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THE ROLE OF PHYSICAL ACTIVITY ON THE DEVELOPMENT OF OSTEOPOROSIS IN CHILDREN AND ADOLESCENTS. LITERATURE REVIEW.

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Abstract

In today's world, osteoporosis is a widespread issue that affects not only adults but also children and adolescents. Various scientific studies indicate that bone strength is determined during childhood as the body matures. This period is marked by a rapid growth spurt that is influenced by genetic factors, hormonal changes, nutritional habits, and chronic diseases. With the onset of puberty, there is a rapid increase in the mineral content in the bones, reaching a peak shortly after the peak increase in growth. Lifestyle choices affect 20-40% of an adult's peak bone mass. It is assumed that exercises during growth counteract the involutional loss of bone mass at a later age due to an increase in peak bone mass. In turn, this disrupts the proper formation and mineralization of the bone skeleton, which actively gains peak mass by the age of 18 (up to 90%). In addition, maximizing age-related bone mass can also prevent fractures during growth, especially fractures of the upper extremities. In order to reduce the chances of experiencing fractures, it is important to implement methods for enhancing bone health from a young age.

The purpose of the study: to study the literature on the influence of physical activity and sports in children and adolescents in the development of osteoporosis.

Methods: A systematic search was carried out in the electronic databases PubMed, Google Academy, Cochrane Library. Key words such as “osteoporosis”, “adolescent”, “dual-energy X-ray absorptiometry”, “exercise”, “sport” were used in the literature search in databases. This search was limited to English-language studies published within 10 years (2013-2023).

Results. This review examined the main risk factors for osteoporosis in children and adolescents. The greatest attention is paid to the effect of physical activity on the bone tissue of children and adolescents and the use of densitometry in a comprehensive examination for early diagnosis of the disease in order to prevent the development of pathology.

Key words: *osteoporosis, adolescents, dual-energy x-ray absorptiometry, bone mineral density, physical activity, sport.*

Резюме

РОЛЬ ФИЗИЧЕСКОЙ АКТИВНОСТИ В РАЗВИТИИ ОСТЕОПОРОЗА У ДЕТЕЙ И ПОДРОСТКОВ. ОБЗОР ЛИТЕРАТУРЫ.

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Актуальность. Остеопороз в современном обществе является глобальной проблемой не только взрослого населения, но и в детском и подростковом возрасте. Многочисленные исследования показывают, что проблема костной прочности закладывается еще в детском возрасте в период созревания организма, когда отмечается резкий скачок роста за короткий период времени, который напрямую зависит от генетических, гормональных изменений,

алиментарных причин и хронических заболеваний. С началом полового созревания происходит быстрое приращение костных минералов, достигающее пика вскоре после пикового увеличения роста. Выбор образа жизни влияет на 20–40% пиковой костной массы взрослого человека. Предполагается, что упражнения во время роста противодействуют инволюционной потере костной массы в более позднем возрасте за счет увеличения пиковой костной массы. В свою очередь это нарушает правильное формирование и минерализацию костного скелета, которая активно набирает пиковую массу к 18 годам (до 90%). Кроме того, максимизация возрастной костной массы может также предотвратить переломы во время роста, особенно переломы верхних конечностей. Чтобы свести к минимуму риск переломов, стратегии улучшения здоровья костей должны быть приняты в самом раннем возрасте.

Цель: изучить данные литературы о влиянии физической активности и занятием спорта у детей и подростков на развитие остеопороза.

Методы: Проведен систематический поиск в электронных базах PubMed, Google Academy, Cochrane Library. В поиске литературы в базах данных были использованы такие ключевые слова, как «остеопороз», «подросток», «двухэнергетическая рентген абсорбциометрия», «физическая нагрузка», «спорт». Этот поиск был ограничен англоязычными исследованиями, опубликованными в течении 10 лет (2013-2023г.г.).

Результаты. В данном обзоре были рассмотрены основные факторы риска развития остеопороза у детей и подростков. Наибольшее внимание уделено влиянию физической активности на костную ткань детей и подростков и применение денситометрии в комплексном обследовании для ранней диагностики заболевания с целью предупреждения развития патологии.

Ключевые слова: *остеопороз, подросток, двухэнергетическая рентген абсорбциометрия, минеральная плотность кости, физическая активность, спорт.*

Түйіндеме

БАЛАЛАР МЕН ЖАСӨСПІРІМДЕРДЕ ОСТЕОПОРОЗДЫҢ ДАМУЫНА ФИЗИКАЛЫҚ БЕЛСЕНДІЛІКТІҢ РОЛІ. ӘДЕБИЕТТІК ШОЛУ.

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Остеопороз заманауи қауымдастықта тек ересек адамдардың ғана емес, сонымен қатар балалар мен жасөспірімдер арасындағы өзекті мәселе. Жыныстық жетілудің басталуымен және жасөспірімдік кезеңдегі өсу қарқынымен сүйек минералдарының тез өсуі байқалады, биіктіктің ең жоғары өсуінен кейін көп ұзамай шыңына жетеді. Өмір салтын таңдау ересектердегі ең жоғары сүйек массасының 20-40% әсер етеді. Өсу кезіндегі жаттығулар сүйек массасын жоғарылату арқылы кейінгі өмірде инволюциялық сүйек массасының жоғалуына қарсы әрекет етеді.

Көптеген зерттеулер көрсеткендей, сүйек беріктігі мәселесі тіпті балалық шақта дененің жетілуі кезінде, қысқа уақыт ішінде күрт өсу қарқыны болған кезде туындайды, бұл генетикалық, гормональды өзгерістерге, ас қорыту себептеріне және созылмалы ауруларға тікелей байланысты. Бұл өз кезегінде сүйек қаңқасының дұрыс қалыптасуы мен минералдануын бұзады, ол 18 жасқа таман (90% дейін) шыңдалып, ең жоғары массаға жетеді. Бұдан басқа, жастық сүйек массасының шыңдалуы өсу кезінде әсіресе қол сүйектерінің сынуын алдын алуға мүмкін болады. Сыну қаупін азайту үшін сүйек денсаулығын жақсарту стратегиялары өте ерте жаста қабылдануы керек.

Зерттеу мақсаты: балалар мен жасөспірімдерде остеопороздың дамуына дене шынықтыру және спортпен шұғылданудың әсері бойынша әдебиеттерді зерттеу.

Зерттеу әдістері: PubMed, Google Academy, Cochrane Library электронды базаларында жүйелі іздеу жүргізілді. Мәліметтер қорынан әдебиеттерді іздеуде «остеопороз», «жасөспірім», «екіэнергиялық рентген-абсорбциометрия», «жаттығу», «спорт» сияқты түйін сөздер қолданылды. Бұл іздеу 10 жыл ішінде (2013-2023) жарияланған ағылшын тіліндегі зерттеулермен шектелді.

Нәтижелер. Бұл шолуда балалар мен жасөспірімдердегі остеопороздың негізгі қауіп факторлары қарастырылды. Дене белсенділігінің балалар мен жасөспірімдердің сүйек тініне әсеріне және патологияның дамуын болдырмау мақсатында ауруды ерте диагностикалау үшін кешенді тексеруде денситометрияны қолдануға үлкен көңіл бөлінеді.

Түйінді сөздер: *остеопороз, жасөспірім, екі-энергетикалық рентген абсорбциометрия, сүйек минералды тығыздығы, физикалық жүктеме, спорт.*

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Introduction.

How we know, physical activity is important for health at any age and especially for children: it supports muscle tone, strengthens the immune system, produces the proper posture, prevents obesity. In addition, physical activity improves the condition of bone and cartilage tissue. Hypodynamia, can lead to fragile bones – osteoporosis (OP), i.e. low physical activity is one of the risk factors for the development of OP in children. Osteoporosis is a global problem in modern society not only of the adult population, but also in childhood and adolescence. The process of bone modeling begins during fetal growth and continues until the second decade of human life. Bone mass is acquired relatively slowly throughout childhood. As we already know, there are 3 types of bone tissue cells — osteoblasts, osteocytes and osteoclasts, which are involved in matrix resorption. It is important to know about the existence of gender differences in the formation of peak bone mass. So, in boys, its accumulation continues also after puberty, and in general, after 15 years, their bone mineral density (BMD) indicators are higher than in girls. In female adolescents, the maximum accumulation of bone mass occurs earlier (± 1-2 years from menarche) [2]. With the onset of puberty and a growth spurt in adolescence, a rapid increment of bone minerals occurs, which reaches a peak shortly after the peak increase in growth. That is, the maximum bone mineral content (BMC) achieved during these years can compensate for age-related bone loss and, therefore, can reduce the risk of fractures and bone fragility associated with osteoporosis. In addition, maximizing age-related bone mass can also prevent fractures during growth, especially of the upper limb [3].

Numerous studies show [5] that the problem of bone strength is laid in childhood during the maturation of the body, when there is a sharp jump in development in a short period of time, which directly depends on genetic, hormonal changes, alimentary causes and chronic diseases. In turn, this disrupts the proper formation and mineralization of the bone skeleton, which is actively gaining momentum by the age of 18 (up to 90%), reaching peak mass [5,20]. Lifestyle choices affect 20-40% of an adult's peak bone mass. It is assumed that exercises during growth counteract the involutional loss of bone mass at a later age due to an increase in peak bone mass [15]. Optimizing lifestyle factors that are known to affect peak bone mass and strength is an important strategy aimed at reducing the risk of osteoporosis or low bone mass later in life [1].

Thus, in order to minimize the risk of fractures, strategies to improve bone health should be adopted at a very early age [15].

Aim: to study the literature data on the influence of physical activity and sports in children and adolescents in the development of osteoporosis.

Search strategy:

A systematic search was conducted in the electronic databases PubMed, Google Academy, Cochrane Library for keywords such as "osteoporosis", "teenager", "dual-energy X-ray absorptiometry", "physical activity", "sport". This search was limited to English-language studies published from 2013 to 2023. A total of 20 sources have been studied.

The criteria for inclusion in the review were (1) data on the prevalence of osteoporosis in the world, (2) data on the causes of osteoporosis in adolescents, (3) studies published in English, (4) diagnostic studies and their role in the early diagnosis of osteoporosis, (5) the impact of physical activity and sports in development osteoporosis.

Exclusion criteria were as follows: (1) studies that described cases in the adult population; (2) the unavailability of the full text of the article for review; (3) studies with low methodological quality, i.e. clinical case reports, case series and comments; (4) studies published in languages other than English; (5) Studies in which densitometry was not performed.

Selection of articles

The search and selection of articles was carried out by authors who selected and excluded all articles that did not meet the requirements of the inclusion criteria. The next stage of our review consisted of the fact that we received the full texts of the articles, which were reviewed and analyzed based on their design.

Ethics Statement

Our analysis was based on studies conducted earlier by other authors; the conclusion of the ethics committee or the consent of patients was not required.

Results

A search using Pubmed, Google Scholar, and BMJ revealed 1801 publications on the keywords "Osteoporosis in adolescents", our search was refined to highlight research methods and risk factors, on request: "Diagnosis of osteoporosis in adolescents by dual-energy X-ray densitometry" and "The effect of physical activity on the development of osteoporosis", where 173 articles were found. The headings and annotations of 173 articles were checked. The 145 articles were excluded from the subsequent analysis because they did not correspond to the main purpose of our literary review (the study was conducted due to other nosology, for example: oncological, endocrine diseases, and others) or it was not possible to obtain the full text of the article (14 publications). The full

texts of 28 studies were analyzed, and 8 of them were excluded for the following reason: review articles.

Finally, 20 articles were analyzed according to the search criteria. Meta-analysis articles were reviewed, on the influence of certain factors in the development of osteoporosis in adolescents.

Discussion

Recognizing and diagnosing osteoporosis in children and adolescents early on can prevent the destruction of bone tissue and the development of irreversible complications that can potentially impact their quality of life in the future. Among the causes of osteoporosis in children, the most common disease is osteogenesis imperfecta: more than 24 genes that cause this disease have been identified [4]. Secondary or acquired osteoporosis develops in children and adults with chronic systemic diseases due to the consequences of the disease itself or its treatment. Consequently, osteopenia in childhood is directly associated with a high risk of osteoporosis and bone fractures in the future [5]. Although OP is usually considered a disease of adults, it is becoming increasingly obvious that osteoporosis may be associated with childhood and adolescence. At these stages of life, bone matrix mineralization occurs, and therefore subjects reach peak bone mass at the end of this growth phase. If this peak is not optimal, it will contribute to the development of osteoporosis in adulthood [8].

Mechanical stress on the human skeleton appears to be a key factor for increasing the accumulation of minerals in bones in children and adolescents. In this context, it seems reasonable that weight training, defined as strength exercises that create a higher mechanical load on the human skeleton than everyday life, such as jumping training or weight training programs, are useful for improving bone health. In carrying out this literary review, we have carefully studied the materials of previously conducted meta-analyses.

According to the results of a meta-analysis conducted in 2013 [7], the effectiveness of training in terms of the accumulation of minerals in bones significantly depends on the maturation status of subjects. The physiological mechanism underlying this observation remains unclear and should be determined in future studies. In addition, the usual intake of calcium significantly affected the accumulation of minerals in the bones caused by exercise. Thus, physical activity combined with high calcium intake should be encouraged at prepubescent age to resist osteoporosis later in life by increasing peak bone mass.

In three trials [16] aimed at determining whether calcium intake affects the bone response to exercise, a greater effect of exercise on the mineral content of leg bones was reported in children who received additional calcium randomly than in children who received placebo (6 out of 22 suitable studies included boys).

The main problem in the diagnosis of osteoporosis is that there is no clear clinic that would be characteristic of this disease. Therefore, knowledge and consideration of all risk factors is one of the main aspects of diagnosis and determination of patient management tactics. There are a lot of risk factors for OP, so far they have not been fully studied, they determine about 80 factors affecting bone mineral density, and as is known, the level of BMD is the main diagnostic criterion of OP, that is, it is an important predictor of osteoporotic fractures [5]. There is a positive relationship between the frequency of fractures and the level of physical activity due to the increased risk of falls during physical activity. Thus, although physical activity is crucial for bone modeling, children with higher levels of physical activity are more likely to have fractures [1]. There was a significant positive relationship between dietary calcium intake and total BMD. The strongest association was observed in light-skinned Americans aged 12-15 years, Mexican Americans aged 8-11 years and 16-19 years, as well as at the age of 16-19 years in people of a different race/ethnicity, in whom calcium intake was increased in each subgroup. In the analysis of subgroups, the authors found turning points in the group of 12-15 years, women and blacks. Their total BMD decreased when dietary calcium intake exceeded 2.6–2.8 g/day. On the other hand, there is a chance to initiate intervention programs to increase peak bone mass in young people, since it has been observed that physical activity is associated with an increase in BMD levels. A 2017 study [13] showed that moderate activity, such as walking, cycling or exercising for at least 4 hours a week, participating in recreational sports for at least 4 hours a week, or participating in heavy training or sports competitions several times a week, can increase BMD is up to 11% and 13%, respectively, in girls and boys aged 15-19 years. Studies conducted on former professional football players have shown that physical exercise is an important factor not only in increasing, but also in maintaining bone mineral density [17]. It has been shown that sports are crucial for healthy bone development, but not all sports have a positive effect on the mass of the skeleton. According to their characteristics, sports can be characterized as osteogenic (exercises with weights) and non-osteogenic (exercises without weights). In addition to numerous health benefits, football is considered an osteogenic sport both in childhood and adolescence, as bone mass increases. On the contrary, sports such as cycling or swimming are associated with no changes or a decrease in bone mass compared to control. This may be an obstacle to obtaining high peak bone mass, which may endanger bone health in the future [17]. Taking into account the different characteristics of exercise and training in sports practiced during the growth period, it is important to determine and classify the adaptation of bones and soft tissues in adolescent athletes. In a study conducted from October 2013 to May 2018, 625 adolescents (from 10 to 17 years old) from 10 sports (football, basketball, volleyball, athletics, judo, karate, kung fu, gymnastics, baseball, swimming) and an unsportsmanlike group were recruited into the sample [18]. Comparison between the groups showed that football had the highest BMD of the whole body (mean ± standard error of the mean: 1,082 ± 0.007 g·cm -2) and the lower extremities (1,302 ± 0.010 g·cm -2). Gymnastics showed the highest BMD of the upper extremities (0.868 ± 0.012 g · cm -2) and the whole body (0.094 ± 0.001 g · cm -3). Swimming showed the lowest values of BMD in all parts of the skeleton (except the upper limbs) and BMD of the whole body [18].

Fractures in childhood are common: about half of children suffer at least one fracture before adulthood. The overall risk of fractures in the period from birth to 16 years

ranges from 42% to 64% for boys and from 27% to 40% for girls. All epidemiological studies have shown that the most frequent site of fractures is the forearm, which accounts for almost half of all fractures [7]. ISCD Recommendations for the diagnosis of osteoporosis in children, updated in 2013 indicates that the diagnosis should not be based solely on densitometric criteria, but requires the presence of a clinically significant fracture in the anamnesis [7]. However, the best treatment for any nosology is disease prevention, since early diagnosis of osteoporosis can help us determine the presence of pathology at an early stage of the disease and prevent the possibility of fracture, complications and consequences of fractures [10]. DXA remains the preferred method for clinical measurements of bone density in children due to its accessibility, reproducibility, speed, low exposure to ionizing radiation and reliable pediatric reference data. Methods of three-dimensional densitometry (QCT, pQCT, HR-pQCT and MRI) provide valuable information about the volumetric bone mineral density (BMD), as well as about micro- and macroarchitectonics [11].

An additional problem in determining osteoporosis is the inclusion of a threshold value of the Z-index of BMD. The Z-scores of the BMD differ by as much as 2 standard deviations (SD) for a given child, depending on the reference database used to create the Z-score. This discovery was described by 3 different groups using pediatric reference data obtained from both Hologic and Lunar; in the largest of these reports, Z-indicators of BMD were obtained from all available data published in English up to and including 2015. This variability of the Z-indices of BMD obtained from various reference databases undermines the use of the threshold value of the Z-index as part of the international definition of osteoporosis in children [7]. However, diagnostic recommendations used in adults cannot be directly extrapolated to children due to the influence of growth and hormonal development on densitometric measurements and due to differences in the epidemiology of fractures in children, adolescents and adults. In contrast to adults, who most often break a hip or spine, in children most fractures occur on the peripheral skeleton, especially the upper extremities. From 27 to 40% of girls and 42-51% of boys get at least one fracture during growth, and the highest frequency of fractures is observed at puberty. There are no clear recommendations regarding the frequency or duration of subsequent DXA measurements. Children with idiopathic osteoporosis may experience spontaneous normalization of BMD after puberty, while adolescents with anorexia nervosa and related endocrine disorders never achieve normal BMD, and the risk of fractures increases up to 40 years after diagnosis [9]. Peak BMD accumulated in early adulthood is an established factor determining the development of osteoporosis later in life. Therefore, routine DXA scanning was proposed after prolonged therapy to detect and correct BMD deficiency, which ideally reduces the risk of subsequent fractures.

Clinical, radiological and analytical parameters should be monitored. It is important to estimate the number of fractures and episodes of pain. From the point of view of densitometry, variations of Z-indicators are important. The optimal frequency for performing DXA is not well defined. It is recommended to repeat the DXA after a year, and then every 1-2 years, depending on the patient's condition, with a minimum interval between checks of 6-12 months [8]. The interpretation of the results of bone densitometry in children differs from that in the elderly. The terms "osteopenia" and "osteoporosis", based only on the results of bone densitometry, should not be used in younger patients; instead, the mineral content or bone density, which falls >2 standard deviations, is marked as "low for age" [11].

According to the updated recommendations of the International Society of Clinical Densitometry in 2013, the international group of bone tissue experts "Pediatric osteoporosis" is determined using 1 of the following criteria: ≥1 vertebral fracture occurring in the absence of local disease or high-energy injury (without or with densitometry measurements) or low bone density for age and significant fractures in anamnesis (defined as ≥2 fractures of long bones under the age of 10 years or ≥3 fractures of long bones under the age of 19 years). Current studies will help determine indications and best methods for assessing bone strength in children, as well as clinical factors affecting the risk of fractures [11]. As many studies have shown, physical activity together with proper nutrition has a beneficial effect on bone tissue, its remodeling and development. Our children will be able to choose the right profession in the future based on their health status. As it turned out, the type of sport also affects the bone tissue positively and negatively. In accordance with this, based on the patient's health data, we must correctly direct the child to a particular sport. There are no scientific data on the impact of sports and physical activity on the bone tissue of adolescents in the Republic of Kazakhstan as a whole. This fact requires a more in-depth further study of the influence of ethnic predisposition of risk factors and diagnosis of osteoporosis, which gives us a lot of thoughts about further scientific activities.

Conclusions

This review focuses on publications that examine the impact of physical activity on the bone tissue of children and adolescents. The use of densitometry in a comprehensive examination helps with the early diagnosis of any disease that may lead to the development of pathology. The review indicates that the lifestyle and physical activity of children significantly affect the development of osteoporosis during adulthood.

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