Mahmoud *et al.*
Bulletin of Faculty of Physical Therapy (2024) 29:2
https://doi.org/10.1186/s43161-023-00170-7

Bulletin of Faculty of Physical Therapy

ORIGINAL RESEARCH ARTICLE

Open Access

Efficacy of modified active physical therapy program on pain, muscle strength, and function in adolescent football players with osteitis pubis

Waleed S. Mahmoud[1,2*], Marwa M. Ibrahim[3,1] and Nadia L. Radwan[4,1]

Abstract

Background In athletes, osteitis pubis (OP) is considered a major cause of chronic groin pain. In addition to the difficulties with diagnosis, controversy exists regarding the most appropriate treatment approach. The study aimed to evaluate the effect of a modified active physical therapy program (MAPT) on pain, hip and trunk muscle strengths, and lower extremity function in adolescent football players with OP.

Methods Fifty football players aged from 12 to 18 years with OP were included and allocated into two groups: the MAPT group ($n = 24$) and the traditional physical therapy (TPT) group ($n = 26$). Each group received a different treatment protocol for 60 min applied 3 times/week for 12 weeks. A visual analog scale, digital hand-held dynamometer (HHD), and lower extremity functional scale (LEFS) were used to measure pain, hip and trunk muscle strengths, and lower limb function, respectively, at baseline and 12 weeks post-intervention.

Results There was a highly significant difference in the TPT group's pain score ($p < 0.001$) compared with the MAPT group. Also, the strength of hip flexors, abductors, adductors, internal rotators, external rotators, and trunk flexors and extensors improved significantly ($p < 0.05$) than the TPT group. However, the between-group analysis revealed that the strength of hip extensors and LEFS in the MAPT group achieved a highly significant difference ($p < 0.001$) compared with the TPT group.

Conclusion MAPT could be recommended strongly in the rehabilitation of OP in adolescent football players in which the functional abilities of OP patients improved because of reduced pain levels and increased hip and trunk muscle strength. (IRCT20210909052421N3, Iranian Registry of Clinical Trials, https://www.irct.ir/trial/68946/pdf, 9-April-2023).

Keywords Osteitis Pubis, Groin pain, Physical therapy program, Lower extremity strength, Lower extremity function

*Correspondence:
Waleed S. Mahmoud
waleeds306@yahoo.com
[1] Department of Health and Rehabilitation Sciences, College of Applied Medical Sciences, Prince Sattam bin Abdulaziz University, Al-Kharj, Saudi Arabia
[2] Department of Basic Sciences, Faculty of Physical Therapy, Cairo University, Giza, Egypt
[3] Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, Giza, Egypt
[4] Department of Biomechanics, Faculty of Physical Therapy, Cairo University, Giza, Egypt

Introduction

Osteitis pubis (OP) is a painful inflammatory lesion affecting the symphysis pubis and the surrounding soft tissues. This type of inflammation is characterized by chronicity which can be disabling if misdiagnosed or mismanaged [1]. Insidious onset of hip adductor pain and abdominal ache, along with pain in the symphysis pubis, is the chief complaint of OP patients [2]. Symphysis pubis pain may be unilateral or bilateral, aggravated by running, ball kicking, hip motion, and rectus abdominis eccentric force [3]. Continued activity with OP could develop progressive deterioration, which demands prolonged rehabilitation time. The incidence of OP has been described as high as 5–13% in football players [4]. Playing football involves sprinting, cutting, and kicking; these movements develop forces leading to severe biomechanical strain on the pubic symphysis and its surrounding soft tissues [5].

The most common mechanism of OP development is the repetitive traction forces placed on the pubic symphysis, especially in the presence of muscle imbalance in the lumbopelvic-hip region [6]. The abdominal and hip adductor muscle imbalance, which increases during growth and reaches its peak in adolescence, has been proposed as a causative factor in OP [7]. This muscle imbalance disrupts the equilibrium of forces around the symphysis pubis leading to chronic microtrauma [8].

Exercise-related unilateral lower abdominal and anterior groin pain that can extend to the perineum, inner thigh, and scrotum is the most common complaint of athletes. Resting helps to reduce pain primarily. However, even with the resolution of symptoms after a period of rest, the soreness frequently reappears when playing again. Pain can occur gradually, but 71% of athletes will relate the recurrence to a specific event like trunk hyperextension that increases tension in the pubic region [9]. The signs and symptoms of OP include (a) a subjective complaint of deep groin or lower abdominal pain; (b) pain that is aggravated with sport-specific movements like sprinting, kicking, and/or sit-ups and is relieved by rest; (c) palpable tenderness over the pubic ramus at the insertion of the rectus abdominus; (d) pain with resisted hip adduction at 0, 45, and/or 90° of hip flexion; and (e) pain with resisted abdominal curl-up [10].

Various treatment modalities for OP have been suggested. Those treatment modalities are generally based on specialists' experiences in clinical practice, not on results obtained from well-controlled, randomized clinical trials. The main conservative treatment methods include rest, activity reduction, ice, and anti-inflammatory medication. Therapeutic exercises have been shown as the most appropriate protocol for treating OP patients [10]. Hölmich et al. [11] compared the results of the therapeutic program (abdominal and hip muscle strength) with passive physiotherapy methods (stretching, TENS, and laser therapy) and reported positive outcomes for the therapeutic exercise group in terms of pain reduction and early return to sports activity. Stretching exercises and adductor or abdominal muscle strengthening programs were considered in many studies [12–14]. Also, Wollin and Lovell [15] suggested a program of gluteal and adductor muscle strength in addition to inner core stability exercises for treating OP patients.

It is crucial, and it is necessary to develop a new active physical therapy program correcting the muscle imbalance around the lumbopelvic-hip region and improving the neuromuscular control of the pelvis. In our suggested MAPT program, Jardí et al. [16] protocol was used as a baseline, with some modifications based on the recommendations of other previous studies [17–19]. Our program focused more on core training, plyometric exercise, high-intensity unilateral exercise, and eccentric exercise through four program stages. Also, the duration of each stage and the total time of each exercise were modified according to the athlete's progression.

Pain and muscle strength assessment is recommended in patients with OP [20]. Most evidence supports the strength loss correlation with OP [21]. So, the purpose of this randomized clinical trial was to compare the effect of a MAPT program with TPT on pain, hip and trunk muscle strengths, and lower extremity function in adolescent football players with OP.

Study design and setting

It was a randomized, single-blinded, parallel-group, clinical trial study. The study was approved by the Standing Committee of Bioethics Research (SCBR) (SCBR-072-2022), and all the methods were accomplished in agreement with the Declaration of Helsinki. Parental consent was obtained before participating in the study. All assessments and interventions were carried out at the outpatient clinic of the Health and Rehabilitation Sciences Department, College of Applied Medical Sciences, Prince Sattam bin Abdulaziz University, Al-Kharj City, Saudi Arabia in the period between June 2022 and January 2023. The following identifier has been assigned to the study on the Iranian Registry of Clinical Trials: IRCT20210909052421N3.

Patients' allocation

A total of 65 male beginner adolescent football players suffering from OP were eligible for this study. They were collected from football junior clubs in Al-Kharj City, Saudi Arabia. After considering the inclusive items, only 58 athletes were chosen. A flowchart of athletes' dropout and exclusion is shown in (Fig. 1). The players' ages ranged from 12 to 18 years, with a history of OP pain extended by more than 3 months. Sports medicine specialist and orthopedic surgeon examined all included players. The diagnosis was attained from the athletes' medical history, physical examination, and confirmed by MRI image. The athletes were included in the study if they have (1) unilateral or bilateral groin pain that increases with movements such as sprinting, cutting, and sit-ups and disappears by rest, (2) positive squeeze test [22], (3) a positive symphysis pubis stress tests [23], (4) pubic bone and pubic symphysis joint tenderness with palpation. While exclusion criteria were: femoral

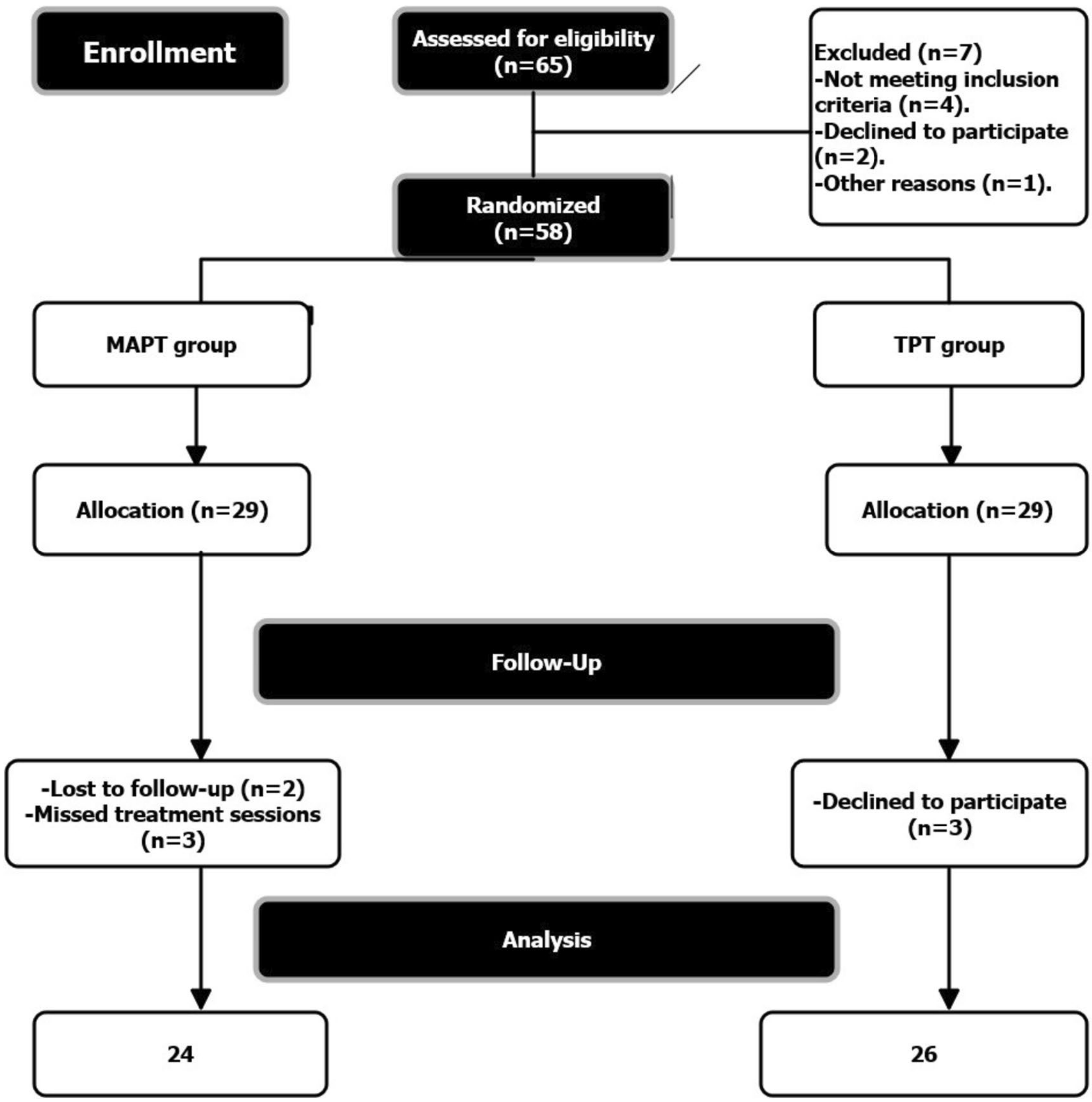

Fig. 1 Flowchart of athletes' dropouts and withdrawals

or inguinal hernia; chronic urinary tract disorder or prostatitis; disease, fracture of the pelvis or lower limbs preventing the participant from completing the treatment plan; genitofemoral entrapment or lower back pain; inability to follow the active physical training plan. Non-steroidal anti-inflammatory medicine was used during the study.

Randomization

After considering the inclusive items, each of the 58 athletes was given a number. A researcher who was not involved in the study performed the randomization using enclosed envelopes. Each envelope with a labeled card as either a MAPT or TPT group. Each athlete was requested to choose an enclosed envelope, 1:1 simple randomization. The examining researcher was not included in the randomization process and is still unaware of the group allocation. During their assessment, athletes were asked not to report their treatment allocation to the examiner.

Outcome measures

Visual analog scale (VAS), handheld dynamometer, and lower extremity functional scale (LEFS) were used to measure pain, hip and trunk muscle strength, and lower limb function, respectively, at baseline and 1 week after the end of the treatment period for both groups.

Assessment

Pain assessment

For the evaluation of pain severity, a VAS was used. Pain assessment was done during the performance of the Squeeze test. The examiner's clenched fist was positioned at the knee's level between the athlete's legs with nearly 45° of hip flexion and knee flexion with heels flat on the bed surface. The examiner asked the athlete to contract both adductor muscles maximally at the same time to squeeze the fist efficiently [5]. On the 10-point line of the VAS, the athlete was asked to mark his pain level. The pain that the participant experienced was recorded for data analysis. The Squeeze test has been shown to be reliable in measuring the presence of pain in patients suffering from OP [11].

Hip and trunk muscle strength assessment

The digital hand-held dynamometer (HHD) (Power Track II Commander, JTECH Medical, Salt Lake City, UT) and an evaluation table were used for assessment. It is a reliable and valid tool to evaluate isometric trunk and hip muscle strength [24]. Moreover, it is a cheap and easy tool to use, making it suitable for the clinical setting. Before testing, the HHD was calibrated, and all test procedures were standardized. All assessment was carried out by a physiotherapist with prior experience using this dynamometer.

Strength measurements were obtained from hip flexors, extensors, abductors, adductors, external, and internal rotators, and trunk flexors and extensors. Table 1 shows a detailed description of the tested muscles, the subject position, the physiotherapist position, and the dynamometer placement. All strength tests were isometric strength tests with selected test positions based on protocols frequently used in clinical settings [20]. The physiotherapist applied resistance in an exact position and the athlete being tested performed a 5-s maximal voluntary isometric contraction against the dynamometer.

The eight-muscle group test sequence was given in a randomized order between athletes at the first test session, and this test sequence was kept in the same order for the same athlete at the re-evaluation session. After the athletes were instructed in the procedures, they were asked to perform one sub-maximal isometric contraction into the physiotherapist's hand, to ensure that the correct action was performed. An extra practical trial, in the form of a maximal voluntary contraction against the dynamometer, was then introduced. The mean value of three consecutive measurements is presented. Every trial was followed by a 30-s rest time. The examiner's command was "Go ahead-push push-push and relax" [25]. Five minutes of rest were allowed in between the examination of each muscle group.

Functional assessment

The lower limb functional disability was measured using the lower extremity functional scale (LEFS), which has high test-retest reliability ($r = 0.94$) [26]. It includes questions about the ability of a person to perform daily activities, which can be used to determine a patient's functional disability of one or both lower limbs [27]. This scale has 20 tasks that range from 0 (indicating severe difficulty in performing the activity) to 4 (no difficulty) with the overall scores ranging from 0 (severe impairment) to 80 (no impairment).

Table 1 Athlete position, physiotherapist position with fixation, and placement of resistance for the muscles examined

Muscle group	Athlete position	physiotherapist's position and stabilization	Resistance
Hip flexors	Sitting, hips, and knees flexed at 90°	Front of the athlete	Anterior thigh just proximal to the patella border
Hip extensors	Prone, knee flexed to 45°	To the side of the athlete; stabilizes the pelvis	Posterior thigh just Proximal to femoral condyles
Hip abductors	Supine, hip, and knee extended	To the side of the athlete; stabilizes the pelvis	Lateral femoral condyle
Hip adductors	Supine, hip, and knee extended; noninvolved knee flexed	To the side of the athlete; stabilizes the pelvis	Medial femoral condyle
Hip external rotators	Sitting, hips and knees flexed at 90°	Front of the athlete	5 cm proximal to the Proximal edge of the medial malleolus
Hip internal rotators	Sitting, hips, and knees flexed at 90°	Front of the athlete	5 cm proximal to the Proximal edge of the lateral malleolus
Trunk flexors	Supine lying with hands placed behind head and neck	To the side of the athlete; hip and knee joints stabilized with straps	On the sternum, below the suprasternal notch
Trunk extensors	Prone lying position with hands placed behind head and neck	To the side of the athlete; hip and knee joints stabilized with strap	Posteriorly at T4 spinous process level

Intervention

Both groups received a 60-min treatment session, three sessions/week for 12 weeks. One minute of rest after each set of exercises was applied. The patients performed a 5-min warmup before the 60-min training session and a 5-min cooling down after the session. One of the research teams supervised all training sessions. During the study period, athletes in both treatment groups were approved not to seek any other treatment for groin pain. No athletic activity was permitted in either group during the treatment period.

Traditional physical therapy (TPT)

- The TPT group used basic physiotherapy methods [18] such as manual therapy, hydrotherapy, electrotherapy, and exercise therapy.
- Hydrocollator® of DJO, LLC., HotPac™ i of DJO, LLC. Comet® of Prestige Brands, Inc. was applied for 5 min and was placed on the painful groin area.
- Transcutaneous electrical nerve stimulation was provided for the painful area for 15 min. The apparatus used was a Biometer, Elpha 500, frequency 100 Hz, a pulse width of one, and a maximum of 15 mA.
- Five minutes of transverse friction massage was given on the painful area of adduct-tor-tendon attachment into the pubic bone from the supine lying position.
- Five-minute stretching exercise for each group of hip flexors from prone position, hip adductors from both supine and crook lying positions, and hamstring muscles from the standing position and through straight leg raising in supine position, with each stretch lasting for 30 s and total time 15 min for all muscle groups.
- Five-minute Laser therapy at the painful points of the adductor-tendon attachment to the pubic bone.
- Resistance exercises of the hip, pelvic floor, abdominal, and gluteal muscles using elastic bands were delivered. Five series of ten repetitions of each exercise for 15 min total.

Modified active physical therapy program (MAPT)

The MAPT in this study consists of four stages. Each stage lasts for 3 weeks.

Stage (1): Pain control and lumbopelvic stability

- Athletes received alternate cold and hot water baths for 15 min.
- Static exercises were given to the transversus abdominis, pelvic floor, multifidus, adductors, and abdominal muscles. Each isometric movement was performed for the 30 s, ten repetitions. Verbal encouragement and tactile feedback were emphasized with a total time of 30 min.
- Prolonged gentle stretching for hip flexors, hip extensors, and hip adductors was applied. The stretching was repeated three times, and each stretch lasted for 30 s with a total time of 15 min.

Stage (2): Strengthening and core stability exercises

- Resistance exercises of the hip, pelvic floor, abdominal, and gluteal muscles using elastic bands were delivered. Five series of ten repetitions of each exercise for 15 min total.
- Abdominal core exercises for the transversus abdominis and abdominal crunch exercises, gluteal bridges with and without elastic bands. Each contraction was held for the 30 s, with ten repetitions for 20 min total.
- Swiss ball exercises were used for the abdominal core and were held for the 30 s, ten repetitions for 10 min total.
- Eccentric adductors and abdominal strengthening exercises were applied. Holding for 30 s with a total time of 15 min.

Stage (3): Closed kinetic chain exercises and balance training

- Closed chain lower extremity exercises such as leg press, squat exercises, squats with a medicine ball between the legs, and side lunges were applied for 20 min.
- Balance training on the wobble board was delivered for 15 min.
- Single-leg balance exercise with knees and hips flexed was done for 15 min on a 360° balance board.
- Slide board skating was given with 1 min continuous work for 10 min.

Stage (4): Plyometrics and sport-specific training

- Running gradually increased with changes in pace and direction. The first run lasted 5 mins, increasing to 1 min per run with a total time of 15 min.
- Sprinting, cutting, and turning at a subjectively estimated 30% of maximum running speed for 15 min.
- Double leg plyometric exercise (double leg depth jump, double leg lateral cone jump) for 10 min.
- One leg plyometric exercise (single-leg forward hop, single-leg lateral cone jump) for 10 min.
- Gentle side kicking off the ball; for 10 min (the legs are alternated).

During the athlete's rehabilitation period, exaggeration of the groin pain was to be avoided. Fatigue during exercise performance was also to be avoided. Incorrect movement patterns or the initiation of muscle tremors are considered symptoms of fatigue and require athletes to rest [28].

Sample size calculation

The sample size was determined with the support of the G-Power software version 3.0.10 (University of Dusseldorf, Dusseldorf, Germany). Based on the effect size (d = 0.4) [16], we determined that 52 athletes would be needed to provide an 80% chance of correctly rejecting the null hypothesis and a probability of 0.05. We raised the sample to 58 athletes in anticipation of approximately 10% of athletes' withdrawals.

Statistical analyses

The statistical analyses were applied using the SPSS statistical package version 23 (Chicago, IL, USA). The outcome measures were presented as (mean ± SD). All data of the study's outcome measures were checked for normalization by the Shapiro-Wilk test. If normalization hasn't been met, Chi-square and Mann-Whitney U tests were used to analyze the differences in categorical and nonparametric data, respectively, between the groups. Changes in main parameter outcomes related to pain, hip and trunk muscle groups' strength, and functional test scores in participants of both groups were determined by paired and independent samples t-test within and between groups, respectively. The significance level was set at 0.05.

Results

According to the previously mentioned methodology, 50 athletes completed the study, and there were no passive or unwanted responses reported during the treatment period. The participants in both groups had practiced regularly with an overall attendance of 97% during the study period. There were no significant differences (p > 0.05) between the MAPT and the TPT groups in the baseline demographic and the clinical characteristics including age, height, body mass, BMI, preferred and affected leg, onset, and duration of symptoms, as depicted in Table 2.

Table 2 The demographic and baseline clinical characteristics data of both groups

	MAPT group (n = 24) Mean ± SD	TPT group (n = 26)	P
Age (years)	**15 ± 1.2**	**14.8 ± 2.1**	**0.77***
Height (cm)	159.3 ± 3.1	162 ± 4.1	0.08*
Body mass (kg)	57.8 ± 3	59.5 ± 2.9	0.2*
BMI (kg/m^2)	21.4 ± 1.3	21.9 ± 1.1	0.3*
	No. (%)		
Preferred leg			0.9**
Right	18(75%)	20 (77%)	
Left	4 (16.7%)	5(19%)	
Equal	2 (8.3%)	1 (4%)	
Affected limb			0.3**
Right	17 (71%)	20 (77%)	
Left	6 (25%)	4 (15%)	
Bilateral	1 (4%)	2 (8%)	
Onset of injury			0.9**
Acute	6 (25%)	8 (31%)	
Gradual	18 (75%)	18 (69%)	
	Median (IQR)		
Duration of symptoms (weeks)	11(11–14.5)	10.5 (9–13)	0.6†

Data are presented as mean ± SD

BMI body mass index, *MAPT* modified active physical therapy, *TPT* traditional physical therapy, *IQR* inter quartile range

*P** non-significant difference (Independent samples *t*-test)

*P*** non-significant difference (chi-square test)

P† non-significant difference (Mann-Whitney *U* test)

The football players in the MAPT group experienced a reduction of the pain level by 25.3% and they improved their hip extensors (43.5%) and trunk flexors (32.9%) extremely significantly. Besides, they gained a moderately significant increased muscle strength in hip flexors (21.5%), abductors (24.3%), adductors (24.7%), internal (26.9%) and external rotators (24.7%), trunk extensors (19%), and in their lower extremity function (16.9%). For the TPT group, the athletes improved highly significantly in the outcome of pain (63.2%), while the hip and trunk muscle groups' strength and the LEFS did not show any significant changes (p > 0.05) as shown in Table 3.

The analysis of between-group scores revealed that the strength of hip extensors and LEFS in the MAPT group achieved an extremely significant difference (p < 0.001) when compared with the TPT group, as given in (Fig. 2). The other variables: the strength of hip flexors, abductors, adductors, internal rotators, external rotators, and trunk flexors and extensors, improved significantly (p < 0.05) than the TPT group. However, there was a highly significant difference in the TPT group's pain score (p < 0.001) compared with the MAPT group, as shown in Fig. 2.

Discussion

OP is a difficult clinical problem due to little consensus on the proper treatment. It has been reported as a self-limiting condition that will eventually resolve with extended rest periods [28]. Recently, the use of an active training program aimed at enhancing lumbopelvic

Table 3 Differences of pain, lower limb and trunk muscle strength (N), and LEFS between MAPT and TPT groups

Variables		MAPT group ($n = 24$)			TPT group ($n = 26$)		
		Before (mean ± SD)	After (mean ± SD)	P	Before (mean ± SD)	After (mean ± SD)	P
VAS		7.5 ± 2.3	5.6 ± 1.2	0.02*	6.8 ± 1.2	2.5 ± 0.1[a]	< 0.001*
Muscle strength	Hip flexors	21.8 ± 5.04	26.5 ± 3.59[a]	0.01*	20.75 ± 2.44	22.5 ± 3.5	0.1
	Hip extensors	20.7 ± 2.36	29.7 ± 4.95[a]	< 0.001*	19.35± 1.92	21.6 ± 4	0.09
	Hip abductors	22.4 ± 4.38	27.85 ± 3.54[a]	0.003*	21.7 ± 5.94	23 ± 3.9	0.5
	Hip adductors	21.65 ± 2.56	27 ± 3.74[a]	0.007*	20.8 ± 1.64	23.1 ± 4.4	0.2
	Hip int rot	13 ± 2.5	16.5 ± 3.2[a]	0.007*	12.3 ± 2.9	13.5 ± 3.1	0.3
	Hip ext rot	15 ± 2.8	18.7 ± 4.4[a]	0.002*	13.6 ± 1	13.9 ± 2.2	0.6
	Trunk flexors	20.7 ± 4.3	27.5 ± 4.2[a]	0.001*	22.45 ± 2.65	23 ± 5.6	0.4
	Trunk extensors	22.6 ± 3.8	26.9 ± 3.3[a]	0.008*	22.33 ± 4.5	23.7 ± 3.51	0.4
LEFS		65 ± 5.8	76 ± 4.3[a]	0.0001*	62 ± 4.3	67 ± 5.2	0.06

MAPT modified active physical therapy, *TPT* traditional physical therapy, *N* Newton, *VAS* visual analog scale, *int rot* internal rotators, *ext rot* external rotators, *LEFS* lower extremity function score

* Significant difference within group (paired samples *t*-test)

[a] Significant differences between groups (Independent samples *t*-test)

stability has been suggested. The purpose of this study was to develop and evaluate the effect of a MAPT program on pain, hip and trunk muscle strength, and lower extremity function in adolescent football players with OP. In the present study, the statistical analyses revealed that both groups behaved differently to the two types of treatment. The players of the MAPT group responded more significantly in terms of their pain level, hip and trunk muscles' strength, and LEFS scores. However, the TPT group improved only their level of pain post-treatment. Comparing the post-treatment results between both groups revealed that MAPT was superior to the TPT in the outcomes of hip and trunk muscles' strength and lower extremity function, while the TPT was only superior in the measures of pain. The differences in the intervention protocol may account for the differences in results. In the current study, the improvement found in the MAPT group could be due to the application of different exercises and techniques, which were proved separately to improve outcomes in patients with OP. This program consisted of four stages; each stage concentrates on different aspects of the athlete's problem.

The first stage of the MAPT program was primarily designed to address the particular deficiencies in lumbopelvic-hip motor control and improve hip muscle flexibility. The main concern was to facilitate the athletes' awareness of their transversus abdominis in a stable supine position. Jansen et al. [4] reported that the transversus abdominis resting thickness is smaller in athletes suffering from OP and might need proper exercises. Hegedus et al. [27] also indicated that training for the transversus abdominis, pelvic floor, multifidus, adductors, and obliques might improve hip muscle strength and minimize pain and discomfort. Hip flexors, hip extensors, and hip adductors stretching exercises were prescribed in this stage to improve muscle flexibility and hip ROM; since the flexibility of these muscles was considered to be a risk factor for injuries in elite European football players [6].

The second stage of the MAPT program focused first on the continuous correction of the lumbopelvic-hip motor control of the athlete via core stability exercises. The purpose of the corrective exercises was to incorporate the athletes' transversus abdominis into unstable-based training through the use of a Swiss ball. The specific Swiss ball training was designed to encourage and strengthen the core muscles. Secondly, manual and resistance hip strengthening with the band was started. Schilders et al. [29] stated that the recruitment of motor units is larger when using elastic bands than when using a weight machine or free weights. Moreover, Via et al. [7] showed that core stability training and muscle strengthening exercises of the abdominal, adductor, flexor, and extensor hip muscles are successful for OP treatment. Finally, eccentric adductors and abdominal wall strengthening exercises were also applied in this stage. Eccentric abdominal and adductor muscle strength exercises were suggested to be included in the rehabilitation program developed for patients with OP [6].

In the third stage of MAPT, closed kinetic chain exercises were introduced. Closed kinetic chain exercises have become common in rehabilitation partly because they are considered to be closer to function than open kinetic chain exercises [14]. As known, the adductor muscle group's key action is defined as hip adduction in the open kinetic chain and stabilization of the lower limb

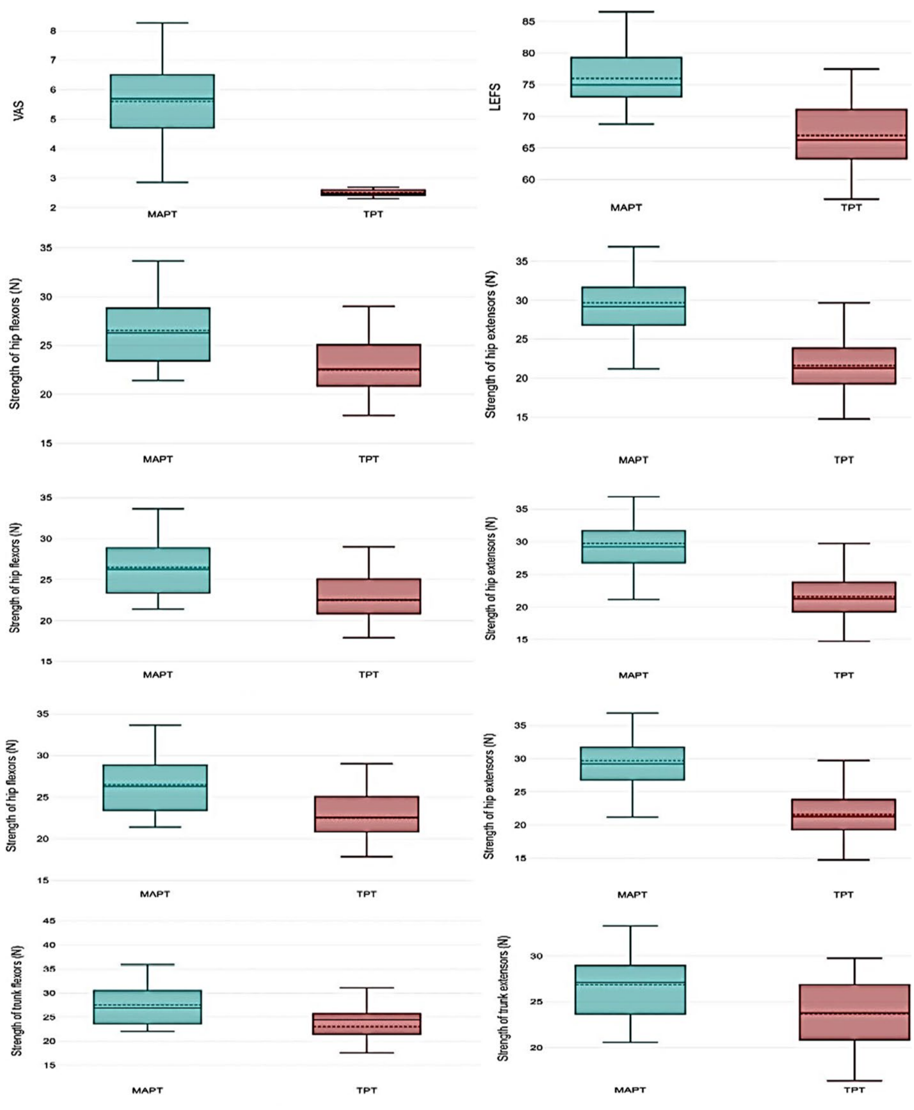

Fig. 2 Boxplots of outcome measures between two groups after the treatment intervention. MAPT: modified active physical therapy, TPT: traditional physical therapy, N: Newton

in the closed kinetic chain. Pandey et al. [30] suggested that the training program should incorporate both activation types. Therefore, we concentrated on closed kinetic chain exercises in this phase. Also, Balancing exercises using the wobble board as a support surface were incorporated during this stage. Heitkamp et al. [31] indicated in their study that balance training is not only beneficial for muscle strength gains but also for the correction of muscle imbalance.

The fourth stage of the program concentrated on functional integration and a return to full training. The advancement of lumbopelvic-hip motor control should be advanced and integrated into more functional tasks. Yousefzadeh et al. [17] emphasized that all athletes should have a defined running program that would teach them how to progressively increase running speed, duration, and other aspects appropriate for returning to sports. Hegedus et al. [27] stated that lower limb and total body anaerobic power, and frequent directional change are all aspects of a properly planned program for the athlete with OP trying to return to their sport.

In this study, we developed a modified version of the Jardí et al. [16] protocol and aimed to evaluate its effects on pain, strength, and function in adolescent football players with OP injury. Our program stages involve more concentration on closed kinetic chain exercises, balance training, and plyometric exercises. The suggested limitations of the Jardí et al. [16] protocol and associated suggestions are defined as follows: (a) patients were not allowed to stretch the adductor muscles in their study. Since stretching is a standard exercise recommended to realign the collagen fibers during muscle repair [5], we suggest that stretching should be a part of our program. (b) Changes in trunk muscle function and core muscle weakness have been proposed to be factors associated with OP in athletes [22]. We suggested that there should be more concentration on core exercises in the training program. (c) Besides, in the current study, plyometric exercises were applied at the last stage. The effects of plyometric exercises on lower limb strength have been reported in many research works. In a recent meta-analysis, a conclusion was made that plyometrics improved one repetition maximum estimated in isometric or slow velocity contractions in leg muscles [32], (d) the contrary to Jardi's protocol; another unique feature of the training described in this study is the use of high-intensity unilateral exercises, and they were also done in a lateral direction, (e) Eccentric exercises were also highlighted as being of great benefit in the treatment of OP [6]. Thus, eccentric abdominal and adductor muscle-strengthening were added to our program.

Regarding the TPT group, the results revealed that athletes improved significantly in the outcome of pain ($p < 0.001$); this improvement might be attributed to the utilization of pain inhibitory modalities such as transcutaneous electrical nerve stimulation and laser therapy, in contrast to the MAPT group who received only alternate cold and hot water baths. In the MAPT group, the pain was initially a limiting factor to the exercise performance, but the groin pain decreased as muscle control and strength improved. On the other hand, all muscle group's strength and LEFS did not show any significant changes in the TPT group. These results might be due to the use of passive physiotherapy modalities (like electrotherapy and lower limb stretching). These findings were in line with Hölmich et al. [11] who found that the results of an active training program were much better than a passive program. Their study reported that 79% of the athletes managed with active training were able to return to pre-injury level, compared to 14% of athletes treated with passive training after a 7-month follow-up. The passive program was composed of manual therapy and electrotherapy, while the active program aimed to improve the athlete's lumbopelvic stability.

A systematic review evaluating muscle strength found that reduced muscle strength and/or muscle ratios were predictive of groin strain injury in OP [21]. It may be that the adductor strength (i.e., concentric and eccentric), as well as the adductor-to-abductor strength ratio, are important factors for avoiding injury [33]. Isometric hip strength plays a significant role in the clinical evaluation of football players with OP injuries. Clinically, isometric tests are usually favored. The benefits of isometric testing are that it creates less stress on the musculoskeletal system and thereby minimizes the risk of injury [25].

In our study, the post-treatment results between the two groups revealed that MAPT was superior to the TPT in the outcomes of hip and trunk muscles' strength as the MAPT program emphasized greatly on lumbopelvic hip muscle strength. This increased hip and trunk muscles strength in the current study may be related to the improvement in the LEFS scores. This comes in line with what was stated by Pandey et al. [30] the training programs aiming to increase muscle strength have been found to produce the most significant amount of functional improvement.

Strength, limitations, and future work

This study's strengths were described as follows: it is the first study to examine the strength outcome of all the hip and trunk muscle groups via an active training program. The program stages were also novel regarding incorporating closed kinetic chain exercises, balance training, and plyometric exercises. While the study limitations were outlined as follows: firstly, the absence of long-term follow-up. Secondly, the study included only males which might affect generalizability, and the obtained results should be interpreted cautiously. Our selection of males was attributed to the prevention of muscle strength discrepancies between males and females and possible false explanations of results that might occur. Regarding future research, we recommend a follow-up study of up to 6 or 12 months to confirm our speculation that improvement in pain, hip and trunk muscle strength, and lower limb function together, not every variable alone, are indicators of complete resolve of OP. Moreover, larger randomized controlled and clinical trials with long-term follow-ups are required and recommended to clarify the effectiveness of active OP treatment.

Conclusions

Based on the study results, MAPT could be recommended strongly in the rehabilitation of Osteitis pubis in adolescent football players. The MAPT program improved the functional abilities of OP patients as a result of reduced pain levels and increased hip and trunk muscle strength.

Abbreviations

OP	Osteitis pubis
MAPT	Modified Active Physical Therapy program
TPT	Traditional physical therapy

HHD Hand-held dynamometer
LEFS Lower extremity functional scale
SCBR Standing Committee of Bioethics Research
VAS Visual analog scale
BMI Body mass index
IQR Inter quartile range
ROM Range of motion

Acknowledgements
The authors of this study expressed their thanks to athletes for their support and help in accomplishing this work.

Authors' contributions
All authors read and approved the final manuscript.

Funding
The study was self-funded by the authors.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Standing Committee of Bioethics Research (SCBR) (SCBR-072-2022), and all the methods were accomplished in agreement with the Declaration of Helsinki. Parental consent was obtained before participating in the study. All assessments and interventions were carried out at the outpatient clinic of the Health and Rehabilitation Sciences Department, College of Applied Medical Sciences, Prince Sattam bin Abdulaziz University, Al-kharj city, Saudi Arabia in the period between June 2022 to January 2023.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no conflict of interest.

Received: 25 October 2023 Accepted: 4 December 2023
Published online: 31 January 2024

References

1. Mohammad WS, Abdelraouf OR, Elhafez SM, Abdel-Aziem AA, Nassif NS. Isokinetic imbalance of hip muscles in soccer players with osteitis pubis. J Sports Sci. 2014;32:934–9.
2. Elattar O, Choi H-R, Dills VD, Busconi B. Groin injuries (athletic pubalgia) and return to play. Sports Health. 2016;8:313–23.
3. Kachingwe AF, Grech S. Proposed algorithm for the management of athletes with athletic pubalgia (sports hernia): a case series. J Orthop Sport Phys Ther. 2008;38:768–81.
4. Jansen J, Weir A, Dénis R, Mens J, Backx F, Stam H. Resting thickness of transversus abdominis is decreased in athletes with longstanding adduction-related groin pain. Man Ther. 2010;15:200–5.
5. Verrall GM, Slavotinek JP, Fon GT, Barnes PG. Outcome of conservative management of athletic chronic groin injury diagnosed as pubic bone stress injury. Am J Sports Med. 2007;35:467–74.
6. Mohammad WS, Elsais WME. Abdominal/adductor strength imbalance in soccer players with osteitis pubis. J Mens health. 2018;14:e33–40.
7. Via AG, Frizziero A, Finotti P, Oliva F, Randelli F, Maffulli N. Management of osteitis pubis in athletes: rehabilitation and return to training–a review of the most recent literature. Open Access J Sport Med. 2018;10:1–10.
8. Rodriguez C, Miguel A, Lima H, Heinrichs K. Osteitis pubis syndrome in the professional soccer athlete: a case report. J Athl Train. 2001;36:437.
9. Brewster BD, Welch Bacon CE, Valovich McLeod TC, Short S. Management and outcomes of chronic athletic groin pain: a comparison of conservative and surgical intervention. Athl Train Sport Heal Care. 2019;11:60–2.
10. Koutserimpas C, Ioannidis A, Konstantinidis MK, Makris MC, Antonakopoulos F, Mazarakis A, et al. Insights in clinical examination and diagnosis of Athletic Pubalgia. G Chir. 2020;41:131–5.
11. Hölmich P, Uhrskou P, Ulnits L, Kanstrup I-L, Nielsen MB, Bjerg AM, et al. Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. Lancet. 1999;353:439–43.
12. Weir A, Jansen J, van Keulen J, Mens J, Backx F, Stam H. Short and mid-term results of a comprehensive treatment program for longstanding adductor-related groin pain in athletes: a case series. Phys Ther Sport. 2010;11:99–103.
13. Almeida MO, Silva BNG, Andriolo RB, Atallah ÁN, Peccin MS. Conservative interventions for treating exercise-related musculotendinous, ligamentous and osseous groin pain. Cochrane database Syst Rev. 2013;2013(6):CD009565.
14. Quinn A. Hip and groin pain: physiotherapy and rehabilitation issues. Open Sport Med J. 2014;4:93–107.
15. Wollin M, Lovell G. Osteitis pubis in four young football players: a case series demonstrating successful rehabilitation. Phys Ther Sport. 2006;7:153–60.
16. Jardí J, Rodas G, Pedret C, Til L, Cusí M, Malliaropoulos N, et al. Osteitis pubis: can early return to elite competition be contemplated? Transl Med UniSa. 2014;10:52.
17. Yousefzadeh A, Shadmehr A, Olyaei GR, Naseri N, Khazaeipour Z. The Effect of Therapeutic Exercise on Long-Standing Adductor-Related Groin Pain in Athletes: Modified Hölmich Protocol. Rehabil Res Pract. 2018;2018:8146819.
18. Abouelnaga WA, Aboelnour NH. Effectiveness of active rehabilitation program on sports hernia: randomized control trial. Ann Rehabil Med. 2019;43:305–13.
19. Slavotinek JP, Verrall GM, Fon GT, Sage MR. Groin pain in footballers: the association between preseason clinical and pubic bone magnetic resonance imaging findings and athlete outcome. Am J Sports Med. 2005;33:894–9.
20. Malliaras P, Hogan A, Nawrocki A, Crossley K, Schache A. Hip flexibility and strength measures: reliability and association with athletic groin pain. Br J Sports Med. 2009;43:739–44.
21. Wörner T, Thorborg K, Eek F. Five-second squeeze testing in 333 professional and semiprofessional male ice hockey players: how are hip and groin symptoms, strength, and sporting function related? Orthop J Sport Med. 2019;7:2325967119825858.
22. Hölmich P, Hölmich LR, Bjerg AM. Clinical examination of athletes with groin pain: an intraobserver and interobserver reliability study. Br J Sports Med. 2004;38:446–51.
23. Hogan A, Lovell G. Pubic symphysis stress tests and rehabilitation of osteitis pubis. Sci Footb IV. 2001:207-211.
24. De Blaiser C, De Ridder R, Willems T, Danneels L, Roosen P. Reliability and validity of trunk flexor and trunk extensor strength measurements using handheld dynamometry in a healthy athletic population. Phys Ther Sport. 2018;34:180–6.
25. Thorborg K, Petersen J, Magnusson SP, Hölmich P. Clinical assessment of hip strength using a hand-held dynamometer is reliable. Scand J Med Sci Sport. 2010;20:493–501.
26. Yeung TSM, Wessel J, Stratford P, Macdermid J. Reliability validity, and responsiveness of the lower extremity functional scale for inpatients of an orthopaedic rehabilitation ward. J Orthop Sports Phys Ther. 2009;39:468–77.
27. Hegedus EJ, Stern B, Reiman MP, Tarara D, Wright AA. A suggested model for physical examination and conservative treatment of athletic pubalgia. Phys Ther Sport. 2013;14:3–16.
28. Jarosz BS. Individualized multi-modal management of osteitis pubis in an Australian Rules footballer. J Chiropr Med. 2011;10:105–10.
29. Schilders E, Bismil Q, Robinson P, O'Connor PJ, Gibbon WW, Talbot JC. Adductor-related groin pain in competitive athletes: role of adductor enthesis, magnetic resonance imaging, and entheseal pubic cleft injections. JBJS. 2007;89:2173–8.
30. Pandey RS, Yadav T, Rayjade A, Chintamani R, Kolhatkar A. Effectiveness of open kinematic chain exercises and closed kinematic chain exercises in adductor groin pain in recreational football players. Indian J Forensic Med Toxicol. 2020;14:276–82.

31. Heitkamp HC, Horstmann T, Mayer F, Weller J, Dickhuth HH. Gain in strength and muscular balance after balance training. Int J Sports Med. 2001;22:285–90.
32. de Villarreal ESS, Requena B, Newton RU. Does plyometric training improve strength performance? A meta-analysis J Sci Med Sport. 2010;13:513–22.
33. Maffey L, Emery C. What are the risk factors for groin strain injury in sport? Sport Med. 2007;37:881–94.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.