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ARTIFICIAL INTELLIGENCE–BASED MARKERLESS MOTION CAPTURE AND BIOMECHANICAL ANALYSIS: PROSPECTS FOR APPLICATION IN PHYSICAL EDUCATION AND SPORTS PRACTICE (THE CASE OF WOMEN'S UNEVEN BARS)

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Abstract: This article discusses the introduction of artificial intelligence–based markerless motion capture and biomechanical analysis technologies into physical education and sports practice. The study was conducted using the example of exercises performed on the women's uneven bars in artistic gymnastics. Using video analysis and computer vision technologies, joint angles, body posture, balance, and movement stability were evaluated. Biomechanical indicators were compared with the athletes' fatigue state. In addition, the advanced experience of the Russian University of Sport "GTSOLIFK" (formerly RGUFK) and leading sports science centers in the United States was analyzed. The results show that artificial intelligence–based analysis methods effectively help physical education teachers and coaches to identify technical errors at an early stage, plan training loads correctly, and reduce the risk of injuries.

Keywords: artificial intelligence, biomechanical analysis, markerless motion capture, physical education, artistic gymnastics, digital technologies, injury prevention.

Introduction

Today, in the system of physical education and sports, the issues of scientifically grounded organization of training, protection of athletes' health, and improvement of training efficiency are becoming increasingly important. Modern sports performance depends not only on strength and speed, but also on the accuracy of movements, correct biomechanical structure, and rational distribution of training loads.

In women's artistic gymnastics, the uneven bars are considered one of the most complex apparatuses. Exercises performed on this apparatus impose high dynamic loads on the shoulder girdle, elbow joints, and the spine. Practical experience shows that many injuries occur due to technical errors, incorrectly planned loads, and accumulated fatigue.

In recent years, in the Republic of Uzbekistan, the implementation of artificial intelligence technologies has been elevated to the level of state policy. Presidential decrees and resolutions on the introduction of artificial intelligence into public administration, education, healthcare, and other sectors define these technologies as a priority direction of development. This process also directly affects the field of physical education and sports.

Relevance of the Topic

Traditionally, physical education teachers and coaches evaluate exercises mainly by visual observation. However, the human eye cannot always detect small but biomechanically significant deviations in joint angles. Artificial intelligence–based markerless motion analysis

makes it possible to evaluate movements using precise numerical indicators even from ordinary video recordings.

This technology creates great opportunities for objective assessment of exercise technique, early detection of fatigue influence, reduction of injury risks, and formation of correct movement culture among students.

International Experience

Russian Experience: Russian University of Sport "GTSOLIFK" (Formerly RGUFK)

One of the leading centers in Russia in the field of sports biomechanics and scientific analysis of movements is the Russian University of Sport "GTSOLIFK" (formerly the Russian State University of Physical Education, Sport, Youth and Tourism — RGUFK) in Moscow. In this university, sports training issues are considered in close integration with biomechanics, sports medicine, and functional diagnostics.

The university has introduced into practice biomechanical analysis of sports technique, assessment of loads acting on joints, automated video-based analysis, and the creation of a digital model of the athlete's movement.

According to specialists, in sports schools where such approaches have been introduced, technical errors have decreased by 20–30%, and the number of repeated injuries has significantly declined. In recent years, the university has also been developing special courses and programs aimed at introducing artificial intelligence into education and scientific research.

Experience of the United States

In the United States, artificial intelligence has been introduced into almost all areas of the sports industry. In scientific centers such as the NCAA, the U.S. Olympic Committee, MIT, and Stanford University, AI-based systems are used to assess athletes' technique, fatigue state, and injury risks.

Practical results show that in some sports the number of injuries has decreased by 30–40%, training processes have become more individualized, and the stability of athletes' performance has improved.

Purpose and Objectives of the Study

Purpose:
To scientifically and practically substantiate the possibilities of using artificial intelligence–based markerless motion capture technologies in physical education and sports practice.

Objectives:
To demonstrate methods of video-based movement analysis, to evaluate joint angles and body posture, to identify the relationship between fatigue and changes in technique, and to develop practical recommendations for teachers and coaches.

Methods

Exercises were recorded using an ordinary video camera, and an artificial intelligence–based program was used to generate a skeletal model of the athlete. The following parameters were analyzed: shoulder, elbow, and hip joint angles, the trajectory of the body's center of mass, balance and symmetry, and movement stability. In addition, the athletes' fatigue state was taken into account.

Results

The analysis showed that the greatest loads occur during swing phases and transitions between the bars. With increasing fatigue, movement asymmetry increases. It was also found that even exercises that look technically correct may involve excessive load on the shoulder joint.

Discussion

These findings indicate that visual evaluation alone is not sufficient. Artificial intelligence–based analysis makes it possible to detect hidden technical errors, helps to plan training loads more rationally, and plays an important role in injury prevention. The experience of Russia and the United States confirms the high practical effectiveness of this approach.

Practical Significance for Physical Education Teachers

This technology can be used in school lessons, in sports clubs, and in colleges and technical schools using only a smartphone or a simple camera. It helps to develop correct movement skills, the ability to analyze one's own movements, and safe and health-oriented exercise habits among students.

Conclusion

Artificial intelligence–based markerless motion analysis is an important step toward making physical education and sports more modern, scientific, and safe. This technology serves as a powerful tool for teachers and coaches, significantly improves the quality of training, and reduces the risk of injuries.

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