OPEN ACCESS Freely available online

IJCMB
International Journal of Clinical Medicine and Bioengineering

ISSN 2737-534X
Volume 3, Issue 4
https://ijcmb.iikii.com.sg/
International Journal of Clinical Medicine and Bioengineering

Technical Paper

Impact of Knee Surgery on Growth in Adolescents: A Review of Epiphyseal Plate Considerations

Joon Hyuk Park [1*], Dahyeon Yoo [2], and Doyun Nam [3]

[1] St. Johnsbury Academy Jeju; Seogwipo 63644, Korea;
[2] Gyeonggi Suwon International School; Suwon 16706, Korea; danayoo0624@gmail.com
[3] St. John's High School; Shrewsbury 10545, USA; doyun06030@gmail.com
***** Correspondence: pjhkmh06@gmail.com

Received: Sep 10, 2024; **Revised:** Oct 10, 2024; **Accepted:** Oct 10, 2024; **Published:** Oct 30, 2024

Abstract: It is necessary to apply methodologies for knee surgery and rehabilitation of adolescents so as not to influence their growth and development after surgery. As the rate of knee injury among adolescents in developed countries increases, it is important to minimize the risk to the epiphyseal plate for continuous growth and development. In this article, techniques are reviewed to understand how to avoid damage to the epiphyseal plate and help the adolescent patient return to normal life in the shortest time without complications. Excellent techniques are used with widely used rehabilitation methods but long-term and longitudinal studies are still needed to observe the growth and development after knee surgery. Enough number of sample cases also needs to be secured to generalize the results, while the biological mechanisms causing growth disturbances after knee surgery must be verified. It is still necessary to conduct longitudinal studies to observe the growth and development after knee surgery. The biological mechanisms causing growth disturbances after knee surgery also need to be studied. Based on the results, medical practices for surgery and rehabilitation in adolescents can be standardized to improve the quality of treatment after knee surgery of adolescents.

Keywords: Knee, Surgery, Adolescent, Ligament, ACL, PCL, Growth, Epiphyseal plate

1. Introduction

The knee is the largest and one of the most complex joints and plays an important role in the movement and stability of the human body. The knee supports the body's weight in walking, running, and jumping as the menisci in the knee absorbs shock to reduce its impact on the bones [1], and involves flexion and extension for sitting, standing, and climbing. The leg is stabilized by the knee which maintains the balance of the whole body [2]. The functionality of the knee is essential for daily activities so the pain or injury occurring in the knee considerably affects one's quality of life as it limits mobility and independence [3]. Knee injuries sometimes require surgical treatments, especially in the following incidents.

1. Ligament damage: Tears in the anterior cruciate ligament (ACL) or posterior cruciate ligament (PCL) require surgery. Ligamentous injuries do not directly affect growth plates. However, surgical intervention to the proximity of the growth plates must be carefully decided. Growth-sparing techniques are used to avoid damaging these plates [1,3].
2. Tears: Damage to the meniscus that absorbs shock to the joint of the knee may need surgery. Tears damage the meniscus which sometimes alters joint mechanics and affects the knee development and functions [1,3].
3. Fractures: Severe fractures of the knee bones, such as the patella, may require surgical fixation. Fractures interfere with the normal growth of the affected bone. In adolescents, uneven bone development might be observed if left untreated or if treated too late. Surgical intervention is conducted, but conservative treatment is preferred to preserve the bone's growth potential [1,3].
4. Osteoarthritis: Severe osteoarthritis requires knee replacement surgery. Osteoarthritis does not directly affect the growth of bones. However, in adolescents, it affects joint function and overall physical activity. Chronic pain and inflammation hinder adolescents from participating in sports and physical activities [1,4].
5. Dislocations: The dislocation of the knee joint damages the knee and requires surgical correction. Knee dislocations directly influence bone growth. In a knee dislocation, damage to the bones and soft tissues occurs causing growth disturbances. [1,3].

Each country has different major knee injuries. For example, knee osteoarthritis is found at the highest rate in South Korea, while ACL and knee contusions prevail in Australia. Knee injuries are common across various age groups but are particularly prevalent among adolescents and young adults due to sports activities [5,6]. Common knee injuries in adolescents include ACL

tears, medial collateral ligament (MCL) injuries, meniscal tears, patellar dislocations, Osgood-Schlatter disease, and patellar tendonitis. These occur mainly by sudden changes in movements and overuse of the knee which occur commonly in sports activities including soccer and basketball. Such injuries often result in acute trauma or repetitive stress and require appropriate diagnosis and management to prevent long-term effects [7,8].

In OECD countries, knee surgeries are common, and 119 knee replacements per 100,000 population are conducted annually [9] (Fig. 1). In South Korea, 150 knee replacements per 100,000 population were performed. In 2021, Switzerland and Finland showed higher rates of 273 and 260 per 100,000 population. Countries with higher rates included Australia, Germany, Austria, and others in which people are keen on outdoor activities and the population of the elderly is relatively large.

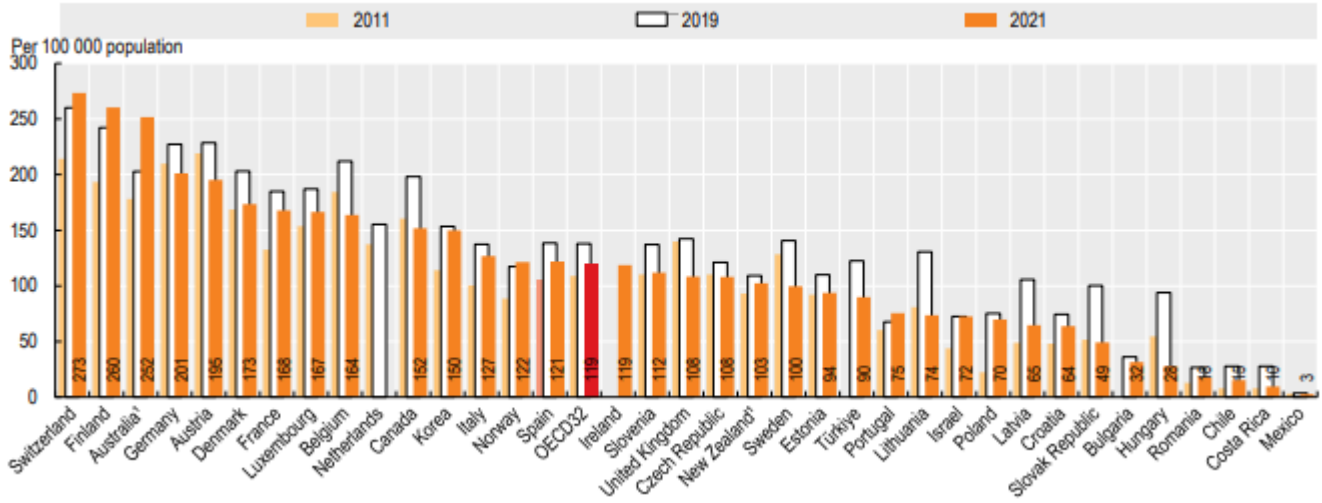

Fig. 1. Cases of knee replacement in OECD countries [https://www.oecd-ilibrary.org/social-issues-migration-health/health-at-a-glance-2023_e1a77af6-en].

Adolescents have open growth plates (epiphyseal plates) for bone growth and development. Surgery involving the ligaments of the knee can potentially damage the plates, which may cause disturbances or deformities in growth. Therefore, it is important to study the impact of knee surgery on epiphyseal plates to prevent long-term complications and ensure continuous skeletal development. In addition, healing and recovery processes in adolescents are different from those of adults due to ongoing growth and higher metabolic activity. The psychological and physical development of adolescents must also be considered to plan medical interventions and minimize the negative effects on their overall development. Adolescents can become vulnerable to psychological effects caused by knee surgery and its effects which manifest emotional distress, anxiety, depression, changes in self-esteem, and social isolation. Thus, adolescents who have undergone knee surgery and rehabilitation must have appropriate coping strategies to recover psychologically Psychological support from family members, friends, and professionals is required to address their anxiety, depression, and fear of re-injury [10−12].

In particular, ligament injuries of the knee are prevalent in adolescents, and the ACL is the most commonly injured ligament. For such ligament injuries, surgical intervention is required, which may influence the open epiphyseal plates in the future. Research on the effect of ligament surgery on adolescents' growth is essential due to the unique physiological and developmental characteristics of this age group. Adolescents are in a phase of growth, and surgical interventions on ligaments can have considerable effects on their musculoskeletal health. Therefore, it is necessary to review how surgery on the knee of adolescents impacts their growth in terms and how to minimize the potential effects of knee surgery on the growth of adolescents. Thus, in this article, the shortcomings of medical interventions and the considerations in the interventions are reviewed to provide recommendations based on the literature review.

2. Current Research: Prospects and Limitations

Previous studies have focused on surgical techniques that minimize the risk to epiphyseal plates such as physeal-sparing techniques in ACL reconstruction. These techniques are used to avoid damage to the plates while still providing stability to the knee joint. Rehabilitation for adolescents to treat knee injuries has been studied extensively, too. In the rehabilitation process, the differences in physical maturity are considered to optimize recovery and shorten the time to return to ordinary activities. The

potential growth disturbances following ligament surgery have been found in studies that showed growth length discrepancies and angular deformities after surgery. In this case, careful monitoring and follow-up are mandatory to prevent them [13−17].

In surgical procedures such as ACL reconstruction, drilling near the lesions potentially influences the growth of the knee and may cause limb length discrepancies or angular deformities. Thus, to avoid disrupting the epiphyseal plate techniques and treat the injury without impacting the growth of the patient, all-epiphyseal techniques are used to bypass the epiphyseal plate to avoid growth disturbance. The results using techniques presented satisfactory outcomes with minimal impact on bone growth [18].

Recent advancements in surgery and rehabilitation have been proven effective in minimizing such damage after surgery for knee injuries. For example, total knee arthroplasty (TKA), though it needs more research, shows its effectiveness and innovations so the demand for TKA is increasing due to the rising prevalence of knee arthritis [19]. High tibial osteotomy (HTO) is also used widely to realign the knee joint. HTO has shown prospective results in delaying the need for TKA [20]. Rehabilitation is mandatory for recovery but kinesiophobia must be overcome for rapid and complete recovery outcomes [21]. Even though such advanced methods are mainly used for adults, the demand for surgery for adolescents is increasing. Knee surgeries for adolescents require thoughtful consideration to prevent damage to bone growth and development. The timing and type of surgery are important to minimize any adverse effects [22].

When applying ligament surgery to adolescents, misalignment or drilling across the epiphyseal plate must be avoided as damaging the plate causes growth disturbances through premature closure and limb length discrepancies or angular deformities. Therefore, the exact tunnel placement is critical in fixing grafts. When a tunnel is placed imprecisely, normal growth patterns are disrupted which causes deformities. Even with successful surgery, excessive scar can restrict joint movement and affect growth as it may influence the alignment or movement of the epiphyseal plate. Post-surgery infections or inflammation must be prevented as it can damage the epiphyseal plate, too. Infections to the epiphyseal plate result in significant growth of tissues. Rehabilitation is essential for recovery and minimizing complications. Inadequate rehabilitation can cause joint stiffness or altered biomechanics which potentially retard growth indirectly by affecting joint function and development. While ligament surgery for adolescents can affect their growth, modern surgical techniques and careful planning can mitigate such risks. The key to successful outcomes of knee surgery is avoiding the epiphyseal plates during surgery by using appropriate techniques considering the patient's age and growth [18, 23−25].

The impact of ligament operations on the growth of adolescents is not significantly different across human races. However, genetic, anatomical, and cultural factors need to be considered as they can indirectly influence the outcomes of the surgery. There are variations in bone growth patterns in different ethnic groups, which are minor and do not significantly affect the impact of ligament surgeries. Genetic factors influence the strength of the ligament, the susceptibility to injury, and healing capacity. However, genetic differences are not presented by ethnic groups [26,27]. Variations can be found in the timing of epiphyseal plate closure among different ethnic groups. For instance, African-American children may experience earlier skeletal maturation compared to Caucasian children, which can potentially influence the timing of surgery. However, this difference is not considered as a direct factor in surgical outcomes [28,29]. The quality of healthcare, the availability of rehabilitation, and follow-up treatment can influence outcomes more significantly than racial differences. Therefore, socioeconomic factors play a more important role in the growth of adolescents who undergo knee surgery [30−32].

The long-term outcomes of ligament surgery in adolescents have not been much explored yet. Therefore, it is necessary to conduct longitudinal studies to trace the growth and development after knee surgery. It is also needed to have an appropriate number of sample sizes to generalize the research results. There is still limited understanding of the biological mechanisms underlying growth disturbances after knee surgery. Thus, it is demanded to explore how knee surgery influences the biological processes of growth. There is still a lack of standardized medical practices for surgery and rehabilitation in adolescents, which help improve the consistency and quality of treatment [18,33-37].

3. Advanced Technologies for Knee Surgery

Various technologies are being developed for knee surgery to avoid the serious effects of the surgery by protecting the epiphyseal plate and accelerating recovery.

First, physeal-sparing techniques are used to avoid damage to the epiphyseal plate of the knee. These techniques allow adolescents to grow after knee surgery by maintaining normal bone development and preventing disturbances in growth. Physeal-sparing techniques are used for ACL and medial patellofemoral ligament (MPFL) reconstructions. In ACL reconstruction, the epiphyseal plate in young patients is reserved by placing the graft within the epiphysis, thus sparing the physis. Knee laxity restoration is excellent compared to partial and complete transphyseal approaches. In MPFL reconstruction, patellofemoral stabilization is confirmed in young patients with recurrent patellofemoral instability. The MPFL is reconstructed without damage to the epiphyseal plate. In extra-physical ACL reconstruction, ACL is reconstructed without drilling holes in the epiphyseal plate. The

graft is placed in a way that avoids contact with the physes so growth disruption or deformity can be prevented. In all-epiphyseal reconstruction, the graft is entirely replaced. This technique is regarded to be useful for young patients who have growth remaining. When physeal involvement is unavoidable, smaller holes must be drilled into the epiphyseal plate. In partial transphyseal techniques, joint stability is assured to sustain growth potential [14,38].

In such surgeries, computer-assisted surgery (CAS) is often used for precise surgical procedures. Using a navigation system, robotic-assisted surgery, and preoperative planning software, the accurate placement of grafts and tunnels is allowed. In the methods, advanced imaging and 3D modeling are used for surgeries of high precision, minimized human errors, and a detailed surgical plan to optimize graft placement and determine appropriate tunnel angles [39]. With these techniques, biodegradable implants are used in knee surgeries to prevent long-term complications. As biodegradable implants dissolve in the tissue, additional surgeries are not necessary [40]. Growth modulation techniques are used when growth disturbances are expected after surgery. Special devices to correct or prevent deformities as the patient grows. Staples, screws, tethers, and plates are used to apply pressure on the epiphyseal plate and slow growth to correct deformities, modulate growth, and correct scoliosis. Tension band plates are fixed across the epiphyseal plate to alter growth direction and correct angular deformities. Sometimes, guided growth devices are used to align the physis for normal growth and prevent deformities [41,42].

These techniques are used to enable the growth and development of adolescents after knee surgery for precise and minimized impact on the epiphyseal plate.

4. Rehabilitation Methods after Knee Surgery

After knee surgery, rehabilitation processes are mandatory to minimize the impact of the surgery on the growth and possible deformities of the patient. In the process, function restoration and complication prevention are emphasized through customized protocols considering the patient's physiological characteristics.

In rehabilitation, gentle and guided movements are instructed as early controlled motions to enhance joint mobility, reduce stiffness, and prevent muscle atrophy. By balancing healing and appropriate stress, recovery can be accelerated. Starting with assisted movements by a therapist or a device, passive range of motion (PROM) is practiced to maintain joint flexibility without stressing the healing structure of the body. Then, the rehabilitation process transitions to active range of motion (AROM) to move the joint in a safe range to promote muscle engagement and strength. Then, continuous passive motion (CPM) is practiced to maintain joint movements enabled in the early rehabilitation process for securing consistent and controlled motions [43,44].

With such motion practices, neuromuscular training is accompanied to improve proprioception, balance, and coordination. Through neuromuscular training, the control and stability of the muscle are increased to return to normal activities. In rehabilitation, it is important to improve balance and exercise to maintain stability [45]. Training programs must be planned for adolescents to increase muscle strength considering the growth and development phases of the patient. Gradual resistance improvement is required but excess load on the epiphyseal plates and soft tissues must be avoided [46,47]. It is important to provide customized rehabilitation programs for each adolescent's specific needs based on precise assessments and feedback. These rehabilitation methods are vital after surgery for continuous growth and complication prevention.

Psychological rehabilitation is also crucial for adolescents due to the emotional challenges accompanying recovery. It is necessary to educate them on the different stages of recovery to reduce anxiety and improve compliance with rehabilitation. Regular consultations are recommended to let them understand progress, adjust expectations, and keep them engaged in their recovery. Then, they can have a mindset to learn and foster resilience to cope with possible frustrations from social isolation they worry [48].

5. Longitudinal Studies and Direction

The long-term effects of knee surgeries, especially ACL reconstruction or meniscal repairs remain under-explored. Longitudinal studies considering technological advancements are mandatory to better understand and validate the impact of knee surgery on adolescent growth. Longitudinal studies are essential for monitoring individuals who undergo knee surgery over several years to assess growth disturbances, length discrepancies, or any deformities [50]. As adolescents experience rapid growth, the timing of surgery is important to avoid disrupted growth. Technological advancements in imaging, such as magnetic resonance imaging (MRI) and 3D imaging need to be used to monitor growth patterns after surgery and diagnose complications. Wearable devices and sensors and AI and machine learning technologies can be used to monitor and analyze the indicators of complications and knee functions [50].

6. Conclusions

Knee injuries such as ligament damage, tears, fractures, and dislocations sometimes require surgical interventions. In developing countries, knee surgeries become common due to popular outdoor sports activities. Though the rate of knee injury among adolescents in the countries is increasing, medical interventions for such injuries have been mainly focused on adults. For adolescents, it is important to minimize the risk to epiphyseal plates and secure continuous growth and development after surgery. Advanced techniques are used to avoid damage to the epiphyseal plate and stabilize the knee joint after surgery. Rehabilitation is critical to return to normal activity with the main purpose of shortening the time. To prevent growth discrepancies and angular deformities after surgery, careful monitoring and follow-up are necessary considering the differences in physical maturity of adolescent patients. When treated and rehabilitated appropriately, damage can be minimized or avoided for adolescents. Techniques including TKA and HTO are used widely to avoid ia must be overcome for rapid and complete recovery outcomes. Then, the impact of knee surgery on the growth of adolescents is not significant. There are variations in bone growth patterns in different ethnic groups, which are minor and do not significantly affect the impact of ligament surgeries. As long-term research on knee surgery in adolescents has not been conducted widely, it is necessary to conduct longitudinal studies to observe the growth and development after knee surgery. An appropriate number of sample cases are also needed to obtain generalized results. The biological mechanisms causing growth disturbances after knee surgery also need to be studied. The research on such topics helps standardize medical practices for surgery and rehabilitation in adolescents and improves the consistency and quality of treatment.

Author Contributions: Conceptualization, J.H. Park.; D. Yoo and D. Nam; data curation, J.H. Park; writing—original draft preparation, J.H. Park; writing—review and editing, D. Yoo; supervision, D. Nam.

Funding: This research did not receive external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Verywell Health. Available online: https://www.verywellhealth.com/knee-anatomy-2549239. (accessed on August 09, 2024).
2. Nagai, Kanto; Nakanishi, Yuta; Kamada, Kohei; Hoshino, Yuichi; Kuroda, Ryosuke. Anatomy and Biomechanics of the Collateral Ligaments of the Knee. In *Orthopaedic Biomechanics in Sports Medicine*; Koh, Jason; Zaffagnini, Stefano; Kuroda, Ryosuke; Longo, Umile Giuseppe; Amirouche, Farid, Eds.; Springer, Berlin: Germany. 2021. https://doi.org/10.1007/978-3-030-81549-3_24.
3. Kenhub. Knee joint. Available online: https://www.kenhub.com/en/library/anatomy/the-knee-joint. (accessed on August 09, 2024).
4. McNally, Euegene; Thompson, Graeme. (2020). Knee: Ligaments and Tendons. In Imaging of Orthopedic Sports Injuries. Medical Radiology; Vanhoenacker, Flip. M.; Maas, Mario; Gielen, Jan.L.M.A., Eds.; Springer, Berlin: Germany. 2021. https://doi.org/10.1007/174_2020_255.
5. Kang, Yunkang; Liu, Chunlong; Ji, Yuncong; Zhang, Haoran; Wang, Yanbo; Bi, Wenzhi; Xu, Jian; Guo, Biao. The burden of knee osteoarthritis worldwide, regionally, and nationally from 1990 to 2019, along with an analysis of cross-national inequalities. *Archives of Orthopaedic and Trauma Surgery* **2024**, *144*, 2731–2743. https://link.springer.com/article/10.1007/s00402-024-05250-4.
6. Medical News Today. Ten common Knee Injuries and Treatment. Available online: https://www.medicalnewstoday.com/articles/319324 (accessed on October 25, 2024).
7. MacDonald, James; Rodenberg, Richard; Sweeney, Emily. Acute Knee Injuries in Children and Adolescents: A Review. *JAMA Pediatrics* **2021**, *175*, 624–630. https:// doi.org/10.1001/jamapediatrics.2020.6130.
8. Up To Date. Available online: https://www.uptodate.com/contents/approach-to-acute-knee-pain-and-injury-in-children-and-skeletally-immature-adolescents. (accessed on August 09, 2024).
9. OECD Library. Health at a Glance 2023. Available online: https://www.oecd-ilibrary.org/social-issues-migration-health/health-at-a-glance-2023_e1a77af6-en. (accessed on August 09, 2024).
10. Timothy Molloy, Yao Wang & George A. C. Murrell (2012). The Role of Ligament Surgery in the Growth and Development of Adolescents. *Journal of Bone and Joint Surgery* **2012**, *94*, 1003–1010. https://doi.org/10.2165/00007256-200333050-00004.
11. Erikson, E. Anterior Cruciate Ligament Tears in Children and Adolescents. *Orthopedic Clinics of North America* **2006**, *46*, 591–598. https://doi.org/10.1007/s00167-006-0153-3.
12. Hoetzel, Jörg; Preiss, Achim; Heitmann, Maximilian; Frosch, Karl-Heinz. Knee injuries in children and adolescents. *European Journal of Trauma and Emergency Surgery* **2014**, 23–36.
13. Migliorini, Filippo; Pilone, Marco; Memminger, Michael Kurt; Eschweiler, Jörg; Giorgino, Riccardo; Maffulli, Nicola. All-epiphyseal anterior cruciate ligament reconstruction yields superior sports performances than the trans-epiphyseal technique in skeletally immature patients: a systematic review. *Official Journal of the Italian Society of Orthopaedics and Traumatology* **2024**, *25*, 7. https://jorthoptraumatol.springeropen.com/articles/10.1186/s10195-024-00751-9.

14. Ishibashi, Yasuyuki; Sasaki, Shizuka; Sasaki, Eiji; Kimura, Yuka; Yamamoto, Yuji; Tsuda, Eiichi . All-Epiphyseal Double-Bundle Anterior Cruciate Ligament Reconstruction for Skeletally Immature Patients. *Arthroscopy Techniques* **2000**, *9*(12), 21993–e2000. https://www.arthroscopytechniques.org/article/S2212-6287%2820%2930233-4/pdf.
15. Melick, Nicky van; Dietvorst, M.; Van Oort, I.A.M; Claessens, Remco L.A.; Janssen, Rob P.A.; Bogie, Rob; Norris, Richard. Anterior Cruciate Ligament Rehabilitation for the 10-to 18-Year-Old Adolescent Athlete Practice Guidelines Based on International Delphi Consensus. *Orthopaedic Journal of Sports Medicine* **2023**, *11*(7). http://dx.doi.org/10.1177/23259671231172454.
16. Johns Hopkins Medicine. ACL Tears in Children. Available online: https://www.hopkinsmedicine.org/health/conditions-and-diseases/acl-injury-or-tear/pediatric-acl-tears. (accessed August 15, 2024).
17. Wegmann, Helmut; Janout, Sophie; Novak, Michael; Kraus, Tanja; Castellani, Christoph; Singer Georg; Till, Holger. Surgical treatment of posterior cruciate ligament lesions does not cause growth disturbances in pediatric patients. *Knee Surgery, Sports Traumatology, Arthroscopy* **2018**, *27*, 2704–2709. https://doi.org/10.1007/s00167-018-5308-5.
18. Moksnes, Håvard; Engebretsen, Lars; Risberg, May Arna. The current evidence for treatment of ACL injuries in children is low: a systematic review. *Journal of Bone and Joint Surgery* **2012**, *94*(12), 1112–1119. http://dx.doi.org/10.2106/JBJS.K.00960.
19. Park, Seung-Hwa;n Jung, Kwang-Hwan; Chang, Sung-Who; Jang, Sung-Min; Park, Ki-Bong. Trends in knee surgery research in the official journal of the Korean Knee Society during the period 1999–2018: a bibliometric review. *Knee Surgery & Related Research* **2020**, *32*, 28. https://kneesurgrelatres.biomedcentral.com/articles/10.1186/s43019-020-00046-3.
20. Gao, Jiaxiang; Xing, Dan; Dong, Shengjie; Lin, Jianhao. The primary total knee arthroplasty: a global analysis. *Journal of Orthopaedic Surgery and Research* **2020**, *15*, 190. https://josr-online.biomedcentral.com/articles/10.1186/s13018-020-01707-5.
21. Dong, Shengjie; Zhao, Yu; Li, Jiao Jiao; Xing, Dan. Global Research Trends in Revision Total Knee Arthroplasty: A Bibliometric and Visualized Study. *Indian Journal of Orthopaedics* **2021**, *55*, 1335–1347. https://doi.org/10.1007/s43465-021-00390-w.
22. Gao, Jiaxiang; Xing, Dan; Dong, Shengjie; Lin, Jianhao. The primary total knee arthroplasty: a global analysis. *Journal of Orthopaedic Surgery and Research* **2020**, *15*, 190. https://doi.org/10.1186/s13018-020-01707-5.
23. Kocher, Mininder; Garg, Sumeet; Micheli, Lyle J. Physeal sparing ACL reconstruction in skeletally immature prepubescent children and adolescents: surgical technique. *Orthopedic Clinics of North America* **2006**, *34*(4), 615–63. http://dx.doi.org/10.2106/00004623-200609001-00012.
24. Jeon, Sang Hyun; Nho, Jin Young; Joo, Sun Young. Management of ACL injuries in children and adolescents. *Journal of Bone and Joint Surgery* **2018**, *97*(7), 575–582. http://dx.doi.org/10.4055/jkoa.2018.53.3.193.
25. Lang, Pamela J.; Sugimoto, Dai; Micheli, Lyle J. Prevention, treatment, and rehabilitation of anterior cruciate ligament injuries in children. *Journal of Sports Medicine* **2017**, *8*, 133–141. http://dx.doi.org/10.2147/OAJSM.S133940.
26. Johns Hopkins Medicine. Available online: https://www.hopkinsmedicine.org/news/articles/2015/07/sparing-the-growth-plate-in-acl-reconstruction (accessed August 15, 2024).
27. Children's Hospital of Philadelphia. Available online: https://www.chop.edu/conditions-diseases/acl-injuries-children-and-teens (accessed August 15, 2024).
28. Verywell Health. Available online: https://www.verywellhealth.com/should-my-child-have-acl-surgery-2549215. (accessed on August 09, 2024).
29. Leslie, William D. Ethnic Differences in Bone Mass—Clinical Implications. The Journal of Clinical Endocrinology & Metabolism 2012, 97(12), 4329–4340. https://doi.org/10.1210/jc.2012-2863.
30. Alvarez, Paul M.; McKeon, John F.; Spitzer, Andrew I.; Krueger, Chad A.; Pigot, Matthew; Li, Mengnai: Vajapey, Sravya P. Socioeconomic factors affecting outcomes in total knee and hip arthroplasty: a systematic review on healthcare disparities. *Arthroplasty* **2022**, *4*, 36. https://doi.org/10.1186/s42836-022-00137-4.
31. Cleveland Clinic. https://consultqd.clevelandclinic.org/socioeconomic-disadvantage-not-race-drives-poor-outcomes-in-joint-replacement-shows-study (accessed on August 09, 2024).
32. Davis, Edward T.; Lingard, Elizabeth A.; Schemitsch, Emil H.; Waddell, James P. Effects of socioeconomic status on patients' outcome after total knee arthroplasty. *International Journal for Quality in Health Care* **2008**, *20*(1), 40–46, https://doi.org/10.1093/intqhc/mzm059.
33. Woods, G. William; O'Connor, Daniel. P. Delayed Anterior Cruciate Ligament Reconstruction in Adolescents with Open Physes. *The American Journal of Sports Medicine*, **2004**, *32*(1). https://doi.org/10.1177/0363546503258868.
34. Collins, Michael J.; Arns, Thomas: Leroux, Timothy; Black, Austin; Mascarenhas, Randy; Bach Jr. Bernard R.; Forsythe, Brian. Growth Abnormalities Following Anterior Cruciate Ligament Reconstruction in the Skeletally Immature Patient: A Systematic Review. *The Journal of Arthroscopic & Related Surgery* **2016**, *32*(8), 1714–1723. https://doi.org/10.1016/j.arthro.2016.02.025.
35. Tang, C.; Kwaees, T.A.; Accadbled, F.; Turati, M.. Surgical techniques in the management of pediatric anterior cruciate ligament tears: Current concepts. *Journal of Children s Orthopaedics* **2023**, *17*(11). http://dx.doi.org/10.1177/18632521221149059.

36. McConkey, Mark O.; Bonasia, Davide Edoardo; Amendola, Annunziato. Pediatric anterior cruciate ligament reconstruction. *Current Reviews in Musculoskeletal Medicine* **2011**, *4*, 37–44. https://doi.org/10.1007/s12178-011-9076-9.
37. Ramski, David E.; Kanj, Wajdi W.; Franklin, Corinna C.; Baldwin, Keith D.; Ganley, Theodore J. Anterior cruciate ligament tears in children and adolescents: a meta-analysis of nonoperative versus operative treatment. *The American Journal of Sports Medicine* **2013**, *42*(11), 2769–2776. https://doi.org/10.1177/0363546513510889.
38. Hoetzel, J.; Preiss, A.; Heitmann, M.A.; Frosch, K.-H. Knee Joint Surgery in Children and Adolescents. *European Journal of Trauma* **2006**, *32*, 150–160. https://doi.org/10.1053/jars.2003.50038.
39. Picard, Frederic. Computer assisted knee replacement surgery: is the movement mainstream? *Orthopedic & Muscular System* **2014**, *3(2)*. http://dx.doi.org/10.4172/2161-0533.1000153.
40. Barber, F. Alan; Dockery, W.D.; Hrnack, Scott A. Long-term degradation of biodegradable implants: a scientific review. *Arthroscopy*, **2011**, *27*, 637–643, https://doi.org/10.1016/j.arthro.2010.11.
41. Stevens, Peter M. Guided Growth for Angular Correction: A Preliminary Series Using a Tension Band Plate. *Journal of Pediatric Orthopaedics* **2007**, *27*(3), 253–259. https://doi.org/10.1097/bpo.0b013e31803433a1.
42. Pablo Castañeda 1, Bradford Urquhart, Elroy Sullivan, Richard J Haynes. Hemiepiphysiodesis for the correction of angular deformity about the knee. *Journal of Pediatric Orthopaedics* **2008**, *28*(2), 188–191. https://doi.org/10.1097/bpo.0b013e3181653ade.
43. Richmond, John C.; Gladstone, James: MacGillivray, John. Continuous passive motion after arthroscopically assisted anterior cruciate ligament reconstruction: Comparison of short- versus long-term use. *Arthroscopy: The Journal of Arthroscopic & Related Surgery* **1991**, *7*(1) 39–44. https://doi.org/10.1016/0749-8063(91)90076-A.
44. Beynnon, Bruce D.; Johnson, Robert J.; Naud Shelly; Fleming, Braden C.; Abate Joseph A.; Brattbakk, Bjarne; Nichols, Claude E. Accelerated Versus Nonaccelerated Rehabilitation After Anterior Cruciate Ligament Reconstruction A Prospective, Randomized, Double-Blind Investigation Evaluating Knee Joint Laxity Using Roentgen Stereophotogrammetric Analysis. *The American Journal of Sports Medicine* **2011**, *39*(12), 2536–2548. http://dx.doi.org/10.1177/0363546511422349.
45. Myer, Gregory; Ford, Kevin R.; Palumbo, Joseph P.; Hewett, Timothy E. Neuromuscular Training Improves Performance and Lower-Extremity Biomechanics in Female Athletes. *Journal of Strength and Conditioning Research* **2005**, *20*(4), 889–896. http://dx.doi.org/10.1519/13643.1.
46. Faigenbaum, Avery D.; Kraemer, William J.; Blimkie, Cameron J. R.; Jeffreys, Ian; Micheli, Lyle Joseph: Nitka, Mike; Rowland Thomas W. Youth Resistance Training: Updated Position Statement Paper From the National Strength and Conditioning Association. *Journal of Strength and Conditioning Research*, **2009**, *23*, S60–S79. https://doi.org/10.1519/JSC.0b013e31819df407.
47. Lloyd, Rhodri; Oliver, Jon. The Youth Physical Development Model: A New Approach to Long-Term Athletic Development. *Strength & Conditioning Journal* **2012**, *34*(3), 61–72. http://dx.doi.org/10.1519/SSC.0b013e31825760ea.
48. Codner, Michelle, Ames, Caroline, & Pluhar, Emily I. The Psychological Effects of Injury on Youth Athletes. In *Psychological Considerations in the Young Athlete*, Christino, M.A., Pluhar, E.I., & Micheli, L.J. Eds.; Springer: New York, USA, 2023. pp. 99-116.
49. Wei, Suyeo & Wu, Zhihui. The Application of Wearable Sensors and Machine Learning Algorithms in Rehabilitation Training: A Systematic Review. *Sensors* **2023**, *23*(18), 7667. https://doi.org/10.3390/s23187667.
50. Lalehzarian, Simon P., Gowd, Anirudh K. & Liu, Joseph N. Machine Learning in Orthopaedic Surgery. *World Journal of Orthopedics*, *12(9)*, 685–699. https://doi.org/10.5312%2Fwjo.v12.i9.685.