Case Report

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Eight Weeks of Plyometric Training for a Professional Volleyball Athlete Four Months Post-Knee Arthroscopy and Bone Repair: A Case Report

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Abstract:

Knee surgery can significantly diminish muscle strength, power, and vertical jump performance in athletes, particularly in volleyball athletes. Plyometric exercises are well-established for their efficacy in enhancing these physical attributes. This case report aimed to demonstrate the application of an 8-week plyometric exercise program to improve knee muscle strength, power, and vertical jump performance in a 20-year-old professional volleyball athlete, 4 months post-arthroscopic removal and repair of left knee osteophytes during the return-to-sport phase. The athlete, who was pain-free and had full knee range of motion at the program's start, showed significant gains: quadriceps and hamstring strength increased by 42%-116% in the left knee and 31%-78% in the right knee, with power output rising up to 400%. Vertical jump performance also improved notably. These results suggest that plyometric training can effectively boost recovery and performance in athletes following knee surgery.

Keywords: isokinetic test, knee arthroscopy, plyometric exercise, vertical jump performance, volleyball

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Introduction

Knee pathology is particularly significant in volleyball athletes[1]. Similar to other sports-related injuries, knee injuries in volleyball can be categorized into overload injuries and traumatic injuries[1]. Overload injuries, which affect high-level athletes, are typically linked to the specific physical demands of the sport[1].

A previous study utilizing magnetic resonance imaging (MRI) found that volleyball athletes are prone to various knee injuries starting in adolescence[2]. The study reported that the prevalence of knee injuries among adolescent volleyball athletes included osteophytes (39%), meniscus injuries (28%), and bone marrow lesions (22%). After 2 years, these injuries further increased, with osteophyte prevalence reaching 100%, and the rates of meniscus and bone marrow lesions rising to 61%. Additionally, male athletes exhibited a significantly higher prevalence of osteophytes in the medial femorotibial joint compared to female athletes[2]. Given that serious knee injuries can limit performance and even lead to the inability to play, surgical intervention is often necessary for volleyball athletes. Unfortunately, post-operative recovery can be challenging, with patients frequently experiencing difficulties walking and doing other physical activities[3]. Mobility typically declines during the first month following knee surgery, and these limitations are closely associated with reductions in muscle strength and power[4]. Such impairments can persist for several months post-surgery.

A well-designed rehabilitation program is crucial for optimizing recovery. Previous studies have shown the benefits of initiating rehabilitation early, typically around 2 weeks after knee arthroscopic surgery and articular repair, in order to restore muscle strength, reduce pain, and improve function[5]. This approach promotes faster recovery, decreases the overall rehabilitation duration, and facilitates a quicker return to the patient's previous activity level. Furthermore, progressive exercise programs that incorporate muscle-strengthening components have demonstrated superior outcomes compared to postoperative treatments that do not include these elements[6]. For jumping athletes, especially, well-designed progressive exercises that enhance strength, power, and jump performance often incorporate plyometric training[7]. The plyometric exercises involve rapid, forceful movements that enable muscles to reach maximum force in a short period. These exercises, which rely on the stretch-shortening cycle (SSC) of muscle fibers, are effective in enhancing physical capacities such as musculotendinous stiffness and power[7]. A systematic review has shown that plyometric training can significantly improve several aspects of performance in volleyball athletes through neuromuscular adaptations[8]. These adaptations allow muscles to exert greater force with less effort, thereby boosting overall strength[7,8]. Plyometric training also enhances power by increasing the rate of force development and stimulating the stretch reflex, which enables athletes to exert force more rapidly[7,8]. Additionally, it improves vertical jump performance through explosive lower-body strength, as muscles become conditioned to utilize the SSC more effectively[7,8]. Flexibility is enhanced due to the improved elasticity of muscles and tendons, while agility benefits from improved neuromuscular coordination, allowing quicker, smoother adjustments during movement[7,8].

Despite the importance of rehabilitation programs for athletes recovering from multi-structural knee injuries, there is a lack of evidence specifically addressing post-operative recovery in volleyball athletes. This case report focuses on a professional volleyball athlete who was four months post-knee surgery, which involved the removal of a bone spur and loose body as well as cartilage repair. To enhance volleyball performance, specifically vertical jump height and knee muscle strength and power, a plyometric exercise program was incorporated into the late rehabilitation phase, under the supervision of a physical therapist, prior to the athlete's return to play. Implementing a plyometric exercise program for a volleyball athlete 4 months post-knee surgery can significantly enhance rehabilitation outcomes by targeting explosive power, proprioception, and neuromuscular control, which are crucial for sport-specific performance.

Case report

This case study was conducted at the Physical Therapy Unit of the Sport Science Center, Sport Authority of Thailand. The patient, a 20-year-old professional volleyball athlete with left-side dominance who is a member of the youth national team, consented to have his physical therapy and training records documented and reviewed for this case report. This case report received ethical approval for human-related research from the Physical Therapy Unit of the Sport Science Center, Sport Authority of Thailand, prior to initiating the intervention.

The patient began experiencing significant issues with his left knee about a year prior, with symptoms worsening rapidly despite continued participation in volleyball. Before this, he had no history of any significant injury. After completing a competition in December 2021, he was unable to bend his left knee beyond 90 degrees and experienced severe pain during all left knee movements. Subsequently, he sought medical evaluation, which included an MRI of the left knee. The MRI revealed intact medial and lateral collateral ligaments, normal size, signal intensity, and contours of the medial and lateral menisci, and no evidence of grade III abnormal signal intensity or meniscal tears. Findings included an anterior cruciate ligament sprain or mucoid degeneration, popliteus and semitendinosus tendinitis, osteoarthritic changes, significant articular cartilage loss, and faint bone marrow edema at the medial and lateral femoral epicondyles. Additionally, there were loose bodies and a spur in the posterior aspect of the knee near the distal posterior cruciate ligament, as well as an avulsion fracture of the femoral lateral epicondyle. Based on these findings, the decision was made to perform knee arthroscopy to remove the spur and loose bodies, and to repair the damaged femur bone and cartilage in his left knee. The arthroscopic procedure was conducted on January 10, 2022.

Nine weeks post-operation, the patient began rehabilitation under the physical therapist's supervision. Prior to this, the patient had been treated by another physical therapist to increase the range of motion (ROM) in his left knee and alleviate post-surgical pain. Upon initial assessment by the physical therapist, the patient exhibited full knee extension and nearly complete knee flexion, with a restriction of approximately 10 degrees in the end range. However, he reported persistent pain in the lateral aspect of the knee. The physical therapist implemented a rehabilitation program focused on improving knee ROM, strengthening the lower extremity, enhancing flexibility, and alleviating pain. After 4 months of rehabilitation, the patient achieved full knee ROM and was almost entirely pain-free in the lateral knee. Before initiating the plyometric training regimen, the physical therapist conducted an assessment of the patient's quadriceps and hamstring strength and power using the Biodex device System 4 Pro™ version (Biodex Medical Systems, NY, USA).

To facilitate the patient's return to sports, improving jump performance was essential. Prior to the injury, the patient achieved a jump height of 324 cm during a countermovement block. Unfortunately, the jump height was not assessed before the initiation of the intervention. The intervention employed in this case report was a plyometric exercise program, adapted from the Boston Sports Medicine and Research Institute[9]. All 3 main phases of the plyometric exercise program were based on the guidelines from the Boston Sports Medicine and Research Institute, except for the final workout in each phase. This program was conducted at the Physical Therapy Unit of the Sport Science Center, Sport Authority of Thailand, from early June to the end of August 2022. Before starting the plyometric exercise program, the patient consulted with a sports physician and physical therapist for pre-assessment tests, including the single-leg hop test, Y-balance test, and knee strength test (isokinetic), to confirm readiness for the program. The patient passed all tests except the quadriceps strength test, which indicated less than 80% strength symmetry compared to the uninjured side. Consequently, the sports physician recommended an MRI to assess bone and soft tissue healing. The MRI confirmed full healing of both bone and soft tissues at 4 months post-surgery. Following this confirmation, the sports physician authorized the physical therapist to initiate the plyometric exercise program.

The plyometric program was specifically designed to address the demands of jumping and landing during sports activities and comprised a series of progressive drills tailored for pre-sports training. The training was structured into 3 progressive loading phases: double-leg training, double-leg complex training, and single-leg training. Sessions were held 3 times per week, with each session lasting between 40 and 60 minutes. A 15–20-minute warm-up preceded each training session, and a 15–20-minute cool-down stretching routine followed.

Throughout the program, the patient progressed by mastering each exercise, performing jumps with the proper technique, and without experiencing muscle tightness, fatigue, or pain. Emphasis was placed on the careful execution of each jump, including a controlled landing with a stick-the-landing technique—maintaining balance briefly before transitioning to the next jump[9]. Proper form included keeping the feet apart, avoiding inward knee rotation, landing on the balls of the feet, and slightly bending the knees and hips to absorb the impact[9]. During this intervention period, the subject participated exclusively in this plyometric exercise program. After each exercise session, the patient received alternating heat and cold therapy on his legs to reduce muscle fatigue caused by exercise, using the MED4 ELITE Multi-Modality Therapy Unit (Game Ready, GA, USA). The details of the program are outlined in Table 1.

Table 1 Plyometric exercise program

Jump and Plyometric Training Progression	Total foot contact
Phase 1	60-foot contacts/session
DL hops on mini-trampoline x 30 reps	
DL hops on soft surface x 10 reps	
DL hops on solid surface x 20 reps	
Phase 2	90-foot contacts/session
Warm-up with DL jumps on mini-trampoline x 30 reps	
DL forward hop x 5 reps	
DL side-to-side hops x 5 reps each side	
DL broad jumps x 5 reps	
DL broad jump-to-vertical x 5 reps	
Alternate SL hops x 30 reps	
Phase 3	120-foot contacts/session
Warm-up with mini-trampoline with DL to SL hops x 60 reps	
DL forward hops (x 5 reps) and side-to-side hops (x 5 reps each direction)	
90° to 180° DL Jumps x 5 reps each	
DL broad jump-to-vertical with 90° to 180° turn x 5 reps each	
SL forward hops (x 5 reps) and side-to-side hops (x 5 reps each direction)	

DL=double legs, SL=single leg, reps=repetitioins

The patient completed Phase 1 of the training program over a period of 2 weeks. During this phase, he reported no pain and successfully performed all the exercises. Following this, he progressed to phase 2, which lasted for 3 weeks. Upon completing phase 2, he advanced to phase 3, also lasting 3 weeks. The physical therapist closely supervised the patient throughout the plyometric exercise program to prevent any accidental circumstances and avoid further injury. Outcome measurements, including isokinetic testing for knee strength and power, were conducted at the end of phase 3. Additionally, vertical jump height was measured after the completion of phases 2 and 3.

In this case study, the Biodex system was utilized to assess knee muscle strength and power, while vertical jump height was measured separately using a countermovement jump test. The Biodex system evaluations included 3 testing conditions to assess peak torque, peak torque/body weight (BW), average peak torque, average power, and hamstring-to-quadriceps (H/Q) ratio at 3 angular velocities: 60 degrees per second (5 repetitions), 180 degrees per second (10 repetitions), and 300 degrees per second (15 repetitions), with one set performed for each test. A 30-second rest period was provided between each testing condition. To measure vertical jump height, the patient stood beneath the Vertec jump tester and performed a countermovement jump, bending at the knees and hips and swinging the arms to generate upward momentum. The patient then jumped as high as possible, reaching with one hand to touch the highest reachable vane. This height was recorded over 2 attempts, with a 30-second break between each attempt. The average height of the 2 trials was used as the final measurement.

Post-phase 3 evaluation results indicated improvements in all measured variables for both legs compared to baseline. Table 2 illustrates the isokinetic data at baseline, after finishing Phase 3 and the percentage improvement from baseline to post-Phase 3. The vertical jump height was measured twice during the rehabilitation process. After Phase 2, the patient achieved a jump height of 314 cm, which increased to 319 cm after completing Phase 3 (Supplementary Figure 1 illustrates the flowchart of this case report).

Table 2 Isokinetic test from Biodex system at baseline, after finishing phase 3, and percentage improvement

Outcomes	Extension (quadriceps)						Flexion (hamstring)					
	60 deg/sec		180 deg/sec		300 deg/sec		60 deg/sec		180 deg/sec		300 deg/sec	
	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt
Baseline												
Peak torque (Nm)	84.2	174.1	79.4	137.1	108.0	118.0	81.6	108.3	63.6	72.0	72.9	67.5
Peak torque/ BW (%)	105.4	218.6	99.4	171.6	135.2	147.7	102.2	135.5	79.6	90.2	91.2	84.5
Average peak torque (Nm)	78.2	151.8	70.0	99.9	94.4	111.2	79.1	90.7	55.8	64.8	67.6	56.0
Average power (watts)	44.3	88.2	48.1	54.7	98.2	229.3	48.1	54.7	81.2	90.0	94.0	69.5
H/Q ratio (%)	96.9	62.0	80.1	52.6	67.5	57.2						

Table 2 (continued)

Outcomes	Extension (quadriceps)						Flexion (hamstring)					
	60 deg/sec		180 deg/sec		300 deg/sec		60 deg/sec		180 deg/sec		300 deg/sec	
	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt
Follow-up (after phase 3)												
Peak torque (Nm)	175.1	291.7	125.6	181.3	93.3	126.0	122.4	136.6	85.6	96.3	66.4	64.7
Peak torque/ BW (%)	219.1	365.1	157.2	226.8	116.8	157.7	153.2	171.0	107.1	120.3	83.2	81.1
Average peak torque (Nm)	168.9	270.2	117.5	152.2	80.0	107.8	115.3	133.1	79.3	85.3	55.4	55.2
Average power (watts)	127.2	171.8	217.6	273.5	197.7	259.5	83.3	100.0	142.8	153.1	99.8	114.3
H/Q ratio (%)	69.9	46.8	68.1	53.0	71.2	51.3						
Percentage (%) improvement from baseline to after finishing phase 3												
Peak torque	107.9	67.5	58.2	32.2	-13.5	6.8	50.0	26.1	34.6	25.2	-8.9	-4.1.
Average peak torque	116.0	78.0	67.9	52.2	-15.3	-3.1	45.8	46.7	42.1	31.6	-18.0	-1.4
Average power	187.1	94.8	353.4	400.0	101.3	13.2	73.2	98.2	142.8	75.9	6.2	64.5

deg/sec=degree/second, BW=body weight, H/Q=hamstring/quadriceps, Lt=left knee, Rt=right knee, left knee is the surgery knee, Nm=Newton meter

Discussion

The objective of this case report was to enhance the strength, power, and vertical jump performance of a volleyball athlete following a 4-month post-knee arthroscopy period, using a plyometric exercise program derived from the Boston Sports Medicine and Research Institute[9]. The intervention was implemented continuously over an 8-week period, during which the patient's discomfort and pain were not exacerbated.

After 8 weeks of plyometric training, significant improvements were observed in quadriceps and hamstring strength at both 60°/sec and 180°/sec testing conditions in both legs. The peak and average torque of the quadriceps and hamstrings increased by more than 25% compared to baseline, while average power showed an overall increase of over 6% across all testing conditions, as well as in peak torque/BW. These findings align with previous studies indicating that sport-specific exercises, such as plyometric training with appropriate progression during the return-to-sport phase following knee surgeries (including articular, cartilage, and anterior cruciate ligament injuries) in athletes, could enhance health, quality of life, functional ability, and facilitating efficient recovery and a safe return to sports activities[10]. Furthermore, a previous review suggested that plyometric training bridges the gap between strength gains and performance return[7]. During plyometric exercises, the contractile components of actin and myosin within the sarcomere play a crucial role in motor control and force production[7]. Current research supports the biomechanical priming of muscles[11], indicating that muscle force generation follows a predictable sequence: eccentric contractions produce the highest force, followed by isometric and concentric contractions[11]. Plyometrics predominantly enhance concentric power production[7], making the eccentric pre-stretch and short amortization phases critical for muscle power development[7,11]. Proprioceptors such as muscle spindles and Golgi tendon organs are stimulated during plyometric exercises, which increase afferent nerve firing and enhance muscle contraction through faster stretch rates[7].

When comparing the isokinetic results between both legs, differences in strength and power were observed. While both knees showed overall improvements in strength and power, the left knee (post-operative side) still exhibited lower results compared to the right knee. It is important to note that further progressive training programs may need to be adjusted to address these asymmetries and prevent potential injuries associated with strength and power imbalances between the knees. Additionally, the H/Q ratio was mostly within the normal range (50%–80%) from baseline to follow-up. The normal H/Q ratio is typically considered to be between 50% and 80% when averaged through the full range of knee motion[12]. As the ratio approaches 100%, the hamstrings demonstrate an increased functional capacity to provide stability to the knee[12].

Despite these improvements, torque at 300°/sec decreased post-training, a finding attributed to the endurance aspect measured by the Biodex system[13]. However, plyometric exercise is known to improve various aspects of muscular fitness including strength, power, and local endurance[7]. This study's results suggest that the specific program used may not have been optimal for enhancing endurance. It is possible that the training regimen lacked the sufficient progression in speed and volume required to enhance endurance. The program emphasized strength and power with a focus on force rather than speed, leading the neuromuscular system to adapt primarily to these demands and potentially resulting in a relative decline in high-velocity performance. Additionally, the high-velocity test at 300°/sec was the final test among the 3 conditions (60°/sec, 180°/sec, and 300°/sec), with only 30 seconds of rest between tests. This order may have led to fatigue, temporarily impairing the muscles' ability to produce force at higher speeds and reducing isokinetic performance.

Plyometric exercises, while commonly performed in closed kinetic chain settings such as jumping, exhibit the capacity to transfer their underlying principles of power generation, force application, and neuromuscular coordination to open kinetic chain activities, including isolated knee extensions and other concentric movements[14]. The focus on plyometric training, combined with the evaluation of concentric contractions and open kinetic chain strength outcomes, emphasizes its adaptability and versatility. Beyond enhancing explosive power, plyometric exercises improve the overall force-generating capacity of muscles, making them applicable across a range of activities that require open kinetic chain strength[14].

Notably, the vertical jump height increased, aligning with findings from the systematic review and meta-analysis studies[8,15] that demonstrated plyometric training's effectiveness in enhancing vertical jump performance[8,15]. Plyometric movements utilize the SSC in order to improve muscle fiber tension and force production, resulting in increased jump height[7]. This training enhances functional neural adaptations, allowing tendons to store and release greater elastic energy during the concentric phase, contributing to improved jump performance[15].

As a case report, the findings from this study are derived from a single patient and may not be generalizable to the broader population. Additionally, the study lacked a comparison group, which limits the ability to attribute the observed outcomes solely to the plyometric intervention. Without a control group, it is difficult to determine if the outcomes are due to the intervention or other factors. Therefore, caution is warranted when applying this protocol and its outcomes to clinical practice. In addition, the isokinetic tests conducted using the Biodex system were performed at 60°/sec, 180°/sec, and 300°/sec, respectively, with only 30 seconds of rest between each test. This rest period may have been insufficient, potentially causing fatigue by the time the final test condition was performed. Moreover, the training program did not emphasize speed or timing in each movement. Further research with larger sample sizes, controlled study designs, more robust outcome measurements, and well-structured plyometric exercise programs is necessary to validate these findings and assess their broader applicability.

This case report offers several notable strengths. First, it provides a detailed case report of a specific plyometric exercise program tailored for a professional volleyball athlete recovering from knee arthroscopy. To our knowledge, this is the first study to implement a volleyball-specific plyometric exercise program for post-operative rehabilitation following knee arthroscopy and bone repair. Most previous studies have primarily focused on anterior cruciate ligament reconstruction or knee arthroplasty. The program was carefully timed and initiated only after thorough pre-program assessments and an MRI confirmed the complete healing of bone and soft tissues. This progressive program in this study, consisting of double-leg training, double-leg complex training, and single-leg training in sequence, successfully improved knee muscle strength, power, and vertical jump height. Moreover, this targeted approach provides an in-depth evaluation of the intervention's effectiveness on strength, power, and vertical jump performance. The use of a well-established plyometric program, adapted from the Boston Sports Medicine and Research Institute[9], adds credibility and relevance to the rehabilitation strategies employed. Additionally, the study employed the objective measurements of muscle strength and power using the Biodex device, which provides robust and quantifiable data. The clear documentation of the patient's progress over the 8-week intervention period, including improvements in muscle strength, power, and jump performance, enhances the value of the findings. Finally, the detailed description of the training protocol and phases provides valuable insights for practitioners and clinicians developing similar rehabilitation programs for athletes recovering from knee surgery.

Conclusion

Plyometric exercise could improve the strength of quadriceps and hamstrings, as well as power and vertical jump performance, in a volleyball athlete 4 months after arthroscopic knee osteophytes removal and bone repair following 8 weeks of training.

Conflict of interest

There are no potential conflicts of interest to declare.

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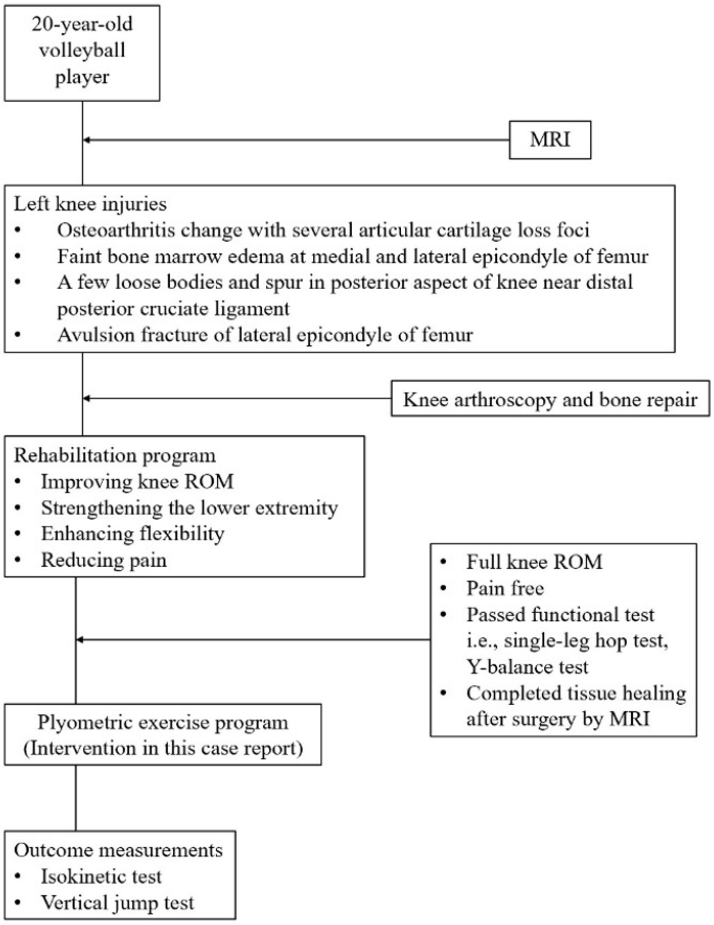

Supplementary Figure 1 Flowchart of this case report