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Review



Idiopathic aseptic necrosis of the femoral head in children who are professionally engaged in gymnastics: A literature review

Ivan Yu. Pozdnikin, Pavel I. Bortulev, Dmitrii B. Barsukov

H. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery, Saint Petersburg, Russia

ABSTRACT

BACKGROUND: Aseptic necrosis of the femoral head in school-age children is a severe, rapidly progressive degenerative and dystrophic disease. A significant proportion of girls aged >10 years with osteonecrosis of the femoral head have been professionally engaged in rhythmic gymnastics. The relationship between professional sports, in particular rhythmic gymnastics, and the development of this pathology and the mechanism of impaired blood flow in the femoral head in such cases remains unclear. The severity of the course and serious consequences of this disease in the form of multidimensional deformities of the femoral head, early arthrosis of the hip joint, and persistent disability, require close attention.

AIM: To analyze modern world literature data on the etiology, pathomechanics, and features of the course and treatment of idiopathic aseptic necrosis of the femoral head in children professionally engaged in rhythmic gymnastics.

MATERIALS AND METHODS: A literature search on the problem of idiopathic aseptic necrosis of the femoral head in children professionally engaged in rhythmic gymnastics in the open information databases was conducted in PubMed, Science Direct, and Library with an analysis depth of 20 years.

RESULTS: The analysis of publications on the osteonecrosis of the femoral head allowed us to talk about the etiological connection of this condition with professional rhythmic gymnastics, namely, high-intensity repetitive loads on the hip joint of a child. Studies using in vivo laser Doppler flowmetry and 3D computer modeling prove the occlusion of blood vessel branches encircling the femur under excessive mechanical stress on the femoral head and potentially unfavorable positions in the hip joint – overextension (hyperextension), external rotation, and abduction.

CONCLUSIONS: Professional gymnastics can be a risk factor for the development of osteonecrosis of the femoral head. Frequent late disease diagnoses with the development of severe deformity of the femoral head and end-stage coxarthrosis requiring total hip replacement in adolescents determine the need for early identification of the causes of hip pain in children engaged in gymnastics. The findings will help improve treatment results and reduce the number of organ replacement interventions.

Keywords: osteonecrosis; gymnasts; aseptic necrosis of the femoral head; Legg–Calve–Perthes disease; sports, injury; coxarthrosis.

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Научный обзор

Идиопатический асептический некроз головки бедренной кости у детей, профессионально занимающихся гимнастикой. Обзор литературы

И.Ю. Поздникин, П.И. Бортулёв, Д.Б. Барсуков

Национальный медицинский исследовательский центр детской травматологии и ортопедии имени Г.И. Турнера, Санкт-Петербург, Россия

АННОТАЦИЯ

Обоснование. Асептический некроз головки бедренной кости у детей школьного возраста — тяжелое, быстро прогрессирующее дегенеративно-дистрофическое заболевание. Значимая часть девочек старше 10 лет с остеонекрозом головки бедренной кости профессионально занималась художественной гимнастикой. Не до конца выяснены зависимость между профессиональными занятиями спортом, в частности художественной гимнастикой, и развитием этой патологии, а также механизм нарушения кровотока в головке бедренной кости в таких случаях. Тяжесть течения и серьезные последствия этого заболевания в виде многоплоскостных деформаций головки бедренной кости, раннего артроза тазобедренного сустава и стойкой инвалидизации заставляют обращать пристальное внимание на данную проблему.

Цель — проанализировать данные современной мировой литературы об этиологии, патомеханике, особенностях течения и лечения идиопатического асептического некроза головки бедренной кости у детей, профессионально занимающихся художественной гимнастикой.

Материалы и методы. Проведен поиск литературы по проблеме идиопатического асептического некроза головки бедренной кости у детей, профессионально занимающихся художественной гимнастикой, в открытых информационных базах PubMed, Science Direct, eLibrary с глубиной анализа 20 лет.

Результаты. Анализ публикаций по проблеме остеонекроза головки бедренной кости позволяет говорить об этиологической связи данного состояния с профессиональными занятиями художественной гимнастикой, а именно с высокоинтенсивными повторяющимися нагрузками на тазобедренный сустав. Работы с применением лазерной доплеровской флоуметрии *in vivo* и компьютерного 3D-моделирования доказывают о возникновении окклюзии ветвей кровеносных сосудов, огибающих бедренную кость, при чрезмерной механической нагрузке на головку бедренной кости и потенциально неблагоприятных положениях в тазобедренном суставе — переразгибании (гиперэкстензии), наружной ротации и отведении.

Заключение. Профессиональные занятия гимнастикой могут быть признаны фактором риска развития остеонекроза головки бедренной кости. Частые случаи поздней диагностики заболевания с развитием выраженной деформации головки бедренной кости и явлениями коксартроза терминальных стадий, требующих проведения тотального эндопротезирования тазобедренного сустава у подростков, определяют необходимость раннего выявления причин боли в тазобедренном суставе у детей, занимающихся гимнастикой. Это будет способствовать улучшению результатов лечения и сокращению числа органозамещающих вмешательств.

Ключевые слова: остеонекроз; гимнастики; асептический некроз головки бедренной кости; болезнь Легга – Кальве – Пертеса; спорт; травма; коксартроз.

Как цитировать

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BACKGROUND

Regular physical activity is beneficial for people of all ages. It determines proper energy balance and weight control, has a positive effect on mental health, and is a means of socialization [1, 2].

Many young people are focusing in one sport (“sports specialization”), which implies the improvement of skills, abilities, and selection of a specific area of sport with intensive year-round training and exclusion of other disciplines. Sports specialization enables an athlete to achieve a high level of professionalism and improves sports performance. However, it is associated with an increase in the general and local levels of loads, increase in training intensity and volume, risk of maladaptation in the absence of sufficient rest for recovery, and injuries [3–5].

Among orthopedists, the active growth period is a critical moment for young athletes, in which they have a high susceptibility to damage at the apophyseal and epiphyseal level, particularly during early sports specialization, which is characterized by chronic local microtrauma [6, 7].

Over the past two decades, the incidence of sports injuries in children tended to increase. In the literature, the incidence of injuries in artistic gymnastics ranges from 1.08 to 50.3 per 1000 h of training. In rhythmic gymnastics, most injuries (60.5%) are registered in the lower extremities, and the hip and pelvic injuries account for 15% of cases [8–11].

Osteonecrosis of the femoral head in adolescents professionally involved in sports is a relatively rare, severe, and rapidly progressive degenerative, dystrophic disease. Synonyms for similar pathological conditions in the world scientific literature include the terms “ischemic,” “nonvascular,” “avascular” necrosis, and “bone infarction”; however, in recent years, the general term “osteonecrosis of the femoral head” is more often used [12–14].

Frequently registered total and subtotal variants of femoral head damage have unsatisfactory treatment results, particularly in the final disease stages [12, 13]. The disease course, severity, and consequences such as multiplanar femoral head deformities, early hip joint arthrosis, and persistent disability force us to pay close attention to this problem.

The study aimed to analyze data from modern world literature on the etiology, pathomechanics, and course and treatment of idiopathic aseptic necrosis of the femoral head in pediatric patients professionally involved in rhythmic gymnastics.

MATERIALS AND METHODS

A search and analysis of data from modern scientific global literature was performed in PubMed, Science Direct, and eLibrary for the period from 2000 to 2023 using

the keywords “Legg–Calvé–Perthes disease” and “aseptic (avascular) necrosis of the femoral head”: Legg–Calvé–Perthes, Perthes-like necrosis, osteonecrosis femoral head, femoral head avascular necrosis late presentation, gymnastics, females, adolescents.

RESULTS AND DISCUSSION

Osteonecrosis of the femoral head is a severe progressive degenerative-dystrophic disease of the hip joint that affects mainly young people of working age [13–19].

If left untreated in the early stages, the femoral head collapses within 3–4 years in 80% of patients, which requires hip replacement. Statistically, 5%–17% of endoprosthetic surgeries are performed for aseptic bone necrosis [14–19].

Moreover, aseptic necrosis of the femoral head is a risk factor for early implant instability. The results of primary endoprosthetics for osteonecrosis of the femoral head are worse than with interventions performed for idiopathic coxarthrosis, and revisions within 10–15 years reach 40%. The situation is also aggravated by the young age of the patients owing to the limited lifespan of the artificial joint in these patients leading an active lifestyle [20–22].

A direct correlation was reported between training volume and intensity and the risk of injury. In sports, the baseline risk of injury in a young athlete increases when performing repetitive, intense exercise that results in chronic microtrauma to the bones, muscles, or tendons [23, 24].

Damage to the hip joint, particularly deformities of the proximal femur of the cam femoroacetabular impingement type, is a common cause of pain in athletes. In 1971, R.O. Murray and C. Duncan were the first to describe the potential association between the involvement in “aggressive” sports in adolescence and the development of proximal femoral deformity in the future [25]. In athletes involved in hockey, basketball, football, long jump, high jump, pole vault, and other sports, such a head deformity occurred up to eight times higher than in those in the control group [26].

According to the literature and our cases, the treatment outcomes of pediatric patients aged <8 years with a typical presentation of Perthes disease can generally be considered good, and the prognosis is favorable. In contrast, late-onset Perthes disease after the age of 9 years, particularly in women, characterized by total and subtotal involvement of the femoral head (Catterall III and IV), is associated with worse outcomes (Stulberg III and IV) and poor prognosis, which determines the great social and economic significance of the problem [27–29].

The ascending branches of the medial and lateral circumflex femoral arteries provide the main blood supply to the femoral head and neck. Femoral head ischemia and the subsequent development of osteonecrosis due to

the mechanical disruption of the integrity of blood vessels during trauma were proven using the "ligature model" [30]. Among other factors that contribute to impaired blood supply in children, thrombophilia-related coagulopathy, chronic glucocorticoid therapy, sickle cell anemia, systemic lupus erythematosus, hyperlipidemia, chronic renal failure, diabetes mellitus, etc., are the most frequently mentioned in the literature [31–33].

Excluding these most possible causes of osteonecrosis of the femoral head, an etiological relationship of this condition with professional sports can be assumed, that is, with high-intensity repeated loads on the hip joint. In particular, high-level gymnastics requires significant flexibility in the hip joints and long training, and exercises often involve positions of extreme range of motion that are not typical for other sports or daily activities. In addition, a high load on the hip joint is associated with somersaults, landings, and strong impacts [4–11, 13, 34, 35]. Several studies have examined this issue, which examines the relationship between professional sports, particularly rhythmic gymnastics, and the development of osteonecrosis of the femoral head [36, 37].

Y. Assouline-Dayane et al. (2002) suggested that the anterosuperior segments of the femoral head, which bear a greater load of the body weight, are more sensitive to the effects of mechanical overload, which may result in vascular occlusion of the lateral segment of the femoral head [38].

This hypothesis was confirmed by K. Mihara and T. Hirano (1998). They revealed that osteonecrosis developed in some rats that were forced to stand on their hind limbs while being fed in high cages; however, this was not observed in control rats fed in low cages. The authors admitted that excessive mechanical load on the femoral head was at least one of the causes of osteonecrosis [39].

In another rat study, G. Yoshida et al. (2000) noted that when the hip was subjected to excessive load using a special device, significant deformity of the femoral head occurred, particularly in the lateral parts, and its severity correlated with the amount of weight. This compression also caused the occlusion of the lateral circumflex epiphyseal arteries at the site of their penetration into the integumentary cartilage [40].

A.N. Larson et al. obtained similar data, suggesting the mechanical nature of osteonecrosis in several of cases, when examining 13 gymnasts with late-onset Legg–Calvé–Perthes disease. In the group aged >10 years, >75% of such patients were girls who were professionally involved in rhythmic gymnastics. Thus, repeated microtrauma of the hip joint structures during training can be considered the main cause of osteonecrosis [37] (level of evidence: IV, case series). Several other animal studies have reported similar findings [41, 42].

Thus, repeated loads in extreme hip positions associated with professional rhythmic gymnastics may be a possible etiological factor of the osteonecrosis of the femoral head [36, 37].

Undoubtedly, this does not happen in the majority of adolescents of this age group involved in sports, particularly gymnastics; however, as with other orthopedic diseases, osteonecrosis of the femoral head is believed to be caused by the combined effects of genetic variability in the anatomical structure of the bone and vascular anatomy and cartilage tissue, which may increase the disease risk under conditions of chronic trauma to the hip joint [38–40, 43] (level of evidence: case series, level IV).

Thus, traumatic injury was the most probable etiological factor in the development of osteonecrosis in female gymnasts; however, its pathomechanical causes were not fully determined [36, 37].

In our opinion, the following two studies are of the greatest interest. H.P. Nötzli et al. (2002), using laser Doppler flowmetry *in vivo*, established a decrease in the femoral head perfusion when the posterolateral surface of the femoral neck contacts the edge of the acetabulum posterior wall, which usually occurs with full extension and/or external rotation of the femur [44]. These changes were reversible and caused by the compression of the retinacular branches of the medial circumflex femoral artery on the posterolateral surface of the femoral neck [45].

S. Blümel et al. (2022) hypothesized that osteonecrosis is caused by repeated exposure to retinacular vessels and their occlusion, as a result of either injury or inflammation and reparative processes in the vascular wall. The medical history excluded trauma, previous avascular necrosis of the femoral head, or hormonal use. Based on laboratory tests, immunological or hematological pathology and other known risk factors were ruled out. To explore this hypothesis, 3D modeling of potentially unfavorable hip joint positions was performed using computed tomography, which demonstrated the contact between the neck and the posterior edge of the acetabulum during hyperextension, external rotation, and abduction [13]. For gymnasts, these extreme positions in the joint are stereotypical movements during "stretching" exercises, which are often with high intensity or for a long time.

An important aspect of the problem is early disease diagnosis. In most cases, determining the cause of hip pain can be a major challenge for orthopedic surgeons [46, 47]. The diagnosis of osteonecrosis of the femoral head is made late; patients visit an orthopedist and are admitted to the hospital only weeks and months after disease onset. The duration of clinical manifestations in such patients before referral to an orthopedist ranges from 4 to 7 months. In our opinion, the following circumstances cause difficulties in the early diagnostics of

aseptic necrosis of the femoral head in children involved in sports:

1. In the absence of an obvious injury, moderate pain after training, during periods of rest and recovery, often stops. In persistent pain, this problem can be regarded as a muscle strain with the appropriate use of painkillers and anti-inflammatory drugs locally and orally, which to some extent disguises the clinical presentation of the disease onset.
2. With more pronounced clinical symptoms, considering the plasticity and mobility of the muscles and ligaments in young female gymnasts, a sports doctor often does not reveal limitations in the range of motion in the joint, particularly abduction and internal rotation of the hip, and, generally, rules out avulsion fractures of the pelvis and hip, which are typical injuries in adolescent athletes (anterior superior and inferior iliac spines, ischial tuberosity, and lesser trochanter) [6, 7, 48].
3. On radiographs of the hip joints at the early disease stage, naturally no signs of aseptic necrosis of the femoral head were found.

Thus, the interpretation of the situation as a consequence of muscle strain and the absence of exclusion of support on the affected limb in untreated symptoms of synovitis leads to the loss of time and development of joint contractures (external rotation and flexion), extrusion, and subluxation of the femoral head with subsequent occurrence of its gross deformity.

A transient inflammatory response of the joint in the initial phase of the development of the femoral head necrosis is typical. However, chronic, long-lasting inflammation, which is often noted in such cases, characterizes an aggressive disease course with signs of osteoarthritis and becomes a serious problem because it directly negatively affects the clinical presentation and disease outcomes [49]. In recent years, studies have reported more severe variants of osteonecrosis in patients with a history of COVID-19, particularly due to a difficult-to-control inflammatory process in the hip joint [50–53]. This necessitates the involvement of a rheumatologist and changing the nature of conservative drug therapy, including the use of bisphosphonates [49].

In gymnasts, an unfavorable factor, particularly contributing to the early development of subluxation in the hip joint with total or subtotal damage to the head, is also often the peculiarities of the anatomical development of the acetabulum and proximal femur, without which increasing the range of motion in the hip joint is impossible. This concerns borderline values of the degree of bone coverage of the femoral head (SCP 2/3 > 3/4 and Wiberg angle 18°–20°) [54, 55].

Considering the age of the patients, femoral head remodeling, which is typical for preschool children with aseptic necrosis and Perthes disease, is impossible because

of limited growth potential. Accordingly, the prognosis of the disease, often called “late-onset Legg–Calvé–Perthes disease,” in patients aged >9 years will be poor [27, 28, 56].

Thus, the treatment of such patients poses a serious problem. Currently, no consensus has been made on this issue. Conservative treatment as monotherapy is possible only for small local lesions centrally located in the femoral head. Minimally invasive interventions often become ineffective in complex disease presentation and even more so if complications occur. In the late diagnostics and beginning of treatment of severe femoral head deformity, more extensive and traumatic interventions, including modeling resections of the femoral head to restore stability and congruence in the hip joint, must be used [44, 45, 57, 58]. Such intra-articular interventions, particularly surgical hip dislocation according to Ganz, are not often performed in Russia, because of their complex technical features. In advanced cases, mainly with intractable symptoms of synovitis in the hip joint and disrupted orthopedic regimen, femoral head collapse and chondrolysis occur with symptoms of terminal stage coxarthrosis, which necessitates total hip arthroplasty as an extreme and compulsory treatment method in adolescents [14, 16, 21, 29]. Expectant management followed by organ replacement interventions conflicts with the currently accepted concept of organ-preserving orthopedic surgery in young patients [59–63]. With early disease diagnostics and treatment initiation in adolescents, conservative orthopedic measures or radical surgeries while reducing the number of organ replacement interventions, which in general can contribute toward improvement of the disease prognosis, is possible in some cases.

In our opinion, parents, coaches, and doctors must consider that a child who complains of pain should seek medical help. The concept of “overcoming pain” cannot dominate gymnastics and youth athletics. Coaches of young female gymnasts should be aware that femoral head necrosis is a serious disease, whose development is quite possible in this sport and can be provoked by aggressive extreme hip joint movements. A systematic approach to studying the etiology of hip joint pain in children (history taking and thorough clinical and radiographic examination) is necessary.

Early differential diagnostics of the causes of hip joint pain in gymnasts should exclude osteonecrosis of the femoral head. In the presence of pain and absence of significant radiograph changes in the hip joints, magnetic resonance imaging using a device with a magnetic field strength of at least 1.5 Tesla is recommended. The initial stages of aseptic bone necrosis can be detected only with magnetic resonance imaging as the most sensitive (71%–100%) and specific (94%–100%) diagnostic method in such cases [12, 20, 64, 65].

Measures to prevent osteonecrosis in gymnasts can include limiting loads accompanied by extreme positions of the hip, use of a correct technique for performing exercises,

sufficient time for recovery and prevention of overtraining, and using a combination of specific and general physical loads.

CONCLUSION

Professional rhythmic gymnastics can be considered a risk factor for osteonecrosis of the femoral head. In young female gymnasts, this disease is caused by excessive loads and repeated extreme positions of the femur at extreme points of the hip joint range of motion, causing occlusion of the main feeding vessels along the posterolateral surface of the femoral neck. Typical extreme positions are hyperextension with external rotation and extension with external rotation in hip abduction. The course of the osteonecrosis of the femoral head in adolescent gymnasts is characterized by the predominance of total and subtotal forms of damage and frequent head extrusion with subsequent severe deformity due to the specific anatomical structure of the hip joint.

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Coaches and doctors must be aware of the existing problem. Issues related to optimizing treatment approaches for such patients also require further study.

ADDITIONAL INFORMATION

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All authors made significant contributions to the research and preparation of the article, and they read and approved the final version before its publication.

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AUTHOR INFORMATION

* Ivan Yu. Pozdnik, MD, PhD, Cand. Sci. (Med.);
address: 64–68 Parkovaya str., Pushkin, Saint Petersburg,
196603, Russia;
ORCID: 0000-0002-7026-1586;
eLibrary SPIN: 3744-8613;
e-mail: pozdnik@gmail.com

ОБ АВТОРАХ

* Иван Юрьевич Поздник, канд. мед. наук;
адрес: Россия, 196603, Санкт-Петербург, Пушкин,
ул. Парковая, д. 64–68;
ORCID: 0000-0002-7026-1586;
eLibrary SPIN: 3744-8613;
e-mail: pozdnik@gmail.com

* Corresponding author / Автор, ответственный за переписку

Pavel I. Bortulev, MD, PhD, Cand. Sci. (Med.);
ORCID: 0000-0003-4931-2817;
eLibrary SPIN: 9903-6861;
e-mail: pavel.bortulev@yandex.ru

Dmitrii B. Barsukov, MD, PhD, Cand. Sci. (Med.);
ORCID: 0000-0002-9084-5634;
eLibrary SPIN: 2454-6548;
e-mail: dbbarsukov@gmail.com

Павел Игоревич Бортулев, канд. мед. наук;
ORCID: 0000-0003-4931-2817;
eLibrary SPIN: 9903-6861;
e-mail: pavel.bortulev@yandex.ru

Дмитрий Борисович Барсуков, канд. мед. наук;
ORCID: 0000-0002-9084-5634;
eLibrary SPIN: 2454-6548;
e-mail: dbbarsukov@gmail.com