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Article

The advance of research on rhythmic gymnastics

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Abstract: This study conducted a systematic review of the existing literature on rhythmic gymnastics. Through searching databases such as PubMed, Web of Science, and Scopus, 37 out of 2319 articles were selected, covering training and physical fitness, nutrition and metabolism, as well as sports injuries and rehabilitation. The findings revealed that: (1) Core physical training significantly enhanced athletes' performance; (2) Inadequate nutritional intake was prevalent; (3) The incidence of sports injuries was high, particularly those resulting from overtraining. The conclusion emphasizes the need to enhance strength training, optimize nutritional management, and further investigate injury prevention and rehabilitation measures to enhance athletes' performance and health status.

Keywords: rhythmic gymnastics; training and physical fitness; sports injuries; nutrition and metabolism

1. Introduction

Rhythmic gymnastics is a sport that combines elegant movements and apparatus performances, emphasizing the coordination of athlete with music. It showcases the artistic and technical skills of athlete through displays of flexibility, agility, and strength. During competitions, athletes are required to execute precise movements in sync with the music, while demonstrating high levels of body control and expressiveness, effectively blending artistry with athleticism (Cleophas and Visser, 2024).

The origin of rhythmic gymnastics can be traced back to 19th-century Europe, initially emerging as a complement to women's gymnastics systems, influenced by Swedish gymnastics and other European gymnastics styles. With the promotion by the Soviet Union in the 1930s, rhythmic gymnastics gradually evolved into an independent sport. In 1939, the first rhythmic gymnastics competition was held in Leningrad, marking the formal establishment of this discipline. Subsequently, rhythmic gymnastics joined the International Gymnastics Federation in 1948 and made its debut at the 1984 Los Angeles Olympics, becoming an internationally recognized competitive sport (Soares, 2023).

Although rhythmic gymnastics and artistic gymnastics share similarities in artistic expression and flexibility, they differ significantly in their objectives and performance styles. Rhythmic gymnastics focuses on the continuity of aerobic exercise, engaging in high-intensity training to fast-paced music to enhance cardiovascular endurance and physical fitness. In contrast, artistic gymnastics prioritizes graceful postures and the display of apparatus skills, with athlete showcasing complex movements using apparatus such as ropes, hoops, balls, clubs, and ribbons. Rhythmic gymnastics is more inclined towards fitness and public

participation, while artistic gymnastics centers around high-level competitive performances (Gaspari et al., 2024).

Rhythmic gymnastics places high demands on athlete's flexibility, agility, and upper and lower body strength, requiring a focus on stability and control in movements. Athlete's training typically includes physical conditioning, resistance training, and vibration training to enhance core strength and coordination. Adequate nutrition management is crucial for athlete to maintain peak performance. Many rhythmic gymnasts rigorously control their diet to maintain optimal physique, which may lead to nutritional deficiencies, particularly in inadequate intake of carbohydrates, proteins, and vitamins, impacting health and performance (Bellafiore et al., 2019).

Due to the high demands of rhythmic gymnastics on flexibility, strength, and coordination, athlete face an increased risk of injury during training and competition, with common injury sites including the ankle, knee, lower back, and groin regions (Cabrejas et al., 2023). Therefore, coaches must devise scientifically sound training programs, adjust training intensity appropriately, and implement effective injury prevention strategies to reduce the likelihood of athlete injuries. Through precise training and scientific nutritional management, athlete can minimize injuries, enhance overall competitive performance, making rhythmic gymnastics a highly demanding sport.

2. Literature review

2.1. Training and physical fitness

Physical fitness, being the fundamental capability for sports, has a significant impact on the athletic proficiency of rhythmic gymnastics (Martuscello et al., 2013). The primary focus of rhythmic gymnastics is to stabilize the engagement of ankle and knee muscles through balancing movements, thereby enhancing the utilization of muscles and the capability to sustain balance. Balance of artistic gymnasts was tested by utilizing surface electromyography, ground reaction forces, and kinematic parameters of movement. It was determined that ankle stabilization is of greater importance for young gymnasts than for those of an older age. Gymnasts who are in their youth tend to have the load placed on the front of the foot, whereas those who are more advanced in age shift the load to the back of the foot. Therefore, by including stability training in their daily training regime, athlete can better control their ankle and knee joints (Sobera et al., 2018). Cabrejas et al. (2022) investigated the effect of eight weeks of functional core training on core stability in young artistic gymnasts. Forty-five young artistic gymnasts were recruited for a functional core stability training program and their core stability was evaluated before and after the program with the knee flexion dislocation test, active straight leg raise test, and pelvic tilt test. The results revealed that the knee flexion dislocation and pelvic tilt had significantly improved after the core stability training. The research implies that by incorporating core fitness exercises into regular training, the stability of athlete can be increased, thus potentially boosting the competitive capability of artistic gymnasts. Meanwhile, (Esteban-García et al., 2021) investigated the effect of 12 weeks of core training on core muscle performance in artistic gymnastics. Twenty-

four artistic gymnasts were recruited for the study, and their body composition, trunk strength, core endurance, and surface EMG of the muscles in the core were measured before and after the intervention training. Results indicated that 12 weeks of core training can improve athlete's performance by increasing trunk lean mass, bone mass, trunk strength, and forward flexion EMG. These improvements can help enhance athletic performance. In addition, Zhang (Zhang et al.,2022) investigated the effects of 8 weeks of core and augmentation training on athlete posture, which showed significant improvements in single-leg stance metrics and balance assessments on both the left and right side before and after training. (Donti et al., 2016) analysis of the influence of physical fitness on technique execution scores among 46 young artistic gymnasts revealed that physical fitness had a greater effect on technique for lower-level athlete, and that there were notable disparities in physical fitness between athlete of different competitive levels. Moreover, numerous studies have indicated that physical training can have a considerable impact on the performance of artistic gymnasts in competitions. Therefore, physical fitness training should be an integral part of the training of artistic gymnasts if they are to reach a higher competitive level.

In addition to physical fitness factors, researchers investigated the effects of resistance training and vibration training on strength, flexibility, and balance in artistic gymnasts. Piazza (Piazza et al., 2014) investigated the effects of resistance training on the explosive power and responsiveness of the lower limbs in artistic gymnasts. The study randomly assigned 57 artistic gymnasts to a dumbbell resistance training group and a weight-band-specific resistance training group, and the subjects performed deep squat jumps, reverse squat jumps, single-leg jumps, hip flexibility, and anthropometric tests before and after 6 weeks of training, and the results showed that both types of training had a positive effect on his subjects' jumping ability and explosive power, with a 6%–7% increase in explosive power, a significant increase in reverse half squat jump stall time The results showed that both types of training had a positive effect on the subjects' jumping ability and explosive power, with a 6%–7% increase in explosive power, a significant increase in reverse half-squat stall time, and a significant decrease in touchdown time.(Battaglia et al., 2014) investigated the short-term effects of whole-body vibration training on balance, flexibility, and lower-body explosive power in good artistic gymnasts. The study divided the subjects into whole-body vibration training and control groups, and data were collected before the start of training and 15 min after the end of training for sitting and forward extension tests to measure flexibility, deep squat jumps, reverse squat jumps, and single-leg squats, and the results demonstrated that athlete's flexibility, strength, and balance improved after 15 min of whole-body vibration training.(Akkari-Ghazouani et al., 2023) studied the characteristics of the jumping movements of seven members of the Tunisian national team in rhythmic gymnastics. The kinetic and kinematic variables of the ball-less gliding soaring jump, the ball-throwing gliding soaring jump and the gliding ball-throwing soaring jump in rhythmic gymnastics were investigated. Subjects performed the jumping experiment on a specially designed carpet with an integrated force plate, which was recorded in 2D by using two cameras. The experimental results yielded significant effects for all three jumps, with the gliding ball toss tentative jump increasing the rate of force

development, horizontal and vertical velocity, and displacement technicality and being the most effective jump.

Athletic performance is not only determined by what is included in training, but also by the intensity of the training. (Debien et al., 2020) explored the relationship between training load and recovery in the pre-Olympic season. In this research, eight elite artistic gymnasts were monitored over a period of 43 weeks to examine the correlation between total weekly training load, intensity, frequency, duration, recovery, and acute and chronic load. Results revealed a gradual increase in the number of training sessions and their length each week. This increase in the amount of time necessary for recovery would create a negative correlation between the two during the season. Therefore, setting the training intensity during the competition phase is the key to ensuring that gymnasts are in good condition for competition. In addition, (Bellafiore et al., 2019) observed the effect of two different training intensities on the oxidative/antioxidant status of artistic gymnasts. Their blood samples were collected from 10 amateur artistic gymnasts before and after high-intensity and low and medium-intensity training, as well as 48 h after training, and analyzed the level of hydrogen peroxide and the total antioxidant capacity of the athlete, showing that the level of hydrogen peroxide was significantly higher after 48 h of high-intensity training than after low and medium intensity training and that hydrogen peroxide decreased significantly immediately after low-intensity training and increased to pre-training levels after 48 h The results showed that hydrogen peroxide levels were significantly higher 48 h after high-intensity training than after low-intensity training. The study suggests that there are differences between the blood oxygen regulation mechanisms of high-intensity training and low-intensity training and medium-intensity training.

Investigations into rhythmic gymnastics have focused on the effects of the content and intensity of training on the performance of rhythmic gymnastics. Results from several studies have indicated that regular core strength training sessions can effectively enhance the athletic performance of artistic gymnasts. Core training has been shown to improve balance in athlete, which is a major factor in the overall athletic ability of artistic gymnasts, thus leading to an increase in athletic performance. Resistance training, vibration training, and jump training can all be beneficial in increasing strength and agility, thus enhancing athletic performance. The intensity of the training is essential for attaining the desired post-training effects. However, the intensity of the training is not the only factor that affects the post-training effects; age and level of athletic performance must also be taken into consideration. Therefore, the relationship between training intensity on the changes of athlete's athletic ability needs to be further investigated.

2.2. Nutrition and metabolism

The rhythmic gymnastics program has relatively high demands on the body shape of athlete. In order to maintain a better body shape, athlete often use controlled intake to regulate the athlete's body shape, but this method often affects the athlete's normal nutritional intake to affect the athlete's physical health and competitive ability. To understand the effects of nutritional intake on athlete, researchers have

conducted studies on the nutrition and diet of athlete. (Kokubo et al., 2016) explored the relationship between dietary status and body iron levels in Japanese collegiate artistic gymnasts. The study investigated subjects' anthropometric data, blood data, and assessment of dietary intake, and the results suggested that Japanese artistic gymnasts' intakes of protein, iron, zinc, and various vitamins did not meet the recommended dietary intakes, resulting in significantly lower iron-binding capacity. In particular, the lower protein intake put the athlete at a higher risk of iron deficiency. In addition, (Paiva and Silva, 2016) explored the relationship between pre-competition sleep habits, nutritional deficiencies, body composition, and athletic performance in outstanding gymnasts. It assessed the daily training, body composition, sleep duration, sleep quality, athletic competition anxiety, and dietary intake of 67 high-level artistic gymnasts. The results showed that high-level gymnasts were prone to energy deficits, including lower intakes of vitamins and minerals important for high-level athlete. (Martínez-Rodríguez et al., 2020) assessed the nutritional diet status, body composition, eating behavior and perceived image of artistic gymnasts. The anthropometric assessment, eating attitude test, body image questionnaire, and collection of socio-demographic, socio-sports, health and food intake data were conducted on 33 female artistic gymnasts. The results showed that the athlete's diets were deficient in macro-nutrients and micro-nutrients such as carbohydrates, proteins, minerals, and vitamins, and that the athlete had low body fat levels. However, no nutritional imbalance was found in artistic gymnasts in the other two surveys. (Salbach et al., 2007).

Investigated the body image and attitudinal aspects of eating disorders in artistic gymnasts. The study analyzed the differences between the prevalence of eating and body image dysmorphism among outstanding artistic gymnasts, patients with anorexia nervosa, and general high school girls using an eating scale. Its investigation of subjects' weight, height, body mass index, presence of amenorrhea, and frequency of exercise showed that excellent artistic gymnasts had a significantly higher body mass index than patients with anorexia nervosa and high school students. In the eating disorders and body dysmorphic tests, patients with anorexia nervosa scored significantly higher than excellent artistic gymnasts and high school students on all scales, and no significant problems were found in the excellent artistic gymnasts in terms of eating disorders. Meanwhile, (D'Alessandro et al., 2007) explored the dietary intake and body composition characteristics of suboptimal artistic gymnasts. The study collected dietary recall, anthropometric and bioelectrical impedance data from 55 artistic gymnasts and 55 non-athlete females and showed that artistic gymnasts had better dietary intake habits compared to age-matched controls.

In addition to the relationship between body size and nutrition, researchers have investigated the relationship between training and nutrition. (Michopoulou et al., 2011) explored the relationship between dietary intake and energy balance exhibited by premenstrual, outstanding artistic gymnasts during intense training. By estimating the daily energy intake, energy expenditure and resting metabolic rate of the athlete, it was found that gymnasts had lower body weight, body mass index, carbohydrate intake and suggested that gymnasts need to increase their daily energy intake to avoid energy deficit in the body during high intensity training. (Paiva and Silva,

2015) This study assessed the dietary intake and body composition of outstanding artistic gymnasts prior to competition. The study evaluated 67 athlete after weekly training, which included the collection of training data and competition data, medical and gynecological history, dietary intake and body composition before the athlete's competitions, and showed that: (1) most of the athlete experienced delayed menstruation and menstrual irregularities; (2) the athlete's weight and body mass index before competitions were below age-normal values and carbohydrate, protein, vitamins, and minerals had low average intakes. Therefore, gymnastics training predisposes athlete to low energy, low body fat, and micronutrient deficiencies. Furthermore, (Kawano et al., 2002) investigated the effect of milk intake at different times on iron stores and dietary habits in artistic gymnasts. The subjects were divided into two groups during the weight loss period; group I subjects took iron supplement tablets at breakfast and dinner time and also consumed low-fat milk twice a day, while group II subjects did not take iron supplement tablets and low-fat milk, and blood was collected four times during the experiment and erythrocyte count, hemoglobin, serum iron, ferritin and erythropoietin concentrations were measured. The results showed that the body mass of the athlete in both groups was significantly lower after three months than in the first two months; the red blood cell count, hemoglobin, and serum ferritin concentrations were significantly higher in group I compared to group II. The energy and carbohydrate intake in group II was significantly lower after three months than in the first two months. Thus, dietary supplementation of iron through milk intake promoted the body's iron stores.

Studies have demonstrated that extended involvement in gymnastics does not result in metabolic issues or nutritional deficiencies for athlete. The exacting standards of the event on the athlete's body shape may cause their diet to be inconsistent, resulting in metabolic issues or nutritional deficiencies. To guarantee the well-being of athlete, it is essential to keep track of their nutritional intake and dietary habit.

2.3. Sports injuries and rehabilitation

Studies on injuries in artistic gymnasts have been conducted to evaluate the prevalence of injuries at different phases of competition and careers, areas of high-risk for injury, and curative measures for injuries and illnesses.

In epidemiological investigations, (Edouard et al., 2018) conducted statistics on the incidence and characteristics of injuries in men's and women's gymnastics (rhythmic gymnastics and trampoline) events at three Olympic Games. The study showed a 95% injury rate in gymnasts, with 38% of injuries resulting in lost athletic time, the most common site and type of injury being ankle (22%) and sprain (35%), respectively, and the most common diagnosis being ankle sprain. Therefore, research should focus on the prevention of ankle sprains in artistic gymnasts and monitoring during important competitions. A comparison of Edouard's research and the pre competition epidemiological research results of rhythmic gymnastics reveals a disparity. (Gram et al., 2021) explored injuries, prevalence, morbidity and risk factors in competitive artistic gymnasts in the pre-competition period. The study investigated the injuries, illnesses and training time of 133 artistic gymnasts in the 15

week prior to competition through a baseline questionnaire, a triad-specific self-report questionnaire, and a health questionnaire from the Oslo Sports Trauma Research Center, which showed that: (1) the prevalence of overuse injuries and acute injuries in artistic gymnasts was 37% and 5%, respectively, and the most severe overuse injuries were in the knee , lumbar and hip, and groin; (2) the appearance of the athlete's first menstrual period decreases the athlete's chances of substantial injuries. The study suggests that gymnasts without menstruation have a higher risk of substantial injury and that injury prevention interventions should begin early, with injury prevention focusing on the knee, low back, hip, and groin. Moreover, (Paxinos et al., 2019) carried out a longitudinal survey to investigate the injuries and illnesses of rhythmic gymnastics athletes over the span of their 10-year sports careers. They reported the injury records of 156 outstanding Greek male and female artistic gymnasts over a 10-year period. The records showed that the most frequently affected areas were the hip, ankle, lumbar spine and foot. The most common diagnosis was tendonitis, followed by low back pain and sprains. Overuse type injuries are more pronounced in competitive gymnasts compared to artistic gymnasts.

In the areas of injures, Sabeti's et al. (2015) research yields us pertinent data in relation to the site of injury. They analyzed the pain areas and pain intensity in outstanding artistic gymnasts and compared the results with age-matched controls. It developed questionnaires for interviews with 144 outstanding artistic gymnasts and 99 high school students with no competitive experience. The results showed that 72% of the gymnasts had pain in at least one body part, compared to 52% of the average high school student. The injury rate for the best gymnasts was three times higher than that of their average peers. Of all gymnasts, 23% did not have access to professional medical care, with the highest incidence in the lumbar spine and ankle. Thus, the intense training of rhythmic gymnastics is an important factor contributing to the fact that gymnasts have more and stronger pain than their peers. Therefore, gymnastics is a sport with a high prevalence of musculoskeletal pathology and requires proper documentation in order to develop preventive measures. A study by (Piazza et al., 2009) analyzed the prevalence of low back pain in artistic gymnasts compared to the general population. The study included 60 artistic gymnasts and 60 adult females who did not participate in high-level sports competitions, and a standardized questionnaire was used to assess the subjects' low back pain symptoms. The results showed that: (1) the age of onset was earlier in athlete than in the general population; (2) athlete who complain of low back pain during sports training have a higher incidence of symptoms during competition and will retire earlier.

In rehabilitation, Lena et al. (2020) investigated the efficacy of Mezerez postural therapy on outstanding artistic gymnasts suffering from low back pain. Ninety gymnasts were divided into an intervention group of 39 and a control group of 51. A total of 60 sessions of Mezerez postural therapy over 24 weeks were administered to those in the intervention group. Univariate ANOVA and independent samples t-test were performed mainly on data related to visual analogue pain scale, sitting and stretching flexibility test, pedometer robot application, Roland-Morris physical disability questionnaire and health status questionnaire. The results showed that the intervention group showed significant improvements in the visual analog

scale, and pain assessment scale. The same was true even for the Roland-Morris questionnaire, physical scores, mental scores, sitting extension flexibility test and running scores, with higher between-group effect values during the 24-week treatment period. Thus, all Mezerez postural therapy had a positive effect on the treatment of low back pain in athlete. With regard to muscle injuries.

Above all, Rhythmic gymnastics has a notably high rate of injuries, particularly among elite athlete. The longitudinal survey revealed that tenosynovitis was the most commonly reported injury, with low back pain and sprains following close behind. Sprains, particularly ankle sprains, were especially common during competitions. To reduce the risk of ankle sprains, it is important to create targeted prevention programs. Over-exertion is a major contributor to injuries among artistic gymnasts, consequently, it is critical for coaches to appropriately manage their training load. Artistic gymnasts have fewer preventive programs and rehabilitation studies available to them, and thus, more research is necessary to create effective programs that can help reduce the risk of injury.

3. Issues and problems

In rhythmic gymnastics programs, the improvement of core strength leads to the improvement of athletic performance. In recent years there has been an increasing interest in how to train core fitness efficiently, consistently and safely. A reading of the literature showed that many of the training methods are based on opinions, personal experiences, and some narrative review articles, which are not based on existing scientific evidence. As a result, there is no consensus on the most validity training methods to stimulate the core muscles. Therefore, there is a need for a systematic evidence-based summary of specific types of core fitness training for rhythmic gymnastics in order to provide informed recommendations for rhythmic gymnastics coaching training.

Due to the perfection and complexity of rhythmic gymnastics techniques, high physical demands are placed on athlete, making them susceptible to a variety of injuries. The safety manual of the American Gymnastics Association defines “gymnastics injury” as any harm that causes gymnasts to miss any part of their training or competitive activities during gymnastics competitions. While there is a wealth of research literature on rhythmic gymnastics injuries and rehabilitation, there is a lack of studies focusing on common injury sites, causes, and probabilities among gymnasts. Despite inconsistent research data, common patterns can be summarized to provide an overview.

Rhythmic gymnastics is a sport that can be practiced and competed in both individually and collectively. As the skill level of rhythmic gymnasts continues to rise, so does their weekly training volume, potentially affecting their training load. It is crucial for gymnasts to recover steadily and promptly within a season to perform at their best during official competitions. However, there is a scarcity of literature on the training load and recovery of rhythmic gymnasts. Existing literature does not clearly outline strategies to enhance athlete’s recovery. Therefore, we are limited to systematically summarizing current research findings to provide training guidelines for rhythmic gymnastics coaches.

Rhythmic gymnasts generally exhibit a petite stature and delayed maturation, largely attributed to the rigorous training and inadequate nutrient intake from a young age. They tend to maintain low body weight and slender figures by reducing their nutrient intake, leading to prevalent cases of malnutrition among elite rhythmic gymnasts. Prolonged intense training results in delayed development, menstrual irregularities, decreased bone density, low body mass index, and insufficient intake of essential nutrients such as proteins and micronutrients, keeping athlete in a suboptimal state of health. Limited literature addresses the inadequate nutrient intake among gymnasts, lacking a comprehensive overview and presenting scattered viewpoints. This article aims to synthesize these perspectives to offer a foundational reference for enhancing the nutritional intake of rhythmic gymnasts.

4. Related studies

This paper provides a systematic review of literature on core physical training in rhythmic gymnastics, categorizing it into "traditional core, core stability, ball/apparatus exercises, free weights, and non-core free weights" (Cabrejas et al., 2022; Esteban-García et al., 2021). These exercises effectively enhance athlete's trunk core strength and endurance. The performance of trunk core strength serves as a crucial link between the upper and lower limbs, transmitting stability to ensure the stability and endurance of gymnasts' movements, thereby enabling rhythmic gymnasts to execute movements with high quality.

After conducting research, it was found that the injury rate of rhythmic gymnasts during competitions is higher than during training. Among individuals with sports injuries, overuse injuries are much more prevalent than acute injuries, with elite athlete experiencing three times the injury rate of ordinary athlete due to high-intensity training (Gram et al., 2021). Female athlete who has reached menarche have a lower likelihood of sustaining substantial injuries. Common sites for sports injuries include the knee joint, ankle joint, lumbar vertebrae, hip joint, buttocks, and groin, with athlete often diagnosed with tendonitis, followed by lower back pain and sprains (Debien et al., 2020).

In the competitive season of rhythmic gymnastics, there are significant variations in the intensity, load, and recovery of training. Proper allocation of training load and intensity is beneficial for gymnasts to compete in a recovered state, optimizing their physical condition during competitions. Moreover, appropriately scheduling training load and intensity helps enhance the athlete's technical proficiency (Silva et al., 2022). Different intensities of training have an impact on the athlete's oxidative/antioxidant status. Following high-intensity training, athlete exhibit significantly higher levels of hydrogen peroxide in their bodies compared to medium to low-intensity training. Conversely, after medium to low-intensity training, athlete show a notable decrease in hydrogen peroxide levels. Therefore, varying training intensities play a regulatory role in the athlete's internal hydrogen peroxide levels.

Rhythmic gymnasts are typically young, undergoing crucial growth and physical development. Given the unique demands of rhythmic gymnastics, it is essential to ensure adequate nutritional intake to maintain athlete's health while also

managing weight and promoting a slender physique. Despite athlete's substantial daily energy intake, their high energy expenditure often leads to energy deficits. Therefore, it is necessary to appropriately increase their energy consumption and enhance the intake of high-quality proteins, especially dairy products, as well as ensure sufficient calcium and vitamin D intake. It is recommended that athlete consume at least > 5 servings of fruits and vegetables daily (Villa et al., 2021). This dietary approach not only meets the athlete's daily energy requirements but also reduces the risk of fractures among athlete.

5. Suggestions and solution

5.1. Suggestions

In rhythmic gymnastics training, physical conditioning primarily focuses on enhancing the core muscle strength of athlete. The stronger the core muscle capacity of athlete, the greater the stability of their movements, particularly beneficial for less experienced athlete. Additionally, incorporating special methods such as resistance and vibration training can improve athlete's lower limb muscle responsiveness, flexibility, and ability to control the direction of force application.

In rhythmic gymnastics, injuries are commonly seen, with a majority happening during competitions and a minority during training. The lower limbs and hip joints are the most vulnerable sites for injuries, underscoring the importance of prioritizing the protection of these areas during both training and competitions.

The ultimate goal of any sports training is to enable athlete to consistently perform well and even excel during competitions, a principle that also applies to rhythmic gymnastics. Properly managing the relationship between training intensity, workload, and recovery in daily training, and incorporating it into the training cycle, not only enhances athlete's professional skills but, more importantly, ensures they can maintain peak performance during official competitions.

Given the characteristics of rhythmic gymnastics programs, athlete are generally young, often in the midst of physical growth and development. However, competition demands that athlete maintain a slim figure, resulting in rigorous training and limited nutritional intake. Consequently, providing athlete with high-protein, low-fat foods can help address issues of nutritional deficiency.

5.2. Solution

Core physical training can enhance the abdominal rectus, internal and external obliques, diaphragm, serratus anterior, transverse abdominis, and quadratus lumborum muscles in rhythmic gymnasts. These core muscle groups play a crucial role in providing stability, control, and support for various complex movements and postures during rhythmic gymnastics, thereby reducing the risk of injury. Training these core muscles helps gymnasts improve body control, balance, and strength, enabling them to perform elegant and precise movements. Applying additional resistance to the lower limbs stimulates muscle elasticity and endurance, which can be achieved using free weights, resistance bands, fitness equipment, or body weight. Furthermore, mechanical vibration can be utilized to stimulate muscles and the

nervous system. This training method involves using a vibration platform or specialized equipment to induce mechanical vibrations that trigger muscle contractions and relaxations. It aims to increase muscle strength, improve flexibility, enhance balance and coordination, and facilitate rehabilitation and recovery training.

In the field of sports injuries, rhythmic gymnastics injuries are a common issue. To prevent such injuries, it is crucial to engage in thorough warm-up and cool-down routines before training sessions. Warm-up activities enhance muscle viscosity, reducing the risk of muscle strains, while cooling down helps alleviate muscle soreness. During training, emphasis should be placed on correct technique and gradual progression in difficulty and challenge. It is essential to focus on achieving overall muscle balance by training core muscles, stabilizing muscle groups, and promoting flexibility. Key areas for training include the abdominal muscles, back muscles, and pelvic muscle groups. Avoiding overreliance on specific muscle groups or exercise methods is important to prevent overuse and injury in certain areas. Lastly, whether during competitions or regular training sessions, providing the body with sufficient rest and recovery time using appropriate methods is crucial to allow for muscle and tissue repair and growth. Additionally, the use of suitable protective gear such as padding and gloves can offer added protection and support.

The relationship between training intensity, load, and recovery is crucial for rhythmic gymnasts to perform effectively in competitions. Coaches must tailor training plans based on athlete's age, abilities, and level, gradually increasing intensity and load. Providing adequate rest and timely recovery interventions post-training is essential. Regular monitoring of athlete's physical condition, pain levels, training progress, and fostering open communication with athlete are key strategies to help them achieve peak performance in competitions.

The rhythmic gymnastics discipline is characterized by high difficulty and high energy expenditure, necessitating athlete to have a well-balanced nutritional intake to meet their body's demands. To address the issue of nutritional deficiencies among rhythmic gymnasts, several solutions are proposed, emphasizing the importance of athlete maintaining a balanced diet. This includes the appropriate intake of carbohydrates, proteins, fats, vitamins, and minerals. Of particular significance is the role of proteins, as they are crucial for muscle repair and growth. Good sources of high-quality proteins include lean meats, fish, legumes, dairy products, and eggs. Carbohydrates serve as the primary energy source for athlete. Vitamins and minerals support normal bodily functions and the immune system. Therefore, it is recommended that athlete consume easily digestible carbohydrates before training to provide energy, and consume proteins and carbohydrates post-training to facilitate muscle recovery and growth.

6. Conclusion

In conclusion, core physical training, strength training, resistance training, and whole-body vibration training can significantly enhance the flexibility, strength, balance, and lower limb explosive power of rhythmic gymnasts, thereby improving their athletic performance. Adequate nutritional regulation is crucial, with athlete needing to increase their intake of carbohydrates, proteins, and micronutrients to

avoid the negative impact of energy deficiency during high-intensity training on their bodies and athletic performance. Furthermore, rhythmic gymnasts are at a higher risk of injury, especially in the knee joints, lower back, and ankle joints, making early prevention and rehabilitation measures key to ensuring the athlete's long-term health and performance. The combination of scientific training, proper nutritional management, and effective injury prevention strategies can significantly enhance athlete's competitive levels and prolong their athletic careers.

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