Research Article

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

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Running title: Plyometric vs aquatic training for patellar pain

Abstract

Background: Patellar tendinopathy is a prevalent overuse injury among volleyball players due to the repetitive jumping, landing, and sudden directional changes. Plyometric training enhances tendon strength and neuromuscular coordination but involves high-impact movements that may worsen symptoms. Aquatic training provides a low-impact alternative, using water's buoyancy to reduce stress while improving strength and flexibility. This study aims to evaluate the effectiveness of these interventions in reducing pain and improving function in volleyball players with patellar tendinopathy.

Method: The study recruited volleyball players aged 18–24 years with diagnosed patellar tendinopathy. A total of 30 university-level volleyball players were randomly assigned into two groups: Group A (plyometric training; n = 15) and Group B (aquatic training; n = 15). All players underwent pretest measurements with the Numeric Pain Rating Scale (NPRS) and the Victorian Institute of Sport Assessment (VISA) Patella (P) score. Posttest measurements were taken at the end of the sixth week.

Results: Comparing pre-test and post-test values of NPRS and VISA-P between 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 treatment was more effective than plyometric training.
Conclusion: This study demonstrates that aquatic training is more effective than plyometric training in managing patellar tendinopathy in university-level volleyball players, showing significant improvements in symptoms.
Keywords: Aquatic therapy; Patellar ligament; Plyometric exercise; Tendinopathy; Volleyball.

Introduction

Patellar tendinopathy, commonly referred to as jumper's knee, is a debilitating overuse injury that can cause significant pain for 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]. Patellar tendinopathy has multiple causes, ranging from 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 patellar tendinopathy, including conservative options like physiotherapy, load management, and eccentric training, as well as advanced procedures like 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 patellar tendinopathy in university-level volleyball players. These training styles aim to enhance neuromuscular efficiency, tendon stiffness, and overall musculoskeletal without aggravating symptoms [6].

Research indicates that patellar tendinopathy (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 PT prevalence of 8.5%, with volleyball players having the highest incidence 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 risks due to decreased tendon stiffness and reduced load tolerance [10].

Plyometric training is widely recognized for improving 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 adaptation [11]. However, its role in treating patellar tendinopathy remains controversial. Research on the impact of plyometric and resistance training suggests that controlled tensile loading can strengthen tendons and reduce injury risk. Nevertheless, excessive loading without adequate recovery may exacerbate symptoms. Thus, plyometric programs must be carefully tailored to avoid overloading the injured tendon while maintaining optimal training intensity [6,12].

Alternatively, aquatic therapy has gained prominence as a rehabilitation method for musculoskeletal injuries, including patellar tendinopathy. 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 among 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 patellar tendinopathy [13]. Combining aquatic and traditional strength training has shown favourable outcomes, suggesting that integrating both plyometric and aquatic methods could optimize recovery [14].

While plyometric and aquatic training each offer unique benefits for patellar tendinopathy, their efficacy depends on injury severity and individual athlete response. 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 existing evidence, there is limited research comparing these therapies specifically in university volleyball players. Most prior studies have focused on a single intervention or lacked sport-specific populations. Thus, this study aims to compare the effects of plyometric and aquatic training on patellar tendinopathy 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 training 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. Inclusion criteria included a clinical diagnosis of patellar tendinopathy, active volleyball training, and commitment to a six-week intervention. Exclusion criteria comprised acute injuries, systemic diseases, recent knee surgeries, and inability to adhere to the training regimen. Participants were randomly assigned to either 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 jumping 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-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 participant 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 and ethical rules

Pain levels were assessed using the Numeric Pain Rating Scale (NPRS), and functional capacity was evaluated using the Victorian Institute of Sport Assessment-Patella (VISA-P) questionnaire.

Data were collected at baseline and after the six-week intervention. Written informed consent was obtained from all participants, and the study received approval from the Institutional Ethics Committee 009/12/2024/ISRB/PGSR/SCPT.

Statistical analysis

The participants' data were analyzed using SPSS (Statistical Package for the Social Sciences) software to ensure accuracy and reliability in 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 the within-group effects from pre-intervention to post-intervention. A significance level of $p < 0.05$ was set for all analyses.

Results

Descriptive and inferential statistical methods were employed to assess the effectiveness of plyometric training and aquatic training on patellar tendinopathy in university-level volleyball players. Independent t-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 and standard deviations were calculated for the NPRS (Numeric Pain Rating Scale) and VISA-P (Victorian Institute of Sport Assessment – Patella) scores, for both groups pre- and post-intervention.

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

Table 1. Demographic characteristics of participants in groups

Variable	Group A (n = 15)	Group B (n = 15)	t	*p* - value
Age (years)	21.07 ± 1.67	20.80 ± 1.42	0.45	0.65
Height (cm)	172.93 ± 5.28	171.20 ± 6.05	0.84	0.41
Weight (kg)	67.53 ± 6.11	66.27 ± 5.89	0.56	0.58
BMI (kg / m^2)	22. 58 ± 1.94	22.57 ± 1.87	0.01	0.99

($p > 0.05$ indicates no significant differences between groups at baseline)

Table 2 presents the mean, standard deviation, t-test, degree of freedom, and p - value for Group A and Group B in both pre-test and post-test assessments. The results indicate no significant difference between Group A and Group B in pre-test values ($p > 0.05$). However, the post-test values ($p \leq 0.001$) showed statistically significant differences between Group A and Group 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 better relief from pain compared with those in the plyometric training group (3.13 ± 0.743).

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

Test	**Group A**		**Group B**		**t**	**df**	***p* - value**
	Mean	**S.D**	**Mean**	**S.D**			
Pre test	6.20	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)

Table 3 presents the mean, standard deviation, t-test, degree of freedom, and p - value for Group A and Group B in both pre-test and post-test assessments. The results indicate no significant difference between Group A and Group B in pre-test values ($p > 0.05$). There was a statistically significant difference between Group A and Group B in post-test values ($p \leq 0.05$). In line with the reduction in pain, the players' VISA-P scores in the aquatic therapy group were slightly better compared with those in the plyometric training group. The Cohen's d value (d= 1.32) indicates 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 compared to participants in the plyometric training group (58.73 ± 5.29).

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

Test	**Group A**		**Group B**		**t**	**df**	***p* - value**
	Mean	S.D	Mean	S.D			
Pre-test	48.13	3.88	47.53	4.83	0.374	28	0.711*
Post-test	58.73	5.29	65.80	5.37	-3.62	28	0.001**

*p > 0.05 (not significant); **p ≤ 0.05 (significant)

Table 4 presents the mean, standard deviation, t-value, and p - value for pre-test and post-test values within Group A and Group B. The results show statistically significant differences between pre-test and post-test values of pain scores in both Group A and Group B ($p \leq 0.05$), indicating that 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 Group A and Group B ($p \leq 0.05$), as shown in Table 5.

Table 4. Comparison of NPRS score within groups

Groups	Pre-test	Post-test	**t**	***p* - value**

	Mean	S.D	Mean	S.D		
Group A	6.20	0.676	3.13	.743	20.08	0.001**
Group- B	6.13	0.838	1.73	.703	33.60	0.001**

**P ≤ 0.05 (Significant)

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

Groups	**Pre-test**		**Post-test**		**t**	***p* - value**
	Mean	**S.D**	**Mean**	**S.D**		
Group A	48.13	3.88	58.73	5.29	-17.00	.000**
Group- B	47.53	4.83	65.80	5.37	-29.06	.000**

**P ≤ 0.05 (Significant)

The analysis of within-group changes from pre- to post-test for both pain and functional ability was conducted using paired t-tests. In Group A (plyometric training), participants demonstrated significant improvements, 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, respectively. 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, independent t-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). While 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; $p \leq 0.05$; between-group d= 1.32), further supporting the superiority of aquatic training. Thus, the null hypothesis was again rejected, with statistically significant differences ($p \leq 0.05$) between pre- and post-test means for both NPRS and VISA-P scores across groups.

Discussion

Patellar tendinopathy, 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 like jumping and bounding, has been extensively studied for its effects on muscle adaptation and tendon stiffness. Brar et al. (2021) demonstrated that lower-limb plyometric and resistance training significantly influences Achilles and patellar tendon stiffness in recreational athletes [6]. Further supporting this, Harput et al. (2022) 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 both 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. (2010) 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 tendinopathy.

Emerging evidence on combined training modalities has shown promising results. Vander Doelen and Scott (2020) 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. (2021) 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 versus plyometric training in volleyball players with patellar tendinopathy. 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 post-intervention, with weekly follow-ups conducted to monitor progress. 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.

Study limitations

This study found that university-level volleyball players with patellar tendinopathy responded better to aquatic training than plyometric exercise for pain reduction and functional improvement, but several limitations should be noted. First, the sample came from only one sports academy, which may limit how broadly the results can be applied. Second, the six-week intervention period was relatively short and lacked follow-up assessments, so we cannot determine if 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 some response bias. For future research, longer-term studies are needed to examine how well the benefits last and whether these treatments 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, adding objective measures like biomechanical assessments or imaging could provide better understanding of how these treatments affect tendon structure**.**

Conclusion

This study demonstrates that aquatic training is more effective than plyometric training for managing patellar tendinopathy 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). Interestingly, Group B exhibited superior improvements in functional capacity and pain reduction. These findings have important clinical implications. Rehabilitation programs for patellar tendinopathy may benefit from incorporating aquatic exercises, which effectively minimize joint stress while promoting functional recovery. For athletes in high-impact sports, aquatic training offers a safer, more tolerable alternative that maintains training consistency without exacerbating symptoms.

Future directions could explore multimodal approaches, combining aquatic training with neuromuscular exercises to further enhance outcomes and reduce reinjury risk.

Ethical Considerations

All procedures complied with ethical guidelines and were approved by the Institutional Ethics Committee (Reference: 009/12/2024/ISRB/PGSR/SCPT)

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Authors contributions

D.M. and B.A. contributed to the study design, literature search, data analysis, and manuscript writing; V.R. and K.M.A. assisted in data interpretation and critical revision of the manuscript; V.R. and B.A. provided final approval of the version; and B.A. assumed accountability for all aspects of the work. Conflict of Interest: The authors declare no conflicts of interest.

Conflict of interest

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