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Hiome Analysis Based on fsQCA: A Study on Sports Injury Factors in Adolescent Physical Training

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Abstract: In recent years, adolescent physical training has received more and more attention, but the risk of sports injury has also increased. Sports injuries not only affect adolescents' physical health and exercise performance but may also negatively affect their psychological development and social adaptation. Therefore, identifying and understanding the key elements of motor impairment in adolescent physical training is essential for developing effective prevention strategies. However, the occurrence of motor injury is often the result of multiple factors, and there may be complex interactive relationships between factors. To more comprehensively reveal the genetic mechanism of motor injury, the fuzzy set qualitative comparative analysis (fsQCA) method was introduced in this study. An fsQCA is a comparative analysis method based on set theory and Boolean algebra that handles small and medium sample data and identifies multiple combinations of factors (configurations) that lead to the outcome variables. The purpose of this study is to use the fsQCA method to explore the key factors of sports injury and their combined pathways in adolescent physical training to provide a theoretical basis and practical guidance for the development of targeted sports injury prevention strategies.

Keywords: Youth; Physical training; Sports injury; fsQCA; Configuration analysis

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1. Preface

In recent years, scholars at home and abroad have conducted extensive research on the problem of adolescent physical training sports injuries, mainly focusing on the following aspects. First, the incidence, type, and location of sports injuries in different sports programs, ages, and genders. Second, explore the influence of individual factors (such as age, gender, physical quality, sports history, etc.), training factors (such as training intensity, frequency, duration, technical movements, etc.), and environmental factors (such as field equipment, coach guidance, protection measures, etc.) on sports injury. However, most of the existing studies use traditional

statistical analysis methods, such as linear regression and Logistic regression, focusing on exploring the influence of a single factor on motor injury, and it is difficult to reveal the complex interaction between multiple factors [1]. In fact, the occurrence of sports injury is often the result of multiple factors, and there may be complex relationships such as substitution, complementarity, or synergy between different factors. For example, good physical fitness may compensate for the lack of technical movements to some extent, while the safety risks of the training environment may exacerbate the influence of other risk factors.

To more fully understand the genetic mechanism of physical training injury in youth physical training, new research methods are needed to consider the combined effect and interactive relationship of multiple factors simultaneously. As a new research method, fuzzy set qualitative comparative analysis (fsQCA) provides a new way to solve this problem. Based on set theory and Boolean algebra, fsQCA can identify multiple combinations of factors (configurations) that lead to the outcome variables and reveal complex causal relationships between factors, which is especially suitable for the analysis of small and medium-sized sample data. Therefore, this study used the fsQCA method to explore the key factors and their combined pathways in adolescent physical training to provide a theoretical basis and practical guidance for the development of more accurate and effective sports injury prevention strategies.

2. Study design

2.1. Study methods

According to the needs of this study, the researchers took adolescents, sports injury, and fsQCA as the search keywords and selected core journals and master and doctoral papers. After reading the topic, abstracts, and keywords, the authors screened the literature unrelated to this study and provided relevant research progress and a solid theoretical basis for this study through the above methods. Then adopt the method of questionnaire survey to collect data, to have occurred sports injury youth athletes questionnaire and recycling work, the condition variables and outcome variables measurement by domestic and foreign famous scholars developed mature scale, and combined with the actual situation to adjust, designed the youth physical training sports injury factors research questionnaire.

After the questionnaire collection, the specific data from the feedback use SPSS and Excel, and the relevant statistical results are obtained, and then the relevant data are processed through fsQCA software to provide data support for the subsequent in-depth analysis of this paper. The motor injury was set as the “outcome variable” and the factors that affect the occurrence of the outcome as the “conditional variable”, thus analyzing the potential relationship between the “conditional variable” and “outcome variable” and the combination of conditions that affect the outcome.

2.2. Model construction

From the perspective of configuration, this study explains the factors of physical training. After further combining the development, the index system of conditional variables was constructed, and the influencing factors were analyzed in groups from a more scientific perspective, and the core conditions, necessary conditions, auxiliary conditions, and various configurations were selected, as shown in **Figure 1** [2].

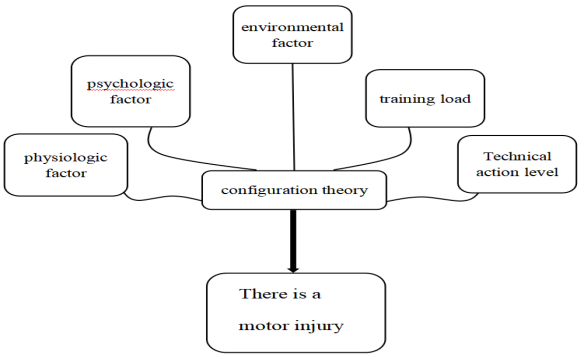

Figure 1. The model construction

3. Research content and analysis

3.1. Data calibration

When applying the fuzzy set analysis method, the calibration of the research data needs to meet the qualification conditions of the numerical interval [0,1], which requires the researchers to conduct a specific transformation process for the information obtained from the original questionnaire scale. The fsQCA software, as a core tool in this study, achieves this goal by quantifying the evaluated qualitative elements assessed as actionable indicator values and assigning the corresponding set member score to each observation. In this study, the authors used the direct calibration method, referring to the study, and chose "5,3,1" as the threshold for the three anchor points, "5 is fully subordinate", "3 is intersection", and "1 is completely non-subordinate", as shown in **Table 1** [3].

Table 1. Part of the data after calibration

Sample serial number	Physiologic factor	Psychologic factor	Environmental factor	Training load	Technical action level	There is a motor injury
Number	SLYS	XLYS	HJYS	XLFH	JSDZSP	FSYDSS
1	0.88	0.501	0.14	0.95	0.92	0.89
2	0.32	0.71	0.82	0.59	0.35	0.94
3	0.62	0.95	0.89	0.82	0.86	0.94
4	0.82	0.92	0.86	0.07	0.86	0.86
5	0.92	0.29	0.18	0.82	0.86	0.43
6	0.92	0.95	0.89	0.07	0.86	0.77
7	0.68	0.92	0.86	0.87	0.86	0.89
.....	.....	.....	.....	.....	.....	.....

3.2. Single-factor necessity analysis

One-factor essentiality analysis is a necessity test (Necessary conditions) for each condition variable, and the concept of a necessary condition means that the condition must exist if the result is going to occur. This step is used to determine whether each condition variable is necessarily related to the outcome variable, where the fsQCA software can derive the consistency (Consistency) and coverage (Coverage) [4]. In general, a condition with a

consistency index greater than 0.9 is considered necessary for the outcome variable. As can be seen from **Table 2**, the consistency of each condition variables is less than 0.9, which means that these factors do not constitute the necessary condition for adolescent physical training, which fully reflects the complexity of adolescent physical training, and that the result of injury is achieved under the synergistic action of different conditions, therefore need combined analysis of various condition variables.

Table 2. Single-factor necessity analysis

Outcome variable: Sports impairment occurred		
Condition variable	**Consistency (Consistency)**	**Coverage (Coverage)**
Physiologic factor	0.726648	0.744341
~Physiologic factor	0.420799	0.826103
Psychologic factor	0.757660	0.718184
~Psychologic factor	0.372888	0.865890
Environmental factor	0.795358	0.706183
~Environmental factor	0.334448	0.850750
Training load	0.663696	0.790183
~Training load	0.479109	0.742019
Technical action level	0.779016	0.764534
~Technical action level	0.379387	0.812972

3.3. Build the truth table

After performing the necessity analysis to determine the interrelationship between the antecedent condition variables and the outcome variables, the data set of fuzzy sets needs to be converted into truth tables, with each column of the truth table representing a different set. In the truth table, there are 2k rows (where k is the number of conditional variables in the study) [5]. It is often possible to determine whether the pathway is relevant to the outcome based on three criteria: Frequency (Frequency), original consistency (Raw consistency), and inconsistent reduction rate (Proportional reduction in inconsistency; PRI). Most current studies use 0.8 as a criterion for the consistency threshold, 0.75 as the standard for PRI. Therefore, in this study, the consistency threshold was set to 0.8 and the PRI threshold to 0.75. When the PRI is higher than 0.75, the outcome variable coding is set to 1, and otherwise, it is set to 0. The truth table is constructed as shown in **Table 3**.

Table 3. True value table

Physiologic factor	**Psychologic factor**	**Environmental factor**	**Training load**	**Technical action level**	**There is a motor injury**	**Original consistency**	**PRI consistency**
SLYS	**XLYS**	**HJYS**	**XLFH**	**JSDZSP**	**FSYDSS**	**Raw consist.**	**PRI consist.**
0	0	0	1	1	1	0.97801	0.944
0	1	0	1	1	1	0.97479	0.930232
1	1	0	0	0	1	0.972222	0.91579
0	0	0	0	0	1	0.960729	0.86214
0	1	1	1	0	1	0.960384	0.854626

Table 3 (Continued)

Physiologic factor	Psychologic factor	Environmental factor	Training load	Technical action level	There is a motor injury	Original consistency	PRI consistency
SLYS	XLYS	HJYS	XLFH	JSDZSP	FSYDSS	Raw consist.	PRI consist.
0	0	0	1	0	1	0.956723	0.745455
1	0	0	1	1	1	0.952026	0.869565
1	0	1	1	1	1	0.936508	0.867986
0	1	1	1	1	1	0.919259	0.835579
1	0	1	0	1	1	0.918691	0.782486
1	0	1	0	0	1	0.901841	0.705882
1	1	1	1	0	1	0.886264	0.693396
1	1	1	0	0	1	0.828883	0.682432
0	1	1	0	0	1	0.817374	0.556354
1	1	1	1	1	1	0.81077	0.714447
1	1	1	0	1	1	0.807811	0.644487

4. Results of the study

4.1. Group configuration analysis

After completing all the above work, standardized analysis is conducted, and then three solutions of qualitative comparative analysis, complex solution (Complex Solution), intermediate solution (Intermediate Solution), and simple solution (Parsimonious Solution) are generated. Intermediate solutions are somewhere between complex solutions and simple solutions, including both observable cases and residuals that are prone to logical reasoning, while simple solutions include important conditions (core conditions) that cannot be ignored by any solution [6]. In fsQCA studies, a reasonable intermediate solution (**Table 4**) is often the first choice for reporting and interpretation. One can distinguish core conditions and auxiliary conditions and combine them with a simple solution (**Table 5**). If a condition appears in both the simple and intermediate solutions, the condition is the core condition in the configuration path. If the variable is only present in the intermediate solution, the condition is the auxiliary condition.

Table 4. Intermediate solution (Intermediate solution)

Configuration	Original coverage	Unique coverage	Consistency
~SLYS*XLYS*HJYS*~JSDZSP	0.371479	0.025743	0.89741
~SLYS*XLYS*XLFH*~JSDZSP	0.395357	0.0187545	0.914257
SLYS*~XLYS*~HJYS*~XLFH	0.345298	0.0227569	0.920541
SLYS*~HJYS*XLFH*JSDZSP	0.315427	0.0212082	0.914254
XLYS*~HJYS*XLFH*~JSDZSP	0.327784	0.017898	0.924578
Overall coverage rate (solution coverage): 0.636583			
Overall conformance (solution consistency): 0.852471			

Table 5. Simple solution (Parsimonious solution)

Configuration	Original coverage	Unique coverage	Consistency
~SLYS*~JSDZSP	0.395124	0.387451	0.895148
~HJYS*XLFH	0.384215	0.34587	0.812456
Overall coverage rate (solution coverage): 0.744104			
Overall conformance (solution consistency): 0.802684			

4.2. Construction of the configuration

This study refers to Ragin expression of fsQCA configuration results, "●" and "•" indicating condition, core condition "●", "•" means auxiliary condition, "⊗" and "⊗" indicate missing condition, "⊗" indicates missing core condition and "⊗", to construct the configuration of adolescent fitness training sports injury factor study, as shown in **Table 6** [7].

Table 6. Configuration in adolescents

Condition variable	Configuration 1	Configuration 2	Configuration 3	Configuration 4	Configuration 5
Physiologic factor	⊗	⊗	●	●	
Psychologic factor	●	●	⊗		●
Environmental factor	●		⊗	⊗	⊗
Training load		●	⊗	●	●
Technical action level	⊗	⊗		●	⊗
Original coverage	0.371479	0.395357	0.345298	0.315427	0.327784
Unique coverage	0.025743	0.0187545	0.0227569	0.0212082	0.017898
Consistency	0.914257	0.944709	0.920541	0.914254	0.924578
Overall coverage			0.636583		
Overall consistency			0.852471		

Hiome path 1: ~ Physiological factors * psychological factors * environmental factors * ~ technical action level

The meaning expressed by this path is that even if teenagers have good psychological quality, are not afraid of training content and dare to do movements, and have good training environment and facilities, they are prone to sports injuries due to their poor physical quality and relatively non-standard technical movements.

Hi configuration path 2: ~ Physiological factors * psychological factors * training load * ~ technical action level

The path expresses the meaning is that teenagers may be due to immature physical development, insufficient muscle strength and other physiological conditions, even in training concentration, training motivation, and there is no anxiety or pressure, etc., because the technical action is not standard or not skilled, high training load cause excessive pressure on the adolescent body, thus easy to induce sports injury.

Hiome path 3: Physiological factors * ~ psychological factors * ~ environmental factors * ~ training load

The meaning of this path is that teenagers have psychological barriers in the training of difficult movements

or have resistance to training, even if the teenagers have good physical quality, but the training environment is poor, the facilities are not perfect, and in small intensity training. In this case, sports injuries are also easy to occur.

Hiuration path 4: Physiological factors * ~ environmental factors * training load * Technical action level

The implication of this path is that no matter whether the teenagers have a good psychological state or not, with intensive training under a very poor training environment, even if the teenagers have good physical quality and skilled technical movements, they are prone to sports injuries.

Hiuration path 5: psychological factors * ~ environmental factors * training load * ~ technical action level

The implication of this path is that teenagers maintain a positive attitude towards training, but they are prone to sports injuries due to the low level of technical movements and the intensive training in the imperfect field environment.

5. Conclusion

The empirical analysis of sports injury factors of adolescent physical training by fsQCA shows that the consistency of each variable in this study did not exceed 0.9, so a single variable cannot constitute a necessary condition of physical training sports injury in adolescents. Physical training sports injury is influenced by many factors, indicating that the role of different factors in participation behavior varies with different paths, and the combination of factors has different effects on participation behavior.

Through the analysis of configuration path, the characteristics of the five kinds of configuration path results show that (1) subjective positive psychological attitude can effectively prevent sports injury in adolescent physical training; (2) environmental factors and appropriate sports load are the auxiliary guarantee of adolescent physical training to prevent physical injury; (3) skilled physical training and healthy physical quality are the key basis to prevent adolescent physical training.

Disclosure statement

The authors declare no conflict of interest.

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