



Impact of Physical Activity on Improving Bone Health in Adolescents : A Literature Study

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Abstract: This research uses the literature review method to analyze and synthesize information from various studies that have been conducted regarding the impact of physical activity on adolescent bone health. The data used in this study came from scientific journals, research articles, books, and reports published in the last 10 years. The data were retrieved from trusted academic platforms such as PubMed, ScienceDirect, Google Scholar, and national journal portals such as Garuda. Data were collected using specific keywords such as “benefits of physical activity for adolescent bones”, “bone and exercise”, and “adolescent bone health”. After the search, relevant articles were identified and selected based on predetermined inclusion and exclusion criteria. Data analysis was performed descriptively to summarize relevant research findings. In conclusion, this study highlights the importance of a holistic approach in supporting bone health. A combination of weight-based exercise, optimal nutrition and injury risk management strategies can provide maximum benefits. By considering individual differences, such as gender, health conditions, and physical activity preferences, appropriate intervention strategies can be implemented to support bone health throughout the life cycle.

Keywords: Physical Activity, Bone, Adolescent, Literature Study

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INTRODUCTION

Physical activity plays an important role in supporting bone growth and development, particularly during adolescence, which is a critical period in bone mass formation (Samaloisa, 2024). Adolescence is known as the stage where the body undergoes accelerated bone and muscle growth, which significantly affects bone health in adulthood. During this period, approximately 40-60% of adult bone mass is formed, making it an ideal time to maximize bone mass accumulation through physical activity. Lack of physical activity at this stage can increase the risk of osteoporosis and fractures later in life (Lubis et al., 2024).

The process of bone formation involves a balance between the activity of osteoblasts, cells that build bone, and osteoclasts, cells that destroy bone. Weight-bearing physical activities, such as running, jumping or playing sports, stimulate osteoblasts to increase bone mineral density. This movement produces mechanical stress on the bone, which then triggers the bone's adaptation process to become stronger. Conversely, a sedentary lifestyle, such as too much sitting or lack of physical activity, can reduce the mechanical stimulus needed to maintain bone strength.

Hormonal factors also play a major role in bone growth during adolescence (Perestroika, n.d.). Hormones such as estrogen and testosterone increase significantly during puberty, supporting the process of bone mineralization. Physical activity can increase the body's sensitivity to these hormones, making them more effective in aiding bone growth. However, if physical activity is excessive, as in the case of intense exercise without pauses, the risk of disruptions to hormone balance and bone health, such as amenorrhea in adolescent girls, may increase.

Bone health in adolescents is also influenced by nutritional intake, especially calcium and vitamin D, which work alongside physical activity in building bone mass (Safitri et al., 2024). Adolescents who combine good nutritional intake with regular physical activity tend to have denser



bone mass compared to those who lack either or both factors. Conversely, lack of intake of essential nutrients may limit the effectiveness of physical activity in promoting bone health.

Research shows that certain types of physical activity, such as sports that involve jumping or explosive movements, provide greater benefits to bone health compared to static or low-impact activities such as swimming. Sports such as basketball, soccer and volleyball can better increase bone density due to the intense movements that involve many muscle groups. In contrast, water sports tend to provide greater benefits to the cardiovascular system, but are less effective in affecting bone density.

The importance of physical activity in bone health is not only limited to physiological aspects, but also impacts the psychological and social aspects of adolescents (Roesdiyanto et al., 2024). Involvement in physical activities that involve a team or group can increase self-confidence, build healthy habits, and create a supportive environment to continue being physically active. This is important in preventing sedentary lifestyles that often begin in adolescence and continue into adulthood.

On the other hand, technology and the development of modern lifestyles have affected adolescents' physical activity patterns. Time spent watching television, playing video games or using gadgets often reduces the time allocated for physical activity. This raises concerns of increased obesity rates, impaired posture and decreased bone quality in the adolescent population.

Cultural and social contexts also play a role in adolescents' physical activity levels. In many developing countries, access to sports facilities and awareness of the importance of physical activity is limited (Melani et al., 2024). In addition, the role of the family in encouraging children to engage in physical activities is a determining factor in shaping this habit. Support from parents, schools and communities is essential to encourage adolescents' participation in regular physical activity.

Intervention programs aimed at increasing physical activity in adolescents have shown promising results in improving bone health. An example is school programs that integrate sports or physical activities into the daily curriculum. These interventions not only improve physical health but also academic performance, demonstrating the holistic impact of physical activity on adolescent well-being.

However, despite the overwhelming evidence supporting the benefits of physical activity, challenges in maintaining this habit among adolescents still exist. Changing priorities, such as academic pressures and interest in technology-based activities, often hinder adolescents' participation in physical activities. Therefore, more innovative and community-based strategies are needed to overcome these barriers and ensure that adolescents gain optimal benefits from physical activity.

Through this study, it is hoped that a more in-depth understanding of the impact of physical activity on adolescent bone health, including its enabling and inhibiting factors, can be gained. Thus, effective recommendations can be designed to improve bone health and prevent bone disorders in adolescents, while building a strong foundation of bone health for the future.

METHODS

This research uses the literature review method to analyze and synthesize information from various studies that have been conducted regarding the impact of physical activity on adolescent bone health. The literature study was chosen because this method allows researchers to explore and analyze relevant secondary data, thus providing an in-depth understanding of the theme under study. The data used in this study came from scientific journals, research articles, books and reports published in the last 10 years. The main focus was on studies that addressed the benefits of physical activity on adolescent bone health. Data were retrieved from trusted academic platforms such as PubMed, ScienceDirect, Google Scholar, and national journal portals such as Garuda.

Data were collected using specific keywords such as “benefits of physical activity for adolescent bones”, “bone and exercise”, and “adolescent bone health”. After the search, relevant articles were identified and selected based on predetermined inclusion and exclusion criteria. Data analysis was conducted descriptively to summarize relevant research findings. The stages of analysis included (Syafuruddin & Suparman, 2023):

1. Identification: Collecting all relevant articles according to the search criteria.
2. Screening: Selecting articles based on the abstract and suitability to the research theme.
3. Critical Evaluation: Analyzing the quality of the referenced research, including methods, population, results, and conclusions.
4. Systematization: Categorize articles based on subthemes.
5. Synthesis: Summarizing the results of the analysis in the form of a structured narrative.

To ensure validity and reliability, this study only used sources from journals that are scientifically recognized and have high credibility. The researcher also ensured consistency of results by triangulating data from various sources. In conducting literature studies, researchers ensure respect for copyright by explicitly mentioning sources and avoiding plagiarism. Analysis was conducted objectively based on previously published data.

RESULT AND DISCUSSION

After searching through various articles, 20 research articles related to the impact of physical activity on adolescent bone health were selected, which will be further discussed in this article before being concluded.

No.	Penulis	Tahun	Judul	Kesimpulan
1	Braam et al.	2018	Effects of combined physical and psychosocial training for children with cancer	Aktivitas fisik terstruktur dapat meningkatkan kesehatan tulang dan kesejahteraan emosional pada anak-anak yang menjalani perawatan kanker (Braam et al., 2018).
2	Vlachopoulos et al.	2019	Longitudinal Adaptations of Bone Mass, Geometry, and Metabolism in Adolescent Male Athletes: The PRO-BONE Study	Olahraga seperti sepak bola memiliki efek osteogenik yang lebih tinggi dibanding renang atau bersepeda pada remaja (Vlachopoulos et al., 2017).
3	Campbell et al.	2019	Guidelines for exercise and bone health improvement	Olahraga intensitas sedang hingga tinggi secara teratur selama masa remaja mendukung akral mineral

			tulang optimal (Campbell et al., 2019).
4	Rauh et al.	2020	Sport Specialization and Low Bone Mineral Density in Female High School Distance Runners Atlet remaja menunjukkan densitas mineral tulang lebih tinggi dibanding non-atlet, terutama pada cabang olahraga berbasis beban (Rauh et al., 2020).
5	Metcalf et al.	2020	An eight-year longitudinal analysis of physical activity and bone strength from adolescence to emerging adulthood: The Iowa Bone Development Study Aktivitas fisik yang konsisten selama masa pertumbuhan dikaitkan dengan peningkatan densitas mineral tulang (Metcalf et al., 2020).
6	Proia et al.	2021	<u>The impact of diet and physical activity on bone health in children and adolescents</u> Kombinasi nutrisi yang baik (seperti kalsium) dengan olahraga meningkatkan kekuatan tulang secara signifikan (Proia et al., 2021).
7	Mesquita et al.	2022	<u>The combined relationship of vitamin D and weight-bearing sports participation on areal bone density and</u> Aktivitas fisik dan tingkat vitamin D optimal berkontribusi pada peningkatan kualitas tulang pada atlet remaja

			<u>geometry among adolescents: ABCD-growth study</u>	(de Lima Mesquita et al., 2022).
8	Cheng X.	2022	<u>Effects of sport on skeletal development in adolescents</u>	Olahraga berbeban tinggi meningkatkan kualitas tulang lebih baik dibandingkan aktivitas ringan atau sedentary (Cheng, 2022).
9	Thein-Nissenbaum et al.	2022	<u>Adolescent bone advantages 3 years after resistance training trial</u>	Latihan resistensi meningkatkan akumulasi mineral tulang dan penguatan struktur tulang pada remaja (Thein-Nissenbaum et al., 2022).
10	Armento et al.	2023	Bone Health in Young Athletes: A Narrative Review of the Recent Literature	Atlet muda berisiko mengalami cedera muskuloskeletal yang unik karena kerangka tubuh yang sedang tumbuh. Mengoptimalkan asupan nutrisi, khususnya yang terkait dengan asupan vitamin D yang cukup dan pencegahan triad atlet, sangat penting untuk mengoptimalkan kesehatan tulang pada atlet muda.

				(Armento et al., 2023).
11	Anversha & Ramalingam	2023	A Systematic Review: Significance of Plyometric Training on Functional Performance and Bone Mineral Density in Basketball Players of Different Age Groups	Latihan plyometric efektif dalam meningkatkan densitas mineral tulang pada remaja laki-laki (Anversha & Ramalingam, 2023).
12	Ren et al.	2024	Association between physical activity, sedentary behavior patterns with bone health among Chinese older women	Aktivitas fisik intensitas sedang hingga tinggi mendukung penguatan tulang selama masa remaja (Ren et al., 2024).
13	Suntornsaratoon et al.	2023	Running exercise with and without calcium supplementation from tuna bone reduced bone impairment caused by low calcium intake in young adult rats	Baik suplementasi kalsium tulang tuna maupun olahraga merupakan intervensi efektif untuk mengurangi keropos tulang akibat kekurangan kalsium. (Suntornsaratoon et al., 2023).
14	Jazi & Shoukahi	2024	The Effect of a 12-week Plyometric Training on Growth Hormone, IGF-1 and Bone	Program plyometrik selama 12 minggu menghasilkan peningkatan yang nyata dalam

			Health Indexes in Adolescent Boys	kesehatan tulang, kekuatan eksplosif, dan hormon anabolik seperti GH dan IGF-1, serta kadar serum 25-hidroksivitamin D (Jazi & Shoukahi, 2024).
15	Jensen et al.	2024	Bone health after exercise alone, GLP-1 receptor agonist treatment, or combination treatment: a secondary analysis of a randomized clinical trial	Dalam uji klinis acak ini, kombinasi olahraga dan GLP-1RA (liraglutide) merupakan strategi penurunan berat badan yang paling efektif sekaligus menjaga kesehatan tulang (Jensen et al., 2024).
16	Agostinete et al.	2024	Resistance training presents beneficial effects on bone development of adolescents engaged in swimming but not in impact sports: ABCD Growth Study	Latihan olahraga berdampak, baik yang dilakukan sendiri atau ditambahkan pada latihan ketahanan, tampaknya masih dapat meningkatkan pertambahan massa tulang (Agostinete et al., 2024).
17	Vasil et al.	2024	Bone health and physical activity in adolescents with juvenile idiopathic arthritis: a	Aktivitas fisik meningkatkan kesejahteraan fisik, emosional, dan mental serta dapat mencegah konsekuensi

			cross-sectional case-control study	sekunder di kemudian hari; oleh karena itu, aktivitas fisik harus tetap didorong untuk anak-anak dan remaja dengan JIA sebagaimana halnya untuk teman sebayanya yang sehat (Vasil et al., 2024).
18	SH Kong	2024	Sex/Gender Differences in Osteoporosis	Remaja laki-laki menunjukkan peningkatan densitas tulang yang lebih besar dibandingkan remaja perempuan dalam program latihan beban (Kong, 2024).
19	Berro et al.	2024	Effects of the Type of Exercise Training on Bone Health Parameters in Adolescent Girls: A Systematic Review	Hasil penelitian menunjukkan bahwa latihan plyometrik meningkatkan massa tulang belakang lumbar pada remaja putri. Uji coba terkontrol acak yang dirancang dengan baik dengan periode latihan yang tepat (> 12 minggu) diperlukan untuk menganjurkan jenis latihan tertentu yang memiliki efek

				osteogenik tertinggi (Berro et al., 2024).
20	Wang Kun et al.	2024	Optimizing bone health interventions in adolescence	Anak-anak remaja harus menghindari SB yang berlebihan, dan melalui berbagai aktivitas fisik sedang hingga berat (MVPA) untuk mengganti atau SB yang terputus-putus, yang secara efektif dapat mencegah atau memperbaiki bahaya SB terhadap kesehatan fisik dan mental (Wang et al., 2024).

Research on bone health in children and adolescents shows the importance of physical activity, nutrition and specific interventions to support skeletal growth and development. Structured physical activities, such as weight-based exercise and plyometric training, have been shown to provide significant benefits to bone health, both in terms of mineral density and quality of bone structure (Braam et al., 2018; Cheng, 2022). Furthermore, regular moderate to high-intensity exercise during adolescence supports optimal bone mineral accrual, making it a highly recommended strategy to maximize bone health (Campbell et al., 2019; Metcalf et al., 2020).

Some types of exercise have a higher osteogenic effect than others. For example, high-impact sports such as soccer are more effective in increasing bone mass than non-impact sports such as swimming or cycling (Agostinete et al., 2024; Vlachopoulos et al., 2017). In addition, resistance training has also been shown to increase bone mineral accumulation and strengthen bone structure, especially in physically active adolescent boys (Anversha & Ramalingam, 2023; Thein-Nissenbaum et al., 2022).

Adequate intake of nutrients, particularly calcium and vitamin D, also plays an important role in bone health. The combination of exercise and good nutrition can significantly improve bone strength. For example, tuna bone calcium supplementation and exercise are effective in reducing the risk of bone loss due to calcium deficiency (Suntornsaratoon et al., 2023). On the other hand, optimal vitamin D levels have also been found to contribute to improved bone quality, especially in adolescent athletes active in weight-based sports (Armento et al., 2023; de Lima Mesquita et al., 2022).

Plyometrics is one form of exercise that has received particular attention for its ability to increase bone mineral density in adolescents. A 12-week plyometric program can significantly improve bone health in both adolescent boys and girls (Berro et al., 2024; Jazi & Shoukhi, 2024).

These benefits are not only limited to bone health but also include increases in anabolic hormones such as GH and IGF-1, which support physical growth and development.

Other studies have shown that consistent physical activity during the growing years is essential for increasing bone mineral density. This includes regular moderate to high-intensity exercise, especially in adolescents who are at the peak of growth (Metcalf et al., 2020; Ren et al., 2024). Physical activity has also been found to be important for children and adolescents with certain health conditions, such as juvenile idiopathic arthritis, where exercise helps improve their physical, emotional and mental well-being (Vasil et al., 2024).

However, there are several challenges in bone health management, especially in young athletes who face the risk of musculoskeletal injuries due to the intensive demands of exercise. To address this, optimization of nutritional intake, including vitamin D and prevention of the athlete's triad syndrome, is essential to maintain their bone health (Armento et al., 2023). In addition, specially designed exercises, such as resistance and impact-based training, are also effective in preventing bone deterioration in adolescent athletes (Agostinete et al., 2024).

Gender differences in the response to exercise and bone health interventions have also been observed. Male adolescents generally show greater increases in bone density than female adolescents in weight training programs (Kong, 2024). However, adolescent girls can also benefit significantly from plyometric exercises, which are known to increase their lumbar spine mass (Berro et al., 2024).

On the other hand, studies in animal populations provide additional insights into the effects of exercise and nutritional supplementation on bone health. Research in rats showed that a combination of exercise and calcium supplementation can effectively reduce bone loss caused by calcium deficiency, providing important implications for human intervention (Suntornsaratoon et al., 2023).

In further efforts to optimize bone health, it is important to consider sedentary habits (SB). Children and adolescents need to reduce excessive sedentary activity and replace it with moderate to vigorous intensity physical activity (Wang et al., 2024). This strategy is not only beneficial for physical health but can also improve their mental well-being.

Exercise combined with pharmacological interventions has also shown promising results. For example, the combination of exercise with a GLP-1RA (liraglutide) was shown to be an effective strategy for weight loss while maintaining bone health in a randomized clinical trial (Jensen et al., 2024). This combination approach shows great potential for application in specific populations.

Overall, research suggests that weight-based, resistance and plyometric exercise are essential for supporting bone health during adolescence. In addition, good nutrition and healthy lifestyle habits, such as reducing sedentary activities, play a crucial role in maximizing these benefits. Given the complexity and variety of conditions in children and adolescents, interventions tailored to individual needs are important. More in-depth research is needed to identify the best strategies to improve bone health based on their age, gender and physical activity level (Berro et al., 2024; Wang et al., 2024).

CONCLUSION

In conclusion, this study highlights the importance of a holistic approach in supporting bone health. A combination of weight-based exercise, optimal nutrition and injury risk management strategies can provide maximum benefits. By considering individual differences, such as gender, health conditions and physical activity preferences, appropriate intervention strategies can be implemented to support bone health throughout the life cycle.

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