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CASE REPORT

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The effect of regular exercises using a specially designed arc support on pes planus feet: a case presentation

Mahmut Acak, Mehmet Fatih Korkmaz

BESYO, Inonu University, Malatya, Turkey
Inonu University School of Medicine, Department of Orthopaedics and Traumatology, Malatya, Turkey

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Abstract
This study was conducted to assess the effect of regular exercises done with specially designed insoles on pes planus. Pes planus occurs when the height of the medial longitudinal arch of the foot decreases or completely collapses. An 18 month of exercise plan was conducted on 1 year old male with rigid pes planus. In order to determine the development of the study on the participant, height, body weight, body fat percentage, 30 m, 60 m sprint tests, vertical jump test, a 12-minute Cooper test, flexibility tests have been applied and podoscopy imaging techniques were used to detect pes planus. The tests were carried out two times, one before the study (pre-test) and at the end of it (post-test). A positive difference between the tests and the podoscope images showing that the arches of the feet came to be in normal sizes, prove a positive outcome. While the arches of the soles of his feet were measured to be zero in the first measurement, the height became 16 mm in the final measuring. It could be considered that the pes planus is eliminated as the participant now walk and run without pain and the soles of his feet seem normal. These positive developments have increased the participants' quality of life.

Keywords: Pes planus, exercise, shoe insole, pool exercises, in house exercises

Introduction

Soles of the feet play a significant role in motor activities like walking, running and supporting the body. The anatomical harmony between foot muscles, bones and the joints ensures the happening of different activities [1]. The structure of the human foot skeleton has an arc, there is a conspicuous concavity in the soles [2,3]. There are three curves in the foot, namely arcus longitudinalis pars medialis, arcus longitudinalis pars lateralis and arcus transversalis [4-6]. Foot arches support the body weight and they are used to push the body forward and absorb shocks during movement [5,7]. Flexible curves allow the feet to adapt to the weight changes and surfaces. [5,8]. When the curves are deformed, the transfer of the weight to the tip of the feet is not possible during walking. Tedious and inefficient, this condition leads to muscle fatigue and pain. Curvature impairment, in time, causes posture disorders and back and leg pain [9].

There are three main elements that protect the arc of the foot. These are: the shape of the arc, strong ligaments and muscle tone [5,10]. Although the elements supporting the arc do not move, the convenience of the articular surfaces of the combined bone structure helps to stop the collapse of the arc. Beyond this, the support depends on the strength of plantar ligaments and leg muscles [5,11]. Therefore, the strength of leg muscles is very important. The structure of the foot arc could deteriorate after birth, or it could also be a birth defect. For example: Individuals with Fragile X Syndrome and those born with Down syndrome are born with pes planus [12]. The pes planus that is seen in adults could form when plantar fascia is overloaded, due to overweight, systemic diseases, neurological diseases and muscle imbalance, as a result of standing up for a long time due to work and bad choice of shoes.

Pes planus is the deformity that is formed when the medial longitudinal arc of the foot looses its height or collapses completely [13,14]. Pes planus has two clinical forms, namely Flexible and rigid pes planus. In the physical evaluation, these two can be separated by dynamically applying weight to the feet. Flexible pes planus, can be seen mainly bilateral in adults but also can be seen as unilateral [15]. It is usually seen with short and contracted achilles, muscle-tendon [16].

The adverse effects of having pes planus for individuals' lives and activities have been well defined [17,18]. In the literature, as a result of pes planus in adults, pain while standing up, tenderness, stiffness, antalgesic walk, imbalance in the leg muscles, strained ligaments and walking fatigue and stress fractures can occur [19]. In addition to these, such changes can also trigger walking disorders, foot, thighs and lower back pain; thus adversely

***Corresponding Author:** Mehmet Fatih Korkmaz, Department of Orthopaedics and Traumatology, Inonu University School of Medicine, Malatya, Turkey
E-mail: fatih.korkmaz@inonu.edu.tr

affecting daily activities such sports, standing up for a long time and walking, and causing negative effects on the physical fitness and quality of life [13,15,17,18,20].

The frequency of pes planus is mentioned in some resources as 7-22% [21,22] and in others as 1.1%, even up to 43.2% [23]. Even the least of these figures show that it is a serious public health issue. Along with that of a passive lifestyle of individuals with pes planus, cardiovascular diseases, obesity, diabetes and similar health problems are triggered. And it is also a fact that each health problem burdens its bearer with huge economic losses.

The purpose and importance of the research: As for the treatments of pes planus, there are multiple options like surgery, insoles, and physical therapy. However, no protocol is specified for the exercises used in the treatment of pes planus. The surface of the ground the exercises are made, the speed and distance are not specified [24]. The aim of this study was prove the efficacy of insoles with regular exercises in the conservative treatment of pes planus and clarify the exercise protocol.

Material and Methods

Case history: The participant is undergoing pes planus treatment since the age of 6 controlled by an orthopedic doctor. He had used orthopedic shoes and orthopedic insoles but still had a low quality of life in childhood. As with the participant's weight gain, he was referred to several types of sports by his family, and finally started swimming because of the leg pain he suffered. As his swimming friends are interested in biathlon and modern pentathlon, he also got interested and wanted to do this sport. He participated in running but couldn't keep up because of pain. In this stage, the researcher was contacted. When the study began, the participant was a male and 16 years old. The study lasted 18 months (see table 1 for work program).

Measurements done in the study

Oral and written information regarding the aim of the study and the practices that will be done, has been given to the family and the participant. Before the study has begun, the family and the participant has signed a parental consent form. The participants sole images were obtained by using podoscope system (Podoscope Lux - Germany) and he was walked on wet surface [25]. As to determine the development of the study on the participant, the following tests were done: height, weight, body fat percentage, 30 m, 60 m sprint test, vertical jump test, a 12-minute Cooper test and flexibility test. Tests were done before (pre-test) and after (post-test) the study. Further information on the applied test are presented below.

General Anthropometric Measurements

For general anthropometric measurements, the individual's height has been measured using meter, barefoot on a flat surface, as the vertical distance between the tip of the heels to the top of the head, in centimeters (cm). Body weight was measured only in underwear, while barefoot with a scale, in kilograms (kg). Leg diameters and leg length were recorded in cm. The arc height of the soles has been measured with calipers in millimeters (mm).

In order to determine the body fat index of the participant, skinfold caliper of Holta brand was used. Measurements were done as the athlete is standing upright from the right biceps, triceps, subscapularis, abdominal, pectoral, suprailiac and quadriceps areas. Anthropometric measurements were observed in all protocols. The obtained values were recorded in mm. The resulting subcutaneous fat measurements were calculated according to the Lange formula. Lange's formula is; body fat ratio = fat ratio sum taken from six regions of the body (Chest + Biceps + Triceps + Supra Iliac + Subscapula + Upper leg) multiplied with 0.097 + 3.64 [26].

30 m Speed test

In a stadium, 30 m running surface was determined, and after 10 minutes warm-up participant was held waiting bending over, and standing 1 m away from the first photocell. Once the start sign was given, the time was measured for the participant to pass the photocell in the 30 m finish line in seconds and milliseconds. Participant was given three chances to run the 30 m and the best score was recorded.

60 m Speed test

In a stadium, 60 m running surface was determined, and after 10 minutes warm-up participant was held waiting bending over, and standing 1 m away from the first photocell. Once the start sign was given, the time was measured for the participant to pass the photocell in the 60 m finish line in seconds and milliseconds. Participant was given three chances to run the 60 m and the best score was recorded.

Vertical jump test

For the vertical jump test, 10 minutes of warm up time was given. This test is the measurement of the distance between the participant's finger-tip, arm stretched out standing near a wall, and again the tip of his finger, after making a full jump ahead. The tools needed are a meter and a piece of chalk. The application of the test is as follows; the participant, at first, stood sideways to the wall, one arm stretched up and leaned towards the wall, the furthest tip of the furthest touching finger is marked with the chalk. Later on, the middle finger of the participant was immersed in chalk powder, and he was made to stand 25 cm off the wall for a comfortable jump. He was asked to jump, with the help of his hands, as high as possible and touch his middle finger as high as possible, to the wall. The distance in between was registered in cm. This was done twice and the best score was recorded [27].

Cooper Test

This is a test done to monitor the development and follow up of aerobic endurance of athletes. Required Materials: 400 m running track - marked every 100 m and a stopwatch [28]. Application of the test; Athlete warmed up for 15 min. Athlete covered as much distance in 12 minutes as he could, and the researcher, once the time is up, measured the distance, taking into account the latest 100 m sign from where the athlete had stopped.

Flexibility (Sit-reach) Test

The platform's dimensions are length 35 cm, width 45 cm and height 32 cm; and the upper surface dimensions are length 55 cm, width 45 cm [29]. After 10 min warm-up, in the sit and reach test, participant was asked to sit on the ground, and put his bare feet against the test platform. Participant then was asked to lean forward, without bending his knees, as further as possible, with his hands stretched and one he reached the furthest, he was asked to hold still for 1 to 2 seconds before the measurement was taken, in cm. This application was repeated twice and the best result was recorded.

Design and Use of shoe insole

At first, the height of foot arches of 30 children with similar characteristics with the participant, and those who do not have pes planus, were recorded. With this data, it was determined that the average foot arc height shall be 16 mm. At first, this height was taken into account in the production of the insole. However, when looked at the achilles tendon of the participant, it was seen that it wasn't making a 90 degree angle to the ground. Thus, the height of the insole was increased so that the participant's achilles tendons make a 90 degree angle to the ground, when looked from behind. This particular arc insole height was 25 mm. 22 mm of this insole was made of compressed solid rubber, and 3 mm of soft silicon surface. No such insole previously manufactured for pes planus was that high. (Current steel insole was 18 mm and silicon arc support insole was 15 mm). The insole was only made to fit for the arc of the foot, which is the inside mid-section of the foot forming the curvature. Thus, while supporting the foot arc, the mobility of the feet is also protected. The participant was given three sports shoes with same properties, with these insoles inserted in, with the same sizes. One shoe was for the street, one for sports activities, and one for in the house (in Turkish culture, outside shoes are not worn inside). So the arc of the foot sole was supported constantly. The shoes were only taken off for sleeping, some of the in house exercises and the swimming pool exercises.

Exercises

Exercises were made in three different methods. First were the pool exercises, second were the fitness saloon exercises and third were daily in house workouts.

1. Pool exercises: The indoor swimming pool of Inonu University, with 16.30 m of length, 6.30 m of width and 1.30 m of depth was used for the exercises, 4 days a week (Tuesday, Thursday, Saturday and Sunday) for the first 4 months of the study, and 3 days a week for the rest (Tuesday, Thursday and Saturday).

2. Fitness saloon exercises: In the first 4 months of these exercises, the frequency was 2 days a week (Monday and Friday), and in other months, 3 days a week (Monday, Wednesday and Friday). The exercises are done in the fitness saloon of Inonu University School of physical education and sports department. In here, the participant was asked to perform stationary cycling with the shoes with insoles, as a warm up. The maximum amount that the participant could lift was measured [30,31]. This amount was checked every 6 weeks and the percentage of the maximum amount was taken and used in forming the new exercise program. The exercises performed included machine row, lumbar extension, leg extension, barbell squat, leg press, dumbbell lunge, cable hip abductions, lying leg curl, standing calf raise, and seated calf raise. Detailed program is given in the table exercise.

3. In house exercises: Participant wore the specially crafted insole shoes at home. However, he did some exercises bare footed. These are; rolling a soda bottle with the soles of the feet, shrinking newspapers with toes, picking and lifting small objects toes and stretching achilles tendon. These indoor exercises are done wearing the specially crafted shoes, after getting up every morning and before bed time at the evening. These exercises started; stepping on the sides of the feet, walking on toes and heels frequently repeated two times in a 5 m area and increased in frequency. When pain was developed, the exercises were interrupted. The feet of the participant were constantly checked for deformities due to elevated soles over sill. All studies were committed to the daily work charts. Detailed program of exercise training studies are given in the table below.

Data analysis

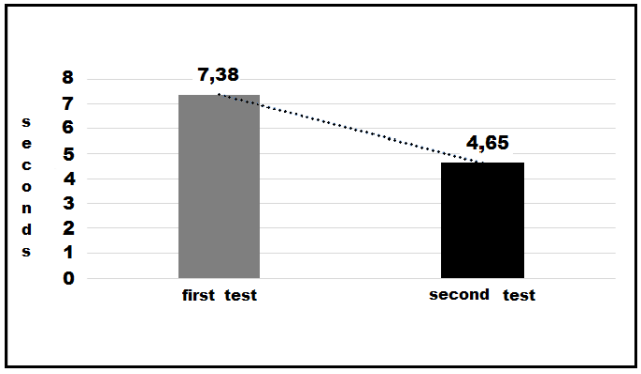
Because this study is carried out with a single participant, only the descriptive statistics (kg., Cm., Mm., Sec., Meters, percent) are included. For this purpose, a measurement tool / method with pre-test and post-test values obtained are presented in comparison with chart.

Table 1. Types, content, duration and purpose of exercises performed in this study.

Month	Type of exercise	Content	Duration	Purpose
1. month	Pool exercises (4 days a week)	Walking in exercise pool, jumping to the sides and leaps	30 min.	Increasing leg strength
	Fitness exercises (2 days a week)	Spinning with the specially manufactured shoes	3X5 min.	Developing overall durability.
	In house exercises (Day / night, every day).	Rolling a soda bottle with the soles of the feet, shrinking newspapers with toes, picking and lifting small objects using toes and stretching leg exercises.	10+10 min.	Increasing the depth of arc of the soles of the feet, strengthening and increasing the flexibility of the leg muscles.
2. month	Pool exercises (4 days a week)	Walking in exercise pool, jumping to the sides and leaps	30 min.	Increasing overall durability and strength.
	Cycling + Exercises using body weight (Twice a week).	Spinning with the specially manufactured shoes. The effort to increase the overall body strength by using the body's own weight	3x6 min. 20 min.	Overall durability. Overall strength work out.
	In house exercises (Every day).	Increasing the efforts in the first month. Walking exercises while stepping on the sides of the feet, on toes and heels.	15+15 min.	Increasing the depth of arc of the soles of the feet, strengthening and increasing the flexibility of the leg muscles.
3. month	Pool exercises (4 days a week)	Walking in exercise pool, running and leg strengthening moves, jumping to the sides.	35 min.	Increasing overall durability and strength.
	Fitness exercises (2 days a week)	Stationary spinning rides with specially crafted footwear. 8, 10, 12 repeats of 2 series rapid weight lifting exercises with 40% of the maximum lifted amount. The exercises include: machine row, lumbar extension, leg extension, barbell squat, leg press, dumbbell lunge, cable hip abductions, lying leg curl, standing calf raise, and seated calf raise moves.	3x8 min. 25 min.	Overall durability. Overall strength work out.
	In house exercises (Day / night, every day).	The frequency of exercises done in 2 months has been increased	15+15 min.	Increasing the depth of arc of the soles of the feet, strengthening and increasing the flexibility of the leg muscles.
4. month	Pool exercises (4 days a week)	The frequency of exercises done in 3 months has been increased	40 min.	Increasing overall durability and strength.
	Fitness exercises (2 days a week)	8, 10, 12 repeats of 2 series rapid weight lifting exercises with 50% of the maximum lifted amount, which was done in the 3rd month.	3x10min. 30 min.	Overall durability. Overall strength work out.
	In house exercises (Every day).	The frequency of exercises done in 3 months has been increased.	15+15 min.	Increasing the depth of arc of the soles of the feet, strengthening and increasing the flexibility of the leg muscles.
5, 6, 7, 8, 9. months	Pool exercises (3 days a week)	The frequency of exercises done in 4 months has been increased	40 min.	Increasing overall durability and strength.
	Fitness exercises (3 days a week)	Treadmill exercises of 2 min run, 2 min walk, 4 min run, 4 min walk, 6 min run, 6 min walk, 8 min run, 8 min walk have been increased in frequency 1 minute in each month.. 8, 10, 12 repeats of 2 series rapid weight lifting exercises with 60-70% of the maximum lifted amount, which was done in the 4th month.	40-60 min. 60min.	Overall durability. Overall strength work out.
	In house exercises (Day / night, every day).	The frequency of exercises done in 4 months has been increased	20+20 min.	Increasing the depth of arc of the soles of the feet, strengthening and increasing the flexibility of the leg muscles.
10, 11, 12, 13, 14. months	Pool exercises (3 days a week)	The frequency of exercises done in 9 months has been increased	45 min.	Increasing overall durability and strength.
	Fitness exercises (3 days a week)	The tempo of the running exercises made in 9 months has been increased.. 8, 10, 12 repeats of 3 series rapid weight lifting exercises with 70% of the maximum lifted amount, which was done in the 9th month.	60 min.	Overall durability. Overall strength work out.
	In house exercises (Day / night, every day).	The frequency of exercises done in 9 months has been increased	20+20 min.	Increasing the depth of arc of the soles of the feet, strengthening and increasing the flexibility of the leg muscles.
14, 15, 16, 17, 18. months	Pool exercises (3 days a week)	The frequency of exercises done in 14 months has been increased	50 min.	Increasing overall durability and strength.
	Fitness exercises (3 days a week)	8, 10, 12 repeats of 3 series 2 sets of rapid weight lifting exercises with 70% of the maximum lifted amount, which was done in the 14th month..	60 min.	Overall durability. Overall strength work out.
	In house exercises (Day / night, every day).	The frequency of exercises done in 4 months has been increased	20+20 min.	Increasing the depth of arc of the soles of the feet, strengthening and increasing the flexibility of the leg muscles.

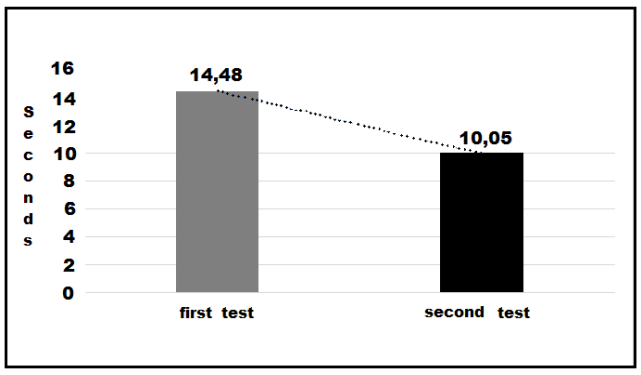
Results

The height of the participant was measured as 160 cm, at the beginning of the study, and became 167 cm at the end of it. In the beginning of the study, his weight was 58 kg and it became 57 kg at the end. Arc height of the soles of the feet were 0 before the study but at the end, it was measured as 16 mm. Fat ratio at the beginning was 15.42 and at the end it was measured as 8.87.



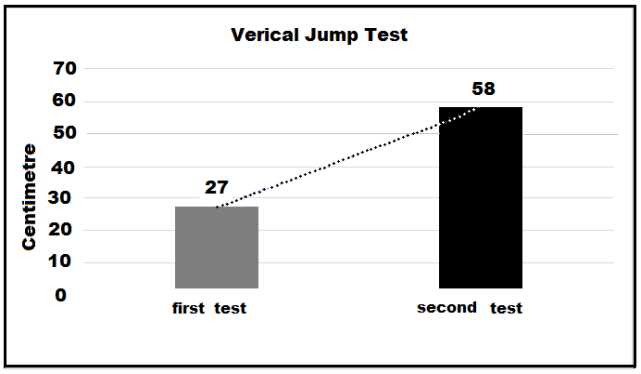
Graph 1. Results of the 30 m speed test

The first measurement of the 30 m speed test was 7.38 seconds, the second was 4.65 seconds.



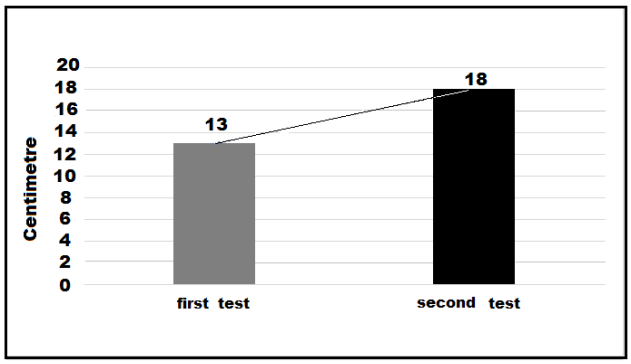
Graph 2. Results of the 60 m speed test

The first measurement of the 60 m speed test was 14.48 seconds, the second was 10.05 seconds.



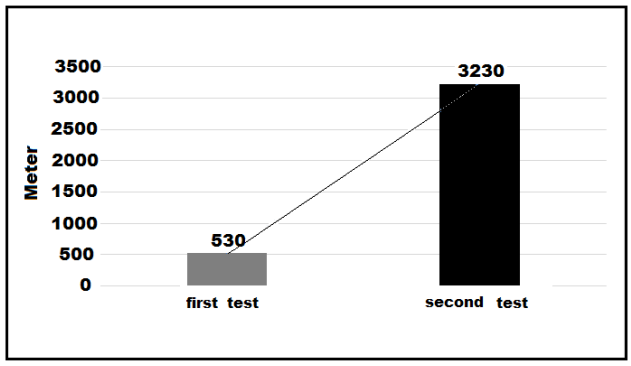
Graph 3. Vertical jump test results

The result of the first vertical jump test was 27 cm, the second was 58 cm.



Graph 4. Flexibility test results

The result of the first flexibility test was 13 cm, the second was 18 cm**.**



Graph 5. Cooper test results

In the first measurement of the Cooper test, the participant ran for 530 meters but had to stop because of fatigue. In the second test, he ran 3230 meters in 12 minutes.

Following figures show podoscope images taken 18 months apart. Figure 1 shows the initial image of the participant's soles before the study, and figure 2 shows the soles of the participant, after the study is over.

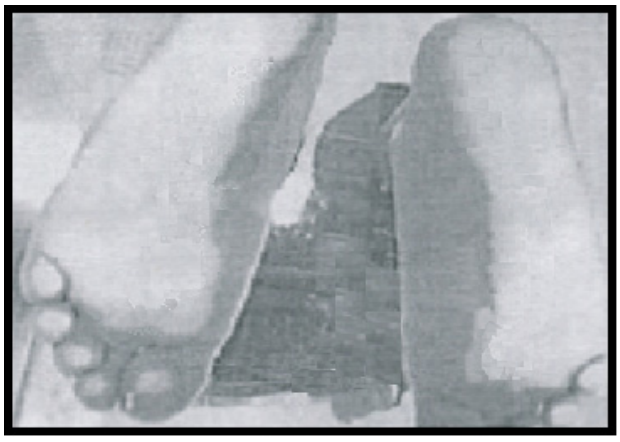


Figure 1. Initial podoscope image

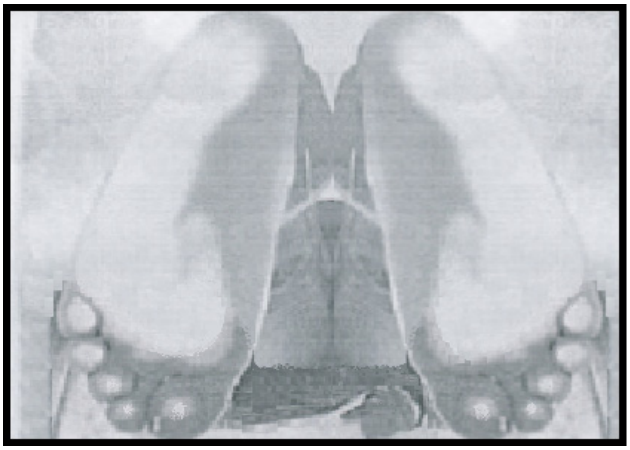


Figure 2. End study podoscope image

Discussion

It was aimed to obtain the quality of the values belonging to the study and it was decided if the study shall be kept going or not, and it was tried to draw attention to the importance of this study, for the future studies.

The individual's body fat ratio was decreased with the running exercises. He completed the 30 m speed test %36.99 faster and 60 m speed test %30.59 faster after the study is compete. The participant couldn't complete the first Cooper test, running only 530 meters before giving up. However, in the second measurement, he ran 3230 meters in 12 minutes. This is a development of %509.43, which is a major difference. In the vertical jump test, the difference between two measurements is %114.81. In the flexibility test, it is %38.46. Sarı (1995), Rose (1992) and Uygur (1992), in their studies, in their assessments of muscle shortness, found out that gastrocnemius muscle shortness was mostly seen in individuals with pes planus [32-34]. The individual's development in the stretch and reach test has gotten close to the levels of his peers without pes planus. His second Cooper test result being 3230 meters, and without any pain means the study achieved its goals. It is a well-known fact that most patients with pes planus experience pain during walking, running and similar dynamic processes [13].

Participant's soles of the feet were photographed with a podoscope on different days repeatedly. In the images, it was seen that the arcs of soles of feet were normal in size. The height of the arcs of soles measured to be 0 before the study, was measured to be 16 mm after it. This value is the value of the individuals without pes planus stated the maximum height of medial longitudinal arc as 15-18 mm from the floor [35]. This work has increased the participants' quality of life and there is no risk whatsoever. However, there are many risks for surgical interventions.

The conclusions of this study based on one patients results. This seems to be major limitation, but we believe that results of this study will encourage the practitioners to apply same protocol in pes planus patients. The other limitation is the need of follow up after the study lasted. Randomized prospective controlled studies with larger series an a longer follow up period are required in the future.

Conclusion

Participant used insoles and orthopedic shoes before. But this usage was limited only to exterior activities, outside the house. This is thought to be a reason for the arc's retrieval to its original position. The height of the steel insoles the participant used before was 18 mm. They are very long in size and cannot be placed in every shoe. And they also limit feet mobility. The insole placed in the arch of the feet in this study is 25 mm in height. With exercises in the beginning, the strength and durability of the feet, feet arc and muscles were increased. The exercises started with pool exercises so that using the buoyancy of the water, the leg muscles were strengthened in a short period of time. With the work done in fitness saloons, the legs and the body was strengthened and increased in durability. With the in house exercises in the mornings and evenings, the arc shape was maintained even in the sleep periods.

It could be considered that the pes planus is eliminated as the participant now walk and run without pain and the soles of his feet seem normal. This study has only been done on one individual with success. It is thought that this study will be a guide for future studies.

Conflict of Interests

The authors hereby declare that they have no competing interests.

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