurance, strength, flexibility, and body composition, are essential for optimal performance and injury prevention. Access to well-equipped sport facilities supports effective training and skill development, while adherence to rules ensures fair competition and sportsmanship. Proper equipment is crucial for safety and performance, with sport-specific gear enhancing efficiency and effectiveness.

An athlete’s attitude influences their determination, resilience, and discipline, all of which contribute to long-term success. Maintaining fitness is equally important, as it enhances endurance and reduces the risk of injuries. Effective time management allows athletes to balance training, recovery, and personal commitments efficiently. Goal setting provides direction and motivation, ensuring athletes remain focused on their improvement. Skill development involves mastering sport-specific techniques and tactical understanding, which are critical for competition. Motivation sustains an athlete’s effort and helps overcome challenges, whether driven by personal fulfillment or external rewards. Lastly, mental rehabilitation supports athletes in managing stress, setbacks, and performance anxiety, fostering mental resilience and overall well-being.

In conclusion, achieving success in sports requires a holistic approach that integrates coaching, physical conditioning, access to facilities, adherence to rules, proper equipment, and mental resilience. While the importance of each sub-factor may vary based on the sport and individual circumstances, their balanced application contributes to overall growth and athletic achievement.

5. CONCLUSION

Based on the objectives stated in the study, the main factors and sub-factors contributing to athlete success were identified and ranked using the fuzzy AHP method. The data for the study were collected from two expert lecturers in the Faculty of Sport Science and Recreation, chosen based on their experience and achievements in sports.

The fuzzy AHP method, which combines fuzzy theory and AHP, effectively achieved the study's objectives by identifying and ranking the main factors and sub-factors that play a crucial role in athlete success. The findings indicate that facilities emerged as the most important factor, followed by discipline, talent, and psychology. Among the sub-factors, coaching exhibited the highest significance, while mental rehab had the lowest level of importance.

In conclusion, this study successfully fulfilled its objectives of identifying and ranking the main factors and sub-factors influencing athlete success using the fuzzy AHP method. The results provide valuable insights for understanding the key elements that contribute to athlete success and can inform decisions related to athlete development and performance.

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7. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

8. AUTHORS' CONTRIBUTION

Khairu Azlan Abd Aziz: Supervision, conceptualisation, development of methodology, and formal analysis; **Wan Suhana Wan Daud**: Data interpretation, manuscript writing, and final editing.; **Mohd Fazril Izhar Mohd Idris**: Conceptualisation, methodology development, and formal analysis; **Muhammad Amsyar Izmi**: Literature review, data collection, simulation of results, and validation; **Rizauddin Saian**: Language editing and contribution to the interpretation of results.

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