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Association rule mining for college students' physical fitness and athletic performance: an empirical analysis based on the Apriori algorithm

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ABSTRACT

This study utilizes the Apriori algorithm for association rule mining, aiming to deeply explore the intrinsic connection between college students' physical health and sports performance. The relevant definitions of association rule mining and the application process of Apriori algorithm in this study are elaborated in detail, including data preprocessing, frequent item set generation, and association rule extraction. Through empirical analysis, various combinations of physical fitness factors affecting college students' athletic performance and the corresponding association rules are revealed. For example, under the condition of support degree of 0.598 and confidence level of 0.709, when male students' "stiffness upward grade" is passing, their athletic performance is also passing. By mining the correlation rules between college students' sports performance and physical health, it provides scientific basis and targeted suggestions for physical education and students' health management in colleges and universities.

Keywords: Apriori algorithm, association rules, physical health, sports performance

1. Introduction

The rapid development of science and technology and economy, and the continuous improvement of living standards have brought better material enjoyment to adolescents, and the introduction of western fast food culture has gradually changed the dietary structure of adolescents, and the excessive intake of high-nutritional, high-fat and high-calorie food easily leads to the rising rate of overweight and obesity, and the probability and risk of suffering from cardiovascular diseases, such as hypertension and diabetes mellitus, have also been increasing [1-3]. Compared with international developed countries, China's sports career has a certain gap in the system and training and other aspects [4].

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The performance of young people is more obvious, and they are almost unwilling to participate in sports after school. The emergence of a series of modern technological products, such as exam-oriented education, heavy homework, cell phones, television, computers, short videos, online games, etc., has reduced the attractiveness of sports to adolescents, and reduced the time and energy of adolescents to participate in sports [5-7]. The reduction of sports stimulation is reflected in the phenomenon of gradual deterioration of some of the motor functions of adolescents, accompanied by problems such as vision loss and immunity decline [8-9]. The issue of adolescents' physical health remains a hotspot of social concern, and in order to promote the coordinated development of adolescents' cultural learning and physical exercise, the state has introduced relevant policies to strengthen the work of school sports. In recent years, the physical health status of college students has attracted much attention [10-12]. The excellent rate of Chinese students' physical fitness and health attainment has gradually risen, students' height, weight, chest circumference and other morphological development indicators have continued to improve, the level of students' lung capacity has been comprehensively improved, primary and secondary school students' qualities such as flexibility, strength, speed and endurance have shown improvement, and the quality of physical education teaching has been continuously optimized and improved [13-15]. However, there is still a downward trend in the physical fitness of college students [16].

There are gender differences in college students' physical fitness and health awareness and behavior, and male students are more fond of sports than female students and are more likely to develop good physical exercise habits [17-18]. In the context of the “Healthy China” strategy, promoting the development of college students' physical health requires strengthening the education of health concepts, enhancing the government's awareness of its responsibility, establishing a physical health management platform and an early warning mechanism, and actively promoting the development of extracurricular sports activities [19-20]. Teenagers are the key period of learning and growth, generally because of the heavy learning tasks, do not have much time to participate in sports, often obesity, vision loss and other problems, is not conducive to the healthy growth of adolescents, resulting in adolescents' physical health show a downward trend year by year [21-22]. And sports can promote the healthy development of adolescents' body and mind from various aspects, and also can carry out the cultivation of moral literacy, so sports have an important practical significance for the growth and development of adolescent groups [23-24].

In this paper, we focus on the logical association between college students' physical fitness and sports performance, based on the Apriori algorithm to mine the association rules between college students' physical fitness test data and sports performance score data. The calculation methods of support degree, confidence degree and enhancement degree in association rule mining are introduced in detail, and the operation process of discovering association rules by Apriori algorithm is also elaborated. The physical fitness test data and sports performance score data of college students in a university are collected, and the data are cleaned and discretized to ensure that the data are more suitable for the application range of Apriori algorithm. The association rule mining of physical fitness test and sports performance data of male and female students respectively is aimed at revealing the intrinsic connection between college students' physical fitness and sports performance. Based on the empirical research analysis, the validity of the results of this paper is demonstrated, and rationalization suggestions are given for physical education and student health management in colleges and universities, while the limitations of this paper are summarized to provide theoretical support for further optimization of future research.

2. Research methodology

2.1. Association Rule Mining

Association rules are a task in data mining [25], which reflect the interdependence and correlation between one thing and other things, revealing unknown dependencies between elements. A dependency exists between two elements, if the value of one element A can be introduced from the value of another element B, it indicates that there is some kind of inherent association between these two elements to obtain the required information.

2.1.1. Association rules. Let $I=\{i_1,i_2,\cdots,i_m\}$ be the set of all items, and D be a transaction database consisting of a set of TID transactions with unique identifiers. Let $X\subseteq I$ be a collection of items called an itemset. If itemset X contains k items, it is said to be an itemset k.

Let $x\subseteq I$, the support $Support(X)$ in item set X be the percentage of supported X transactions in the transaction database D over all transactions in the transaction database, denoted as:

$$Support(X)=\frac{Support(X)}{DataBase(D)}\times 100\% \tag{1}$$

An item set is said to be a frequent item set, or a large item set, if the support of the item set is greater than a minimum support threshold given by the user.

Let $X\subset I, Y\subset I$, and $X\cap Y=\varnothing$, then the implication expression $X\Rightarrow Y$ is called an association rule, and the support of association rule $X\Rightarrow Y$ is the percentage of occurrences of $X\cup Y$ in transaction database D out of the total number of transactions in D, denoted as:

$$Support(X\Rightarrow Y)=\frac{Support(X\cup Y)}{DataBase(D)}\times 100\% \tag{2}$$

Let $X\subset I, Y\subset I$, and $X\cap Y=\varnothing$. The ratio of the number of transactions containing $X\cup Y$ to the number of transactions containing X in the transaction database D is called the trust level, also known as confidence or trustworthiness, of the association rule $X\Rightarrow Y$, and is denoted as:

$$Confidence(X\Rightarrow Y)=\frac{Support(X\cup Y)}{Support(X)}\times 100\% \tag{3}$$

The degree of lift represents the ratio of the probability of a condition containing X that also contains Y to the probability of a condition not containing X but containing Y, denoted as:

$$lift=\frac{P(X\cup Y)}{P(X)P(Y)}\times 100\% \tag{4}$$

2.1.2. Apriori algorithm. Apriori algorithm is a highly influential algorithm for discovering association rules [26], which is characterized by the fact that a subset of a frequent itemset must be a frequent itemset and a superset of an infrequent itemset must be an infrequent itemset. The set of items of greater length is formed by the known frequent itemsets and is called candidate frequent itemset. The set of candidate frequent itemsets is the set of items that are likely to be candidate frequent itemsets. The algorithm first calculates all candidate 1-item sets C_1, and finds the frequent 1-item sets L_1 from C_1. Then, it determines the candidate 2-item sets C_2 according to L_2, and finds all frequent 2-item sets L_2 according to C_2. Then it determines the candidate 3-item sets C_3 according to L_2, and finds all frequent 3-item sets L_3 according to C_3, and so on until it cannot find the frequent item sets of higher dimensions, and the flow is shown in Fig. 1.

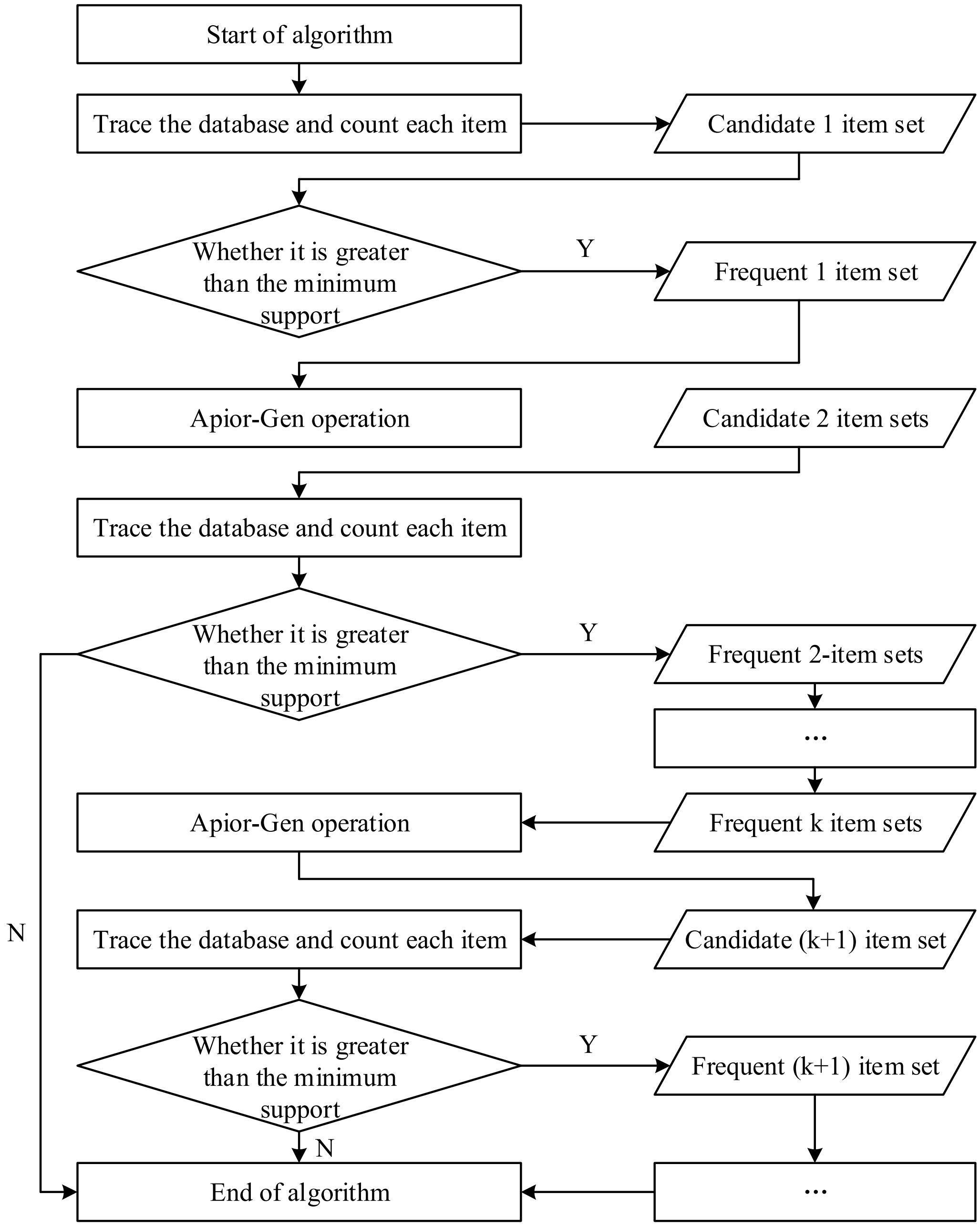

Fig. 1. Flowchart of Apriori algorithm

2.2. Data collection and pre-processing

2.2.1. Data collection. In this study, physical fitness test data and athletic performance data were collected from 21,231 college students in a university during 2021-2024. The physical fitness test data covered a number of items in the National Physical Fitness Standards for Students [27], including height, weight, lung capacity, 50-meter run, standing long jump, seated forward bending, pull-ups (male)/sit-ups (female), and 1,000-meter run (male)/800-meter run (female), and so on, and each item corresponded to a specific test score. Athletic performance data is quantified into a specific athletic performance score through a comprehensive assessment of students' performance in interscholastic athletic competitions, physical education courses, and extracurricular athletic activities.

2.2.2. Data pre-processing:

1) Data Cleaning. The collected data were cleaned to check and deal with missing values, duplicates and outliers. For missing values, the mean fill method is used, which is based on the average of all non-missing values of the item. For duplicate values, duplicate records are directly deleted. For abnormal values, identify and correct them by setting a reasonable range of values, e.g., if the 50-meter running performance exceeds the maximum of the normal range, it will be considered as an abnormal value to be corrected.
2) Data discretization. Since the Apriori algorithm is suitable for processing discrete data, the continuous physical fitness test scores and sports performance test scores are discretized. The equal-width discretization method is used to divide the scores of each item into a number of intervals, for example, the 50-meter run score is divided into four intervals: excellent, good, passing, and failing. A similar discretization was performed for the athletic performance scores, which were divided into different grade intervals.

3. Empirical analysis

3.1. Analysis of the results of descriptive statistics

The basic distribution of this data was observed by performing the basic statistical analysis of each variable. This physical fitness test and athletic performance data contains a total of 9 variables, 33 variable categories, and 21,231 data samples, and the results of descriptive statistics are shown in Table 1.

Table 1. Student data descriptive statistics

Variable	Variable class	Number			Proportion/%		Cumulative ratio/%	
		Boys	Girls	Total	Boys	Girls	Boys	Girls
Height weight	Fatness	493	242	735	4.80	2.21	4.80	2.21
	Overweight	1562	1048	2610	15.21	9.56	20.01	11.77
	Normal	7648	9327	16975	74.45	85.11	94.46	96.88
	Low weight	569	342	911	5.54	3.12	100.00	100.00
Lung capacity	Excellence	3987	3412	7399	38.81	31.13	38.81	31.13
	Good	2348	2063	4411	22.86	18.82	61.67	49.95
	Passing	3572	5239	8811	34.77	47.81	96.44	97.76
	Fail	365	245	610	3.56	2.24	100.00	100.00
50m run	Excellence	2291	159	2450	22.30	1.45	22.30	1.45
	Good	1542	864	2406	15.01	7.88	37.31	9.33
	Passing	6348	9739	16087	61.80	88.87	99.11	98.20
	Fail	91	197	288	0.89	1.80	100.00	100.00
1000m/800m run	Excellence	162	458	620	1.58	4.18	1.58	4.18
	Good	819	1483	2302	7.97	13.53	9.55	17.71
	Passing	6837	8136	14973	66.56	74.24	76.11	91.95
	Fail	2454	882	3336	23.89	8.05	100.00	100.00
Pre-flexion	Excellence	2819	3479	6298	27.44	31.75	27.44	31.75
	Good	1903	2236	4139	18.53	20.40	45.97	52.15
	Passing	5238	5218	10456	50.99	47.61	96.96	99.76
	Fail	312	26	338	3.04	0.24	100.00	100.00
Fixed jump	Excellence	219	417	636	2.13	3.81	2.13	3.81
	Good	638	1283	1921	6.21	11.71	8.34	15.52
	Passing	6572	6974	13546	63.98	63.64	72.32	79.16
	Fail	2843	2285	5128	27.68	20.84	100.00	100.00

Lead up/Sit-ups	Excellence	487	128	615	4.74	1.17	4.74	1.17
	Good	439	309	748	4.27	2.82	9.01	3.99
	Passing	3691	9237	12928	35.93	84.29	44.94	88.28
	Fail	5655	1285	6940	55.06	11.72	100.00	100.00
Active watch	Excellence	219	73	292	2.13	0.67	2.13	0.67
	Good	2136	2274	4410	20.79	20.75	22.92	21.42
	Passing	7248	8429	15677	70.56	76.91	93.48	98.33
	Fail	669	183	852	6.52	1.67	100.00	100.00
Total		10272	10959	21231	48.38	51.62		

3.2. Association Rule Operations

In this study, association rules were analyzed for seven test indicators height-weight class, lung capacity-weight class, 50-meter run class, 1000/800-meter run class, seated body flexion class, standing long jump class, pull-up/one-minute sit-up class, and one athletic performance class for male and female physical test data, respectively, by setting minimum support and confidence thresholds, as well as by stipulating the rule's postcondition, the and filtering rules greater than 1 for arithmetic analysis.

Using the Apriori algorithm of the arules package in R language, the association rules of this physical fitness test were obtained by setting the minimum support (min_sup) to 0.3 and confidence (min_conf) to 0.5, as well as filtering the strong association rules with lift greater than 1, and setting the rule postconditions.

Frequent item sets with greater than 20% support in the boys' and girls' physical fitness test and sports performance datasets were found:

Calculate the frequent item sets for boys' and girls' physical fitness test and sports performance data sets separately. The frequent item sets for boys' physical fitness test and sports performance are shown in Fig. 2, where G1 indicates the gender of boys. P1-P9 indicate a normal height and weight grade, a passing grade in lung capacity, an excellent grade in lung capacity, a passing grade in the 50-meter run, a passing grade in the 1,000-meter or 800-meter run, a passing grade in the seated forward bends, a passing grade in the standing long jump, a failing grade in the pull-ups or the one-minute sit-ups, and a passing grade in the pull-ups or the one-minute sit-ups, respectively. A indicates a passing grade in athletic performance. As can be seen from the graph, there are six item sets that exceed 60% of the boys' physical fitness test data, which are P1, P4, P5, P6, P7, and A.

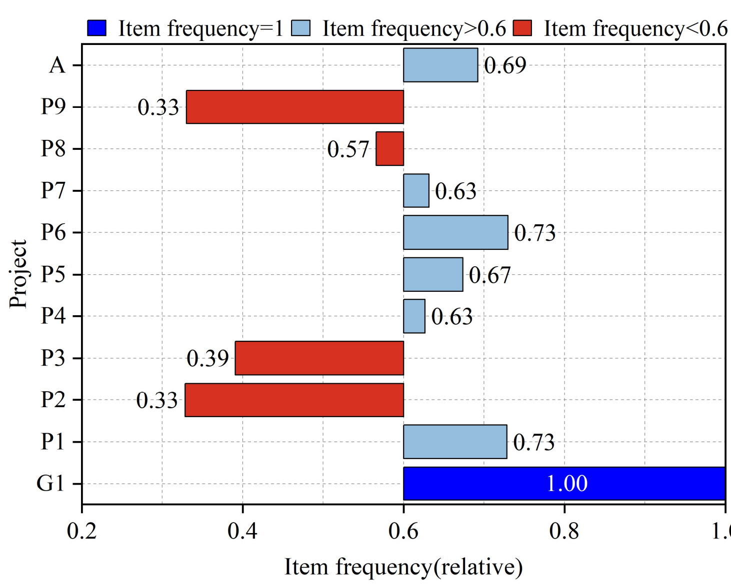

Fig. 2. Boys data item frequency

Figure 3 shows the physical fitness test and sports performance data of female students, in which G2 indicates that the gender is female, Q1-Q9 indicate that the height and weight grade is normal, the lung capacity grade is normal, the lung capacity grade is excellent, the 50-meter run grade is passing, the 1,000-meter or 800-meter run grade is passing, the seated forward bending grade is excellent, the standing long jump grade is passing, the pull-ups or one-minute sit-ups grade A indicates a passing grade in athletic performance. The data in the graph shows that there are six items in the girls' physical fitness test and athletic performance data that exceed 60%, with three items in Q1, Q4, and Q9 exceeding 80% probability.

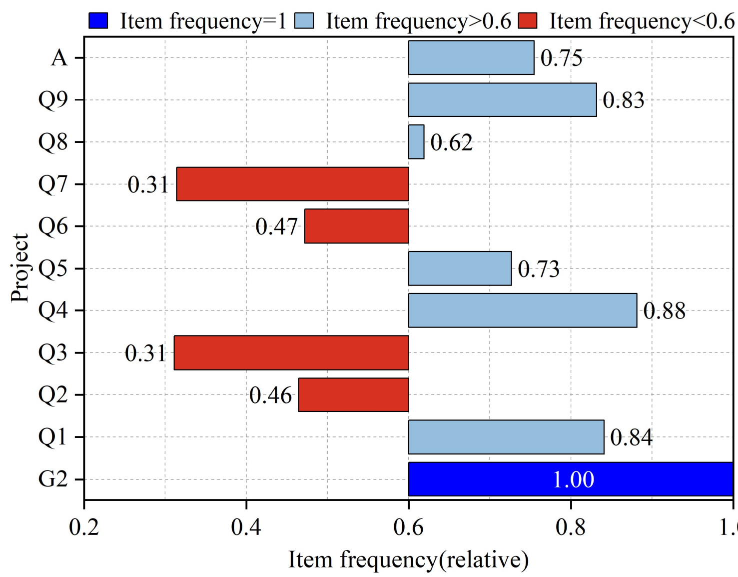

Fig. 3. Girls data item frequency

3.3. Analysis of results

3.3.1. Association rule mining for all boys. For the physical fitness test and sports performance data of 10272 male students, based on the Apriori algorithm, set the minimum support degree as 0.3, the minimum confidence level as 0.5, and the lift is greater than 1, nine strong association rules were obtained as shown in Table 2, where T1-T7 denote the height and weight grades, the lung capacity and weight grades, the 50-meter run grades, the 1,000/800-meter run grades, the seated body flexion rank, standing long jump rank, pull-up/minute sit-up rank, the same below. Mining yielded nine strong association rules, which were valuable and meaningful to analyze, and the rules reflected the relationship between the individual indicators of the boys. Rule 1 indicated that 59.8% of the boys who passed pull-ups also passed their athletic performance and the significance of this rule was 70.9%. Rule 2 indicates that 59.3% of the boys who pass the 1000 meter run have a good athletic performance rating and the importance of this rule is 86.2%. Rule 3 indicates that 58.6% of the boys who passed the seated forward bends also had a passing grade in athletic performance and the importance of this rule was 79.3%. Rule 4 indicates that 59.1% of the boys with a normal height and weight class have a passing motor performance class and the importance of this rule is 75.6%. Rule 5 indicates that 63.7% of the boys who failed pull-ups had the same failing athletic performance grade and the importance of this rule was 83.6%. Rule 6 indicates that 64.2% of the boys with an excellent rating in the 50-meter run also have an excellent Sports East performance rating, and the importance of this rule is 83.6%. Rule 7 indicates that 60.9% of the boys who have a passing grade in the 50 meter run have a passing sport performance grade and the importance of this rule is 84.9%. Rule 8 indicates that there are 58.4% of boys with a good lung capacity rating whose athletic performance rating is pass and the importance of this rule is 81.7%. Rule 9, on the other hand, indicated that 61.2% of the boys had a failing grade in standing long jump and their athletic performance grade was also failing and the importance of this rule was 79.9%. From the correlation rules, it can be found that height and weight, lung capacity, 50 meter run, 1000 meter run, sitting forward bending, standing long jump and pull-ups have a strong correlation with male students' athletic performance, and that students who have an average performance in the quality of speed, flexibility, endurance, and explosiveness will not perform well in their athletic performance.

Table 2. The association rules of boys' data

Serial number	Rules		Support	Confidence	Lift
	Fore-term	After-term			
1	T7= Passing	Active watch= Passing	0.598	0.709	1.402
2	T4= Passing	Active watch= Good	0.593	0.862	1.316
3	T5= Passing	Active watch= Passing	0.586	0.793	1.409
4	T1=normal	Active watch= Passing	0.591	0.756	1.173
5	T7=Fail	Active watch= Fail	0.637	0.836	1.482
6	T3= Excellence	Active watch= Excellence	0.642	0.828	1.369
7	T3= Passing	Active watch= Passing	0.609	0.849	1.274
8	T2= Good	Active watch= Passing	0.584	0.817	1.198
9	T6= Fail	Active watch= Fail	0.612	0.799	1.401

3.3.2. Association Rule Mining for All Female Students. The 10959 girls' physical health test and sports performance data were mined for association rules based on the Apriori algorithm, and the same minimum support was set to 0.3, the minimum confidence level was 0.5, and the degree of enhancement was greater than 1, and 10 strong association rules were obtained as shown in Table 3. The 10 strong association rules obtained from mining reflect the relationship between girls' physical fitness test and their athletic performance, in which Rule 1 indicates that there are 68.9% of girls who have a passing grade in one-minute sit-ups also have a passing grade in athletic performance, and the importance of the rule is 87.6%. Rule 2 indicated that 74.7% of the girls who had a passing grade in standing long jump also had a passing grade in athletic performance and the importance of the rule was 88.2%. Rule 3 indicated that 65.2% of the girls who had an excellent grade in one-minute sit-ups had a good athletic performance grade and the importance of the rule was 84.7%. The rest of the rules were interpreted in this manner. As in the case of boys, there was also a significant correlation between physical fitness test factors and athletic performance in girls, with girls who had higher individual physical fitness test factors generally having better athletic performance.

Table 3. The association rules of girls' data

Serial number	Rules		Support	Confidence	Lift
	Fore-term	After-term			
1	T7= Passing	Active watch= Passing	0.689	0.876	1.363
2	T6= Passing	Active watch= Passing	0.747	0.882	1.306
3	T7= Excellence	Active watch= Good	0.652	0.847	1.413
4	T6= Fail	Active watch= Fail	0.713	0.895	1.475
5	T4= Passing	Active watch= Passing	0.738	0.836	1.268
6	T2= Good	Active watch= Passing	0.694	0.828	1.192
7	T2= Fail	Active watch= Fail	0.762	0.837	1.384
8	T1= Normal	Active watch= Passing	0.598	0.844	1.453
9	T3= Excellence	Active watch= Good	0.715	0.816	1.409

10	T5= Fail	Active watch= Fail	0.726	0.842	1.386

The above results show that this study utilized the Apriori algorithm to mine the association rules of college students' physical fitness and athletic performance data, and successfully discovered a variety of combinations of physical fitness factors affecting college students' athletic performance and the corresponding association rules. To a certain extent, these rules reflect the intrinsic connection between college students' physical health and athletic performance, which provides valuable references for physical education and student health management in colleges and universities. By comparing with the actual teaching experience and related research results, it is found that the association rules derived from this study have a high degree of rationality and validity. For example, the effects of lung capacity, standing long jump and pull-ups/minute sit-ups mentioned in the rules on athletic performance are in line with the theory of traditional physical education teaching and the practical experience, which further verifies the reliability of the methodology and the results of this study.

The findings of this paper are also useful references for colleges and universities to further optimize physical education teaching and student health management. Based on the analysis of the research results, this paper believes that physical education in colleges and universities can be optimized in terms of personalized teaching, curriculum optimization and health management guidance.

1) Personalized teaching. Based on the mined association rules, college physical education teachers can understand the potential needs of students with different physical health characteristics in terms of sports performance, so as to formulate a more personalized teaching plan. For students with better performance in lung capacity and standing long jump, more challenging high-intensity training programs can be provided to further explore their athletic potential. For students with poor performance in pull-ups or one-minute sit-ups, special training courses can be arranged to help them make up for their shortcomings and improve their overall athletic ability.

2) Curriculum Optimization. Research results show that a variety of physical health factors have a comprehensive impact on sports performance. Therefore, colleges and universities should pay more attention to the diversity and comprehensiveness of course content in the physical education curriculum. In addition to traditional athletics and ball games, courses that help improve students' flexibility, coordination and core strength, such as yoga, gymnastics and calisthenics, can be added to promote the overall development of students' physical fitness.

3) Health management guidance. The health management department of students in colleges and universities can provide students with more scientific health management advice based on the rules of association. For example, for students with poor performance in certain items in the physical fitness test, they are reminded to pay attention to other physical fitness factors related to them, and are instructed to improve their overall health through reasonable exercise and dietary adjustments, so as to improve their athletic performance.

It should also be noted that the study in this paper still has some limitations, which can be summarized as follows:

1) Data limitations. This study only collected data from students in one university, and there are some limitations in the representativeness of the sample. There may be differences in physical fitness and sports performance among students from different regions and different types of colleges and universities, and future studies can expand the sample range to cover student data from more colleges and universities in order to improve the generalizability of the research results.

2) Limitations of the algorithm. The Apriori algorithm may have efficiency problems when dealing with large-scale data and generates a large number of frequent itemsets and association rules, which need to be further screened and analyzed. In addition, the algorithm is based on the thing database for mining, and may not be able to fully mine some complex data structures and relationships. In the future, we can try to combine other data mining algorithms or techniques in order to analyze the relationship

between college students' physical health and athletic performance in a more comprehensive and in-depth way.

3) Complexity of influencing factors. The athletic performance of college students is influenced by a combination of factors, including psychological factors, athletic training methods, exercise habits, and lifestyles, in addition to the physical health factors involved in this study. This study only mined the correlation attribution from the perspective of physical health data and failed to comprehensively consider the influence of other factors. Follow-up studies can further expand the scope of the study to comprehensively consider the effects of multiple factors on college students' athletic performance.

The above limitations should be emphasized in future studies so as to improve the study of the intrinsic relationship between college students' physical fitness and athletic performance.

4. Conclusion

In this study, the Apriori algorithm was applied to mine the association rules between college students' physical fitness and athletic performance data, and multiple association patterns between the two were successfully revealed. By generating frequent items and extracting association rules, we found that the association between lung capacity and 50-meter running performance, pull-ups and 1000-meter running performance, and standing long jump and seated forward bending performance had a significant effect on the athletic performance of college students. These findings provide a scientific basis for physical education and student health management in colleges and universities, and help to guide colleges and universities to develop more personalized and targeted physical education programs and health management strategies, and to promote the overall improvement of college students' physical fitness and athletic performance. Although there are some limitations in this study, it provides a useful reference for subsequent related studies, and future studies can further explore in depth in terms of expanding the sample range, improving the algorithm, and considering multiple factors.

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