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Application of Digital Twin Technology in Aerial Techniques of Competitive Cheerleading

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Abstract: With the continuous development of science and technology, we have already entered the digital age. While big data, artificial intelligence, and digital twin technology provide convenience for various fields of people's lives, they also bring new opportunities for the innovation and development of competitive cheerleading. Especially for the training of aerial techniques in competitive cheerleading, which has high requirements for accuracy, coordination, and safety, the traditional training model has problems such as empiricism and insufficient risk prediction, which directly affect the quality of training. This article discusses the application value and application countermeasures of digital twin technology in the aerial techniques of competitive cheerleading, hoping to provide some reference for relevant personnel.

Keywords: Digital twin technology; Competitive cheerleading; Aerial techniques; Application value; Application countermeasures

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1. Introduction

The aerial techniques of competitive cheerleading integrate technology and strength, covering a variety of complex movements such as aerial tumbling and tossing, and have extremely high requirements for the accuracy and safety of athletes' skills. However, in the past training process, there were problems such as empiricism and insufficient safety protection, which not only affected the training effect of athletes but also posed a huge hidden danger to their personal safety. As a "digital clone" construction technology, digital twin technology can rely on the core framework of "physical entity - virtual model - data interaction" to provide support for the safe and high-quality development of aerial technique training in competitive cheerleading. Therefore, it is imperative and timely to actively explore the application countermeasures of digital twin technology in the aerial techniques of competitive cheerleading[1].

2. Application value of digital twin technology in aerial techniques of competitive cheerleading

2.1. Enhancing training precision and overcoming limitations of experience-based training

In the previous training process of aerial techniques in competitive cheerleading, the issue of "empiricism" often arose. This means that instructors would identify athletes' shortcomings through subjective experience-based judgment and observation, and then provide targeted training and guidance accordingly. However, under this model, instructors cannot gain a good understanding of specific aspects such as athletes' physical coordination, which often makes their training guidance less scientific and precise [2]. Furthermore, under the traditional "empiricist" model, the achievement of athletes' technical standards is also not ideal.

Due to differences in individual conditions and technical mastery levels among athletes, the training of aerial techniques in competitive cheerleading under the traditional model mostly adopts a "one-size-fits-all" approach, which also leads to unsatisfactory training quality. The application of digital twin technology, however, can build a digital twin model that matches an athlete's physical conditions and technical mastery level. This model enables accurate analysis of the entire process of the athlete's aerial techniques in competitive cheerleading. At the same time, based on various data, it allows coaches to quickly identify shortcomings, thereby conducting more scientific training and comprehensively improving the scientific nature and precision of training.

2.2. Strengthening safety protection and predicting sudden technical risks

The aerial techniques in competitive cheerleading also have high requirements for athletes' coordination. During the specific practice process, how to effectively address safety issues is a pressing question that every coach must consider. It can be observed that under the traditional training mode in the past, there were often many potential safety hazards in the training of aerial techniques for competitive cheerleading. For example, coaches usually built safety protection models based on their own experience judgments and the analysis and review conducted after safety accidents occurred.

However, this model also has significant problems of blindness and one-sidedness. This is because the safety risks of aerial techniques are multifaceted, such as the athletes' own physical conditions, interference from the external environment, and inadequate team coordination. If these risks cannot be accurately identified, the injury rate of athletes will increase directly. Digital twin technology, however, can establish a scientific safety response system of "pre-accident prevention and control + post-accident response" for the training of aerial techniques in competitive cheerleading by constructing a corresponding safety simulation system. This helps relevant personnel accurately predict and resolve potential safety risks, thereby better ensuring the safety of athletes during the training of aerial techniques in competitive cheerleading [3].

2.3. Innovate teaching models and break the constraints of time and space

In the past, the teaching of aerial techniques in competitive cheerleading was plagued by problems such as a single model and lack of interest. The teaching process relied heavily on the "demonstration + imitation" model, resulting in unsatisfactory actual teaching and training effects. Moreover, under the traditional model, the time and space for aerial technique training of competitive cheerleading are fixed, which often confines the training to physical classrooms and fixed time periods; otherwise, it is difficult to carry out the training efficiently. Nevertheless, digital twin technology boasts strong interestingness and flexibility.

On one hand, it can construct digital virtual scenarios and create a new audio-visual integrated, in-depth

experiential teaching model. This effectively enhances the interest and effectiveness of teaching, enabling students to master relevant technical movements more comprehensively and profoundly, and improving their overall quality and level. On the other hand, it can break through the traditional constraints of time and space, allowing students to conduct aerial technique training of competitive cheerleading anytime and anywhere, thereby facilitating the improvement and development of their professional abilities in the future [4]. In addition, digital twin technology can also bring more digital resources such as digital cases to the aerial technique training of competitive cheerleading. This optimizes the teaching content, further stimulates students' interest in learning, strengthens their mastery of techniques, enhances their training experience, and drives the quality of teaching and training to a higher level [5].

3. Application strategies of digital twin technology in aerial skills of competitive cheerleading

3.1. Building an adaptive technology platform: constructing a twin system of "Multi-dimensional Data Collection + Real-time Simulation"

Building an adaptive technology platform is the fundamental prerequisite for the application of digital twin technology in the aerial skills of competitive cheerleading, with the core being the realization of in-depth collaboration between "accurate data collection" and "virtual real-time simulation" [6]. Relevant technical equipment should be introduced to collect data on athletes' aerial skills in competitive cheerleading. For instance, a motion capture system can be adopted, along with high-precision cameras, to accurately collect data on the athletes' training venues and actual conditions. This enables better capture of detailed trajectories of athletes' performance in aerial skills, such as aerial somersaults and base lifts. On this basis, electromyographic sensors can be introduced to accurately sample the muscle groups of athletes' bodies, allowing for better recording of the force intensity and rhythm of athletes during certain movements.

On top of that, pressure-sensing mats can be introduced to effectively monitor the foot force of athletes when they land, thereby gaining a better grasp of data related to their training and performance in aerial skills and laying the foundation for the optimization and innovation of subsequent training processes. A high-fidelity virtual model should be built based on the data collection system [7]. For example, by introducing relevant dynamic algorithms to detect the body force application of athletes in aerial skills, problems such as incomplete movements and disjointed movements can be identified in a timely manner. Additionally, the specific movements can be virtually replicated, enabling coaches to more accurately identify details and shortcomings, and continuously improve the precision and effectiveness of coaching guidance [8].

3.2. Establishing a standardized data system: standardizing data standards for "Movement Parameters + Risk Thresholds + Teaching Templates"

The lack of unified data standards can easily lead the application of digital twin technology into a dilemma of "data fragmentation". Therefore, a scientific data standard system should be established based on digital twin technology to provide effective information support for aerial skill training [9]. In terms of movement parameter standards, parameter definition should be carried out according to the difficulty level based on the classification of core movements in aerial skills. For example, for some advanced somersault movements, the rotation angle and landing buffer time (0.3–0.5 seconds) should be standardized; for primary toss movements, it is necessary to clarify the toss height (1.8–2.2 meters) of athletes during the movement and the degree of body straightening ($\geq 95\%$) [10].

In addition, the formulation of parameters should be scientific and rigorous. For example, sports biomechanists or relevant sports associations can be collaborated with to scientifically design standard data standards based on a large amount of actual data, standardize athletes' movement skills, and improve the accuracy and scientificity of training. Risk threshold standards need to focus on potential safety hazards in aerial skills, divide risk levels, and clarify corresponding parameters. For example, if it is found that the deviation of an athlete's landing from the center line is significant (15 cm), a "high-risk warning" will be issued immediately to remind the athlete to pay attention to the standardization of technical movements; if it is found that there is a certain degree of deviation in the force application of the base athlete, a "medium-risk warning" will be issued immediately to remind the athlete to adjust their technical movements; and if it is found that the force-bearing condition of an athlete when landing on one foot is acceptable but still has shortcomings (such as the force-bearing ratio exceeding 70%), a "low-risk warning" will be issued. Through such hierarchical risk threshold setting, clear standards are provided for the training of aerial skills in competitive cheerleading [11].

Besides, in terms of teaching template standards, a three-level database (elementary, intermediate, and advanced) can be established based on the classification of athletes' levels. Coaches can select targeted data resources according to the athletes' levels. For example, for athletes who have a high level of mastery of aerial skills, coaches can introduce advanced data templates that focus on team cooperation and the precise achievement of technical standards to provide more professional guidance for athletes. Collectively, it should be noted that the teaching templates in the database should be updated in real time based on changes in the professional rules of cheerleading and adjusted parameters, so as to ensure the scientificity, rationality, and progressiveness of the training process.

3.3. Promoting scenario-based implementation and application: Extending from "Single Training" to "Full-Process Empowerment"

In the aerial technical training of competitive cheerleading, the application of digital twin technology should also focus on scenario-based implementation. Specifically, optimization and innovation should be carried out based on the concept of "step-by-step progress and demand orientation" to effectively avoid potential blindness. This will transform the aerial technical training of competitive cheerleading from the previous "single-type training" to a "full-process empowerment" model under digital twin, thereby further highlighting the application value of digital twin technology [12].

In the initial stage of training, a simplified digital training scenario can be built to help athletes better learn and master the key points of relevant technical movements. For instance, in the early stage of aerial skills training, many athletes have the problem of "non-standard landing buffering". In response to this situation, coaches can collect and analyze the specific data of athletes' technical movement performance based on digital twin technology, then compare it with the established parameters, and formulate corresponding training plans to help them solve the non-standard problem step by step [13]. On this basis, relying on the virtual simulation technology under digital twin, the formulated training plan can be verified and analyzed to further improve the scientificity and effectiveness of training. Based on practical guidance, the records and analysis of athletes' movement corrections can be documented as specific digital virtual cases, so as to provide "replicable resources" for the training of relevant movements in the future.

The aerial skills of competitive cheerleading have high requirements for athletes' team coordination. Therefore, in the middle stage of training, digital twin technology can be introduced based on the "coordination"

feature of aerial technology to effectively analyze the coordination data of trainers. This includes collecting and recording data such as the time difference between athletes' cooperation and the synchronization of the base's force application. Then, targeted training activities are carried out to solve the problem of multi-person coordination in aerial technology [14]. Taking the training of the "double toss" technical movement as an example, coaches can simulate athletes' aerial technical movements and trajectories based on the virtual simulation model under digital twin, timely identify trajectory changes under different force application rhythms, and then optimize team coordination training in a targeted manner to improve the coordination of team cooperation. Building on this, an "error database" can also be built based on the team coordination problems existing in reality, which records various problems and data analysis reports that occur in students' team coordination, so as to provide more convenient reference and guidance for subsequent team coordination training.

Other than that, in the later stage of training, according to the students' mastery of aerial skills and actual needs, digital twin technology should be actively applied to links such as competition preparation and competitions to promote athletes' practice and performance [15]. For example, in the competition preparation stage, relevant equipment can be used to build a digital virtual scenario, simulate different competition environments, record athletes' performance data, and then flexibly adjust the training plan based on this. In the competition stage, digital twin technology can be combined to analyze athletes' competition performance, record the completion of their technical movements, provide accurate data basis for subsequent post-competition review, and clarify the optimization direction of subsequent aerial technical training.

4. Conclusion

In conclusion, in this digital age, the aerial techniques of competitive cheerleading have also ushered in new opportunities for reform. In particular, the emergence of digital twin technology has provided important support for the optimization and reform of competitive cheerleading aerial technique training. In this regard, relevant personnel should not only deeply grasp the value and significance of this technology but also continuously adopt new ideas and methods to apply modern technologies, such as digital twins to training. By doing so, a new model of competitive cheerleading aerial technique training based on digital twin technology can be created, which will continuously enhance the scientific nature, interest, and effectiveness of training. This will effectively ensure the training effect and safety of athletes, inject sustained impetus into the long-term development of the competitive cheerleading program, and help it achieve new breakthroughs in the competitive field.

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