Research Article

The Effectiveness of Plyometric Training and Aquatic Training on Patellar Tendinopathy among University-Level Volleyball Players

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ABSTRACT

Introduction: Patellar tendinopathy (PT) is a prevalent overuse injury among volleyball players, primarily due to repetitive jumping, landing, and sudden directional changes required in the sport. Plyometric training enhances tendon strength and neuromuscular coordination; however, it involves high-impact movements that may exacerbate symptoms. Aquatic training offers a low-impact alternative, using water's buoyancy to reduce stress while enhancing strength and flexibility. This study aimed to evaluate the effectiveness of these interventions in reducing pain and improving the function of volleyball players with PT.

Materials and Methods: Volleyball players aged 18–24 years who had been diagnosed with PT were recruited. Thirty university-level volleyball players were randomly assigned to two groups: Group A (plyometric training; n=15) and group B (aquatic training; n=15). All players underwent pre-test measurements using the numeric pain rating scale (NPRS) and the Victorian Institute of Sport Assessment-Patellar (VISA-P) score. Post-test measurements were taken at the end of the sixth week.

Results: Comparing pre-test and post-test values of the NPRS and VISA-P between the groups revealed significant differences. Group B showed better outcomes, with a mean NPRS value of 1.73±0.703 compared to group A's 3.13±0.743 ($P \leq 0.05$, effect size d=1.93). Similarly, group B's mean VISA-P score (65.80±5.37) was higher than group A's (58.73±5.29) ($P \leq 0.05$, effect size d=1.32). These results indicate that aquatic training was more effective than plyometric training.

Conclusion: This study demonstrates that aquatic training is more effective than plyometric training in managing PT in university-level volleyball players, showing significant improvements in symptoms.

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Introduction

Patellar tendinopathy (PT), commonly referred to as jumper's knee, is a debilitating overuse injury that can cause significant pain in athletes, particularly those participating in high-intensity sports, such as basketball and volleyball. This condition arises from pain and dysfunction in the patellar tendon. Failure to properly manage it can substantially impact an athlete's performance and may even result in long-term consequences [1]. PT has multiple causes, including intrinsic and extrinsic factors, such as chronic mechanical stress, poor biomechanics, and inadequate rest periods [2].

Historically, a variety of treatment techniques of varying effectiveness have been used to manage PT, including conservative options, such as physiotherapy, load management, and eccentric training, as well as advanced procedures, such as shockwave therapy and platelet-rich plasma injections [3]. Among these methods, two exercise techniques, plyometric training [4] and aquatic training [5], have emerged as particularly effective for managing PT in university-level volleyball players. These training styles aimed to enhance neuromuscular efficiency, tendon stiffness, and overall musculoskeletal function without aggravating symptoms [6].

Research indicates that PT is most prevalent among professional volleyball players, with a rate of 45% [7]. Among elite athletes across nine different sports, the overall prevalence was 14.2% [7]. Another study involving volleyball players reported PT in 18.6% of participants, with 6.3% diagnosed with bilateral PT and 12.3% with unilateral PT [8]. A separate study of 891 non-elite male and female athletes from seven sports found an overall prevalence of PT of 8.5%, with the highest incidence in volleyball players at 14.4% [9]. Further analysis of the mechanical characteristics of the patellar tendon in elite volleyball athletes revealed that those with tendinopathy faced increased injury risk due to decreased tendon stiffness and reduced load tolerance [10].

Plyometric training is widely recognized for its ability to improve explosive strength, agility, and neuromuscular coordination. Studies have shown that plyometric training enhances quadriceps strength, jump height, and patellar tendon morphology in adolescent volleyball players, particularly in terms of structural and functional adaptations [11]. However, its role in treating PT remains controversial. Research on the impact of plyometric and resistance training suggests that controlled tensile loading can help strengthen tendons and reduce the risk of injury. However, excessive loading without adequate recovery may exacerbate symptoms. Thus, plyometric programs must be carefully tailored to avoid overloading injured tendons while maintaining optimal training intensity [6, 12].

Aquatic therapy has gained prominence as a rehabilitation method for musculoskeletal injuries, including PT. The properties of water, particularly buoyancy and hydrostatic pressure, reduce gravitational stress on joints and tendons, enabling athletes to perform strength and endurance exercises with minimal discomfort. This makes aquatic training especially beneficial for chronic tendon rehabilitation. Studies on water therapy have demonstrated improvements in tendon health, functional performance, and pain relief in volleyball players [5, 13]. Additionally, aquatic exercises enhance proprioception and neuromuscular control, facilitating better movement patterns post-injury. Experts recommend incorporating multi-modal rehabilitation strategies, including aquatic exercises, for athletes with PT [13]. Combining aquatic and traditional strength training has shown favourable outcomes, suggesting that integrating both plyometric and aquatic methods can optimize recovery [14].

While plyometric and aquatic training each offer unique benefits for PT, their efficacy depends on the severity of the injury and the individual athlete's response to treatment. A study on young volleyball players found that combining both modalities yielded superior results compared to traditional rehabilitation [14], supporting the potential of a hybrid approach for optimal recovery [15].

Despite the existing evidence, there is a lack of research specifically comparing these therapies in university-level volleyball players. Most prior studies have focused on a single intervention or lacked sport-specific populations. Thus, this study aimed to compare the effects of plyometric and aquatic training on PT in this demographic. The primary objective is to evaluate their respective impacts on pain and function, with the hypothesis that there will be a significant (or no significant) difference between the two interventions.

Materials and Methods

Study design

This experimental study aimed to investigate and compare the effects of plyometric and aquatic training on pain and functional ability in volleyball players.

Selection criteria

Thirty university volleyball players (18–24 years) from DREAM STAR Sports Academy in Tiruvallur, Chennai, India, participated in this study. The inclusion criteria included a clinical diagnosis of PT, active participation in volleyball training, and a commitment to a six-week intervention. The exclusion criteria included acute injuries, systemic diseases, recent knee surgeries, and inability to adhere to the training regimen. Participants were randomly assigned to group A (plyometric training, n=15) or group B (aquatic training, n=15).

Procedure, materials, and tools

Both groups followed a 6-week structured training protocol, with 60-minute sessions held four times a week. Each session began with a general warm-up (light cardio and dynamic stretching) and concluded with a 5–10 minute cool-down (low-intensity exercises and static stretching). Group A (plyometric training) performed land-based exercises, including lateral bounds, single-leg hops, box jumps, depth jumps, squat jumps, and lunges. These exercises consisted of three sets of 6–10 repetitions, with 60–90 seconds of rest between sets and 2–3 minutes between exercises. Group B (aquatic training) performed water-based exercises in a swimming pool, such as water jogging, cycling, leg swings, aquatic squats, leg lifts, and resisted knee flexion and extension. These exercises comprised three sets of 10–20 repetitions, with 30–60 seconds of rest between sets. The volume and intensity of the exercises in both groups were gradually increased each week based on the participants' performance and tolerance. The materials used in this study included jump boxes, mini-hurdles, medicine balls, cones, a swimming pool, and resistance bands.

Data collection

Pain levels were assessed using the numeric pain rating scale (NPRS), and functional capacity was evaluated using the Victorian Institute of Sport Assessment-Patellar (VISA-P) questionnaire. Data were collected at baseline and after the six-week intervention.

Statistical analysis

The participants' data were analyzed using SPSS software, to ensure the accuracy and reliability of the results. To ensure homogeneity between groups at baseline, independent t-tests were conducted before the interventions. Additionally, independent t-tests were used to compare the differences between the plyometric training and aquatic training groups on outcome measures, including pain levels and functional capacity. Paired t-tests were used to assess within-group effects from pre-intervention to post-intervention. The significance level was set at P<0.05 for all analyses.

Results

Descriptive and inferential statistical methods were employed to assess the effectiveness of plyometric and aquatic training in PT in university-level volleyball players. Independentpre-tests were conducted to verify the homogeneity of the two groups at baseline, comparing age, height, weight, and body mass index (BMI). The results revealed no statistically significant differences between group A (plyometric training) and group B (aquatic training) in any demographic variable (P>0.05), indicating that the groups were comparable prior to the intervention (Table 1). The Mean±SD were calculated for the NPRS and VISA-P scores in both groups, both pre- and post-intervention.

Table 1. Demographic characteristics of participants in groups

Variables	Mean±SD		t	P
	Group A (n=15)	Group B (n=15)		
Age (y)	21.07±1.67	20.8±1.42	0.45	0.65
Height (cm)	172.93±5.28	171.2±6.05	0.84	0.41
Weight (kg)	67.53±6.11	66.27±5.89	0.56	0.58
BMI (kg/m²)	22. 58±1.94	22.57±1.87	0.01	0.99

BMI: Body mass index.

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Note: P>0.05 indicates no significant differences between groups at baseline.

Table 2. Comparison of NPRS scores between groups A and B

Test	Mean±SD		t	df	P
	Group A	Group B			
Pre-test	6.2±0.676	6.13±0.838	0.421	28	0.812*
Post-test	3.13±0.743	1.73±0.703	5.29	28	0.001**

*P>0.05 (not significant), **P≤0.05 (significant).

Pairedpre-tests for both groups (A and B) showed significant reductions in the NPRS and improvements in the VISA-P scores (P<0.001), confirming that the intervention had a statistically significant effect.

Table 2 presents the Mean±SD, pre-test, degree of freedom, and P for groups A and B in both pre-test and post-test assessments. The results indicated no significant difference between group A and group B in pre-test values (P>0.05). However, the post-test values (P≤0.001) showed statistically significant differences between groups A and B. The Cohen's d value of 1.93 indicates a large effect size, exceeding the threshold of 0.8. The participants in the aquatic therapy group (1.73±0.703) experienced greater pain relief than those in the plyometric training group (3.13±0.743).

Table 3 presents the Mean±SD, pre-test, degree of freedom, and P for groups A and B in both pre-test and post-test assessments. The results indicated no significant difference between groups A and B in pre-test values (P>0.05). A statistically significant difference was observed between groups A and B in post-test values (P≤0.05). Consistent with the reduction in pain, the players' VISA-P scores in the aquatic therapy group were slightly better than those in the plyometric training group. The Cohen's d value (d=1.32) indicated a large effect size, exceeding the threshold of 0.8. The participants in the aquatic therapy group (65.80±5.37) showed better improvement in functional ability than those in the plyometric training group (58.73±5.29).

Table 4 presents the Mean±SD, t, and P for pre-test and post-test values within groups A and B. The results showed statistically significant differences between the pre-test and post-test pain scores in groups A and B (P≤0.05), indicating that the players responded well to the interventions. Similarly, the players' responses on the VISA-P showed statistically significant differences between pre-test and post-test values in both groups A and B (P≤0.05) (Table 5).

The analysis of within-group changes from pre- to post-test for both pain and functional ability was conducted using pairedpre-tests. In group A (plyometric training), participants demonstrated significant improve-

Table 3. Comparison of VISA-P score between groups (A & B)

Test	Mean±SD		t	df	P
	Group A	Group B			
Pre-test	48.13±3.88	47.53±4.83	0.374	28	0.711*
Post-test	58.73±5.29	65.8±5.37	-3.62	28	0.001**

*P>0.05 (not significant), **P≤0.05 (significant).

Table 4. Comparison of NPRS score within groups

Groups	Mean±SD		t	P
	Pre-test	Post-test		
A	6.20±0.676	3.13±0.743	20.08	0.001**
B	6.13±0.838	1.73±0.703	33.60	0.001**

**P≤0.05 (Significant).

Table 5. Comparison of VISA-P score within group (A&B)

Groups	Mean±SD		t	P
	Pre-test	Post-test		
A	48.13±3.88	58.73±5.29	-17.00	0.000**
B	47.53±4.83	65.80±5.37	-29.06	0.000**

**P≤0.05 (significant).

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ments, with NPRS scores decreasing from 6.20±0.68 to 3.13±0.74 (P<0.001; large effect size, d=4.58) and VISA-P scores increasing from 48.13±3.88 to 58.73±5.29 (P<0.001; large effect size, d=2.26), confirming significant enhancements in pain reduction and functional ability. Similarly, group B (aquatic training) showed pronounced reductions in pain (NPRS: 6.13±0.83 to 1.73±0.70; P<0.001; very large effect size, d=5.97) and greater functional gains (VISA-P: 47.53±4.83 to 65.80±5.37; P<0.001; very large effect size, d=3.66), leading to rejection of the null hypothesis.

For between-group comparisons, independentpre-tests revealed superior outcomes in group B. Specifically, group B's post-test NPRS score (1.73±0.70) was significantly lower than group A's (3.13±0.74; t=5.29, P=0.0001), with a large between-group effect size (d=1.93). Although both groups exhibited significant improvements in VISA-P scores, group B's post-test mean (65.80±5.37) surpassed group A's (58.73±5.29; P≤0.05; between-group d=1.32), further supporting the superiority of aquatic training. Thus, the null hypothesis was rejected again, with statistically significant differences (P≤0.05) between the pre- and post-test means for both the NPRS and VISA-P scores across groups.

Discussion

PT, commonly known as jumper's knee, is a prevalent and challenging condition among athletes, particularly those participating in high-impact sports, such as basketball and volleyball, that involve repetitive jumping movements [2, 7, 8]. Various therapeutic approaches have been explored to alleviate symptoms and promote tendon recovery, with plyometric training and aquatic training emerging as particularly promising interventions [5, 6, 11].

Plyometric exercise, characterized by explosive movements, such as jumping and bounding, has been extensively studied for its effects on muscle adaptation and tendon stiffness. Brar et al. demonstrated that lower-limb plyometric and resistance training significantly influenced the stiffness of the Achilles and patellar tendons in recreational athletes [6]. Further supporting this, Harput et al. found that plyometric training enhances jump performance, quadriceps strength, and sonographic characteristics of both the quadriceps muscle and patellar tendon in adolescent female volleyball players, suggesting its dual role in injury prevention and rehabilitation [11].

In contrast, aquatic training has garnered attention for its ability to provide resistance while minimizing joint stress. Kamalakkannan et al. demonstrated that aquatic training significantly improved physical fitness metrics in volleyball players [5]. The reduced gravitational load in aquatic environments enables pain-free movement, making swimming an effective rehabilitation approach for athletes with patellar tendinitis, also known as PT.

Emerging evidence on combined training modalities has shown promising results. Vander Doelen and Scott reported in their study of basketball players that a multimodal rehabilitation strategy, integrating diverse training methods, enhances tendon recovery outcomes [13]. Additionally, Sprague et al. highlighted the importance of pain-guided activity modification during rehabilitation, noting that structured training adaptations can optimize tendon health and function [12].

This study aimed to compare the efficacy of aquatic and plyometric training in volleyball players with PT. Thirty participants were enrolled in a 6-week intervention involving targeted muscle-strengthening exercises. Using a pre-test/post-test experimental design, measurements were recorded at baseline and after the intervention, with weekly follow-ups to monitor progress. The results revealed superior improvements in the aquatic training group compared to the plyometric group. Analysis of VISA-P and NPRS scores demonstrated significantly greater enhancements in pain reduction and functional ability among participants undergoing aquatic training.

Conclusion

This study demonstrates that aquatic training is more effective than plyometric training for managing PT in university-level volleyball players. The aquatic training protocol significantly improved outcomes, with marked differences in post-test values for both the NPRS and VISA-P scores between group A (plyometric) and group B (aquatic). Group B exhibited superior improvements in functional capacity and pain relief. These findings have important clinical implications. Rehabilitation programs for PT may benefit from incorporating aquatic exercises that effectively minimize joint stress while promoting functional recovery. For athletes in high-impact sports, aquatic training provides a safer and more tolerable alternative that maintains training consistency without exacerbating symptoms. Future studies should explore multimodal approaches, combining aquatic training with neuromuscular exercises to further enhance outcomes and reduce the risk of reinjury.

Study limitations

This study found that university-level volleyball players with PT responded better to aquatic training than to plyometric exercise for pain reduction and functional improvement. However, several limitations should be noted. First, the sample was drawn from only one sports academy, which may limit the broad applicability of these results. Second, the six-week intervention period was relatively short and lacked follow-up assessments; therefore, we could not determine whether the improvements were maintained over time. Third, since the study only included collegiate volleyball players, the findings may not apply to athletes in other sports or different age groups. Additionally, the results relied more on subjective measures (pain and function scores) than objective measurements, which could introduce response bias. Longer-term studies are needed to examine the durability of the benefits and whether these treatments can help maintain tendon health. Researchers should also investigate combining these methods with neuromuscular training and test them in more diverse groups, including female athletes, recreational players, and those with chronic tendinopathy. Finally, incorporating objective measures, such as biomechanical assessments or imaging, could provide a better understanding of how these treatments affect tendon structure.

Ethical Considerations

Compliance with ethical guidelines

All procedures complied with ethical guidelines and were approved by the Ethics Committee of Saveetha Institute of Medical and Technical Sciences, Chennai, India (Code: 009/12/2024/ISRB/PGSR/SCPT). Written informed consent was obtained from all participants.

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Authors' contributions

Study design, investigation, data analysis, and writing the original draft: Divyashree Magendran and Buvanesh Annadurai; Data interpretation, review and editing: Vinodhkumar Ramalingam and Kajamohideen Abdul Rahman; Final approval: Vinodhkumar Ramalingam and Buvanesh Annadurai; Supervision: Buvanesh Annadurai.

Conflict of interest

The authors declared no conflict of interest.

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