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Original Article

Plantar Pressure Characteristics and Prevention of Painful Accessory Navicular in Military Recruits

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Abstract

Objective: The objective of this study was to provide practical guidance for the prevention of painful accessory navicular among recruits by comparing and analyzing the plantar pressure parameters of individuals with normal foot, flat foot, and accessory navicular. **Methods**: After training, a total of 90 military recruits were included in this study, comprising 30 with normal foot, 30 with flat foot, and 30 with painful accessory navicular. The plantar pressure distribution was measured for all participants. **Results**: In individuals with flat feet, there was an increase in plantar pressure on the medial side of the forefoot, as well as a significant increase in pressure on the medial side of the heel and arch ($P<0.05$). Conversely, there was a significant decrease in pressure on the lateral side of the heel and arch ($P<0.05$). In patients with painful accessory navicular, the medial pressure on the foot arch showed a further increase ($P<0.001$), while the lateral pressure on the foot arch exhibited a further decrease ($P<0.001$), indicating highly significant differences. **Conclusion**: Compared to participants with flat feet, participants with accessory navicular demonstrated faster and more impulsive impact on the ground within the same stress area, resulting in more noticeable pain caused by the injury to the accessory navicular.

Keywords: Accessory Navicular, Painful Accessory Navicular, Plantar Pressure, Foot Pain

Introduction

Walking plays an irreplaceable and crucial role in our daily lives. Based on the individual's common walking characteristics, the walking posture is subdivided and referred to as "gait," leading to the development of gait analysis technology. The study of gait analysis was proposed by European scholar Beely in the 1880s, which was mainly applied in medical fields such as assessment and examination of flat feet and lower limb rehabilitation. Hannah Rice et al. conducted 32 weeks of military training on 145 male Royal Navy recruits and found that the peak pressure of the first metatarsal bone was higher, indicating an increased risk of ankle injury during high-intensity vertical force medial movements. Currently, application of gait analysis is becoming more widespread in the diagnosis of foot diseases and evaluation of treatment effectiveness[1,2]. The condition known as painful accessory navicular, also referred to as accessory navicular pain, manifests as a series of symptoms including secondary pain and localized bulging of the accessory navicular region, collectively known as accessory navicular pain syndrome. Friction and collision between the inner sides of the feet can lead to structural or functional damage to the accessory navicular, resulting in inflammation of the surrounding soft tissues and tendons. The incidence is about 5-14%. It is often bilateral and inherited as an autosomal dominant trait with incomplete penetrance[3]. In recent years, there has been a rise in the incidence and operation rate of painful accessory navicular among military trainees, which has drawn the attention of professionals[4,5].

The study aimed to identify the causes of painful accessory navicular in young soldiers by analyzing the characteristics of plantar pressure distribution in patients who developed accessory navicular pain syndrome after regular training so as to prevent the progression of the condition, treat it effectively, and promote early recovery.

The authors have no conflict of interest.

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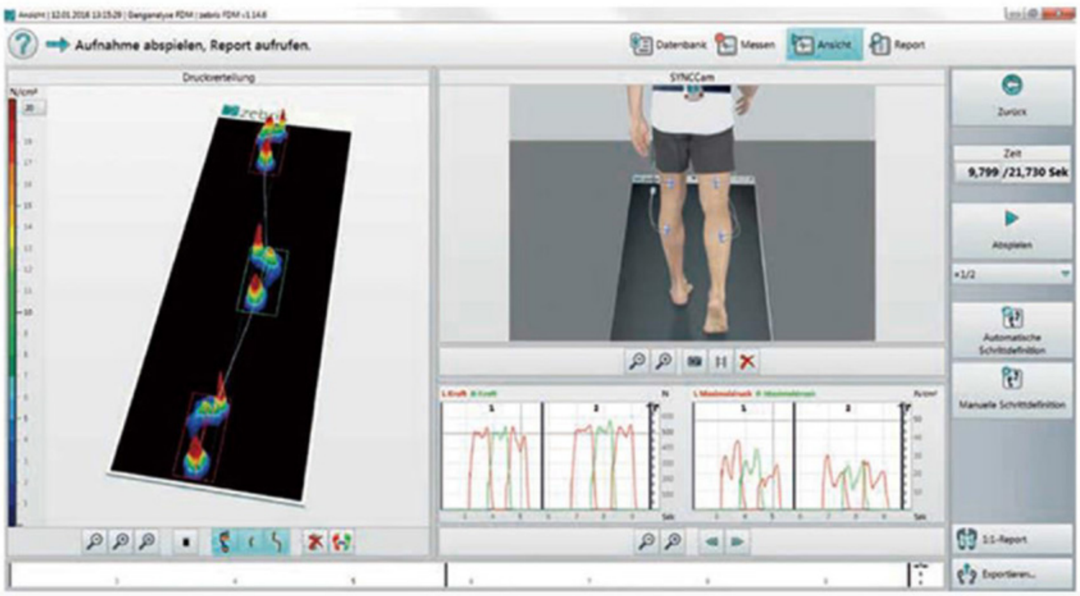

Figure 1. Platform plantar pressure test system.

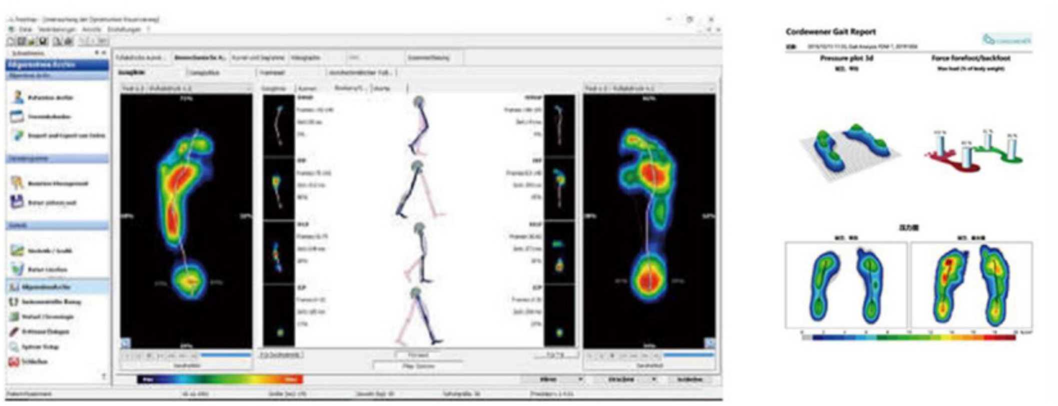

Figure 2. Multi-dimensional dynamic plantar pressure test on a runway.

Method

Participants

The sample of this study was randomly selected from 4311 recruits after three months of military training. A total of 90 recruits were included in this study. Thirty soldiers with reduced or disappeared arches underwent screening for flatfoot by routine physical examination of the foot. Soldiers who experienced medial foot pain after training and had positive oblique X-ray foot radiographs suggesting the presence of an accessory navicular were further screened. Thirty patients were diagnosed with painful accessory navicular and included in the accessory navicular group. Additionally, thirty recruits with normal foot structure were enrolled in the normal foot group. A thorough physical examination and imaging assessment revealed no abnormal foot conditions among the recruits in the normal foot group. Basic demographic data of participants, including height, weight, age, sex, and BMI. There were no significant differences in the basic information, including height, weight, age, and body mass index (BMI) ($p>0.05$), among the thirty soldiers in each group (Figure 11).

Sample size estimation

Take α=0.05, β=0.1, using a bilateral test. The estimated sample incidence rate P1=10% in the test group and P2=25% in the control group are taken into the formula:

$$n_1=n_2=1641.6\left(\frac{u_{\alpha}+u_{2\beta}}{\sin^{-1}\sqrt{P_1}-\sin^{-1}\sqrt{P_2}}\right)^2$$

At present, the sample size for each group of studies is tentatively set at 30 cases.

Inclusion criteria: 1. age between 18 and 24 years old. 2. No deformities in the lower limbs and feet. 3. Mental health and communication accessibility. 4. Agree to accept testing.

Exclusion criteria: 1.BMI>24. 2. Deformities in the lower limbs or feet. 3. Communication disorder. 4. Disagree to accept testing.

Measuring equipment

Height and weight measurement: participants' height and weight were measured using electronic scales (Brand: Xiaomi, Size: 320mmX345mmX35mm, Weighing range: 0.1-150kg). The measured person stands barefoot on the base of the height meter, with their heels and shoulders tightly against the column of the height meter. Move the horizontal plate of the height meter to the top of the person's head to measure their height. Measurement of plantar pressure parameters: The German Cordewener gait analysis system was used for testing (Brand: Cordewener GmbH, Scanning area: 1370mmX535mmX15mm, Frequency: 120Hz, Operating platform: Microsoft Windows). The Cordewener treadmill plantar pressure test system allows for continuous testing and analysis of zonal pressure distribution across different plantar segments, fulfilling the requirements for analyzing data on flat feet with accessory navicular pressure (Figures 1-2).

The plantar pressure measurements included peak plantar pressure, plantar pressure impulse, and a comparison of pressure between the front and rear plantar regions, which were divided into a total of 11 plantar pressure zones (Figure 3).

Maximum plantar pressure peak: The peak plantar pressure test provides accurate data parameter for assessing local pressure on the sole of the foot. It can analyze the magnitude of plantar valgus pressure and comprehensively evaluate differences in pressure values among flat feet. Gait balance is also an important evaluation index.

Plantar pressure impulse: The plantar pressure impulse reflects the product of plantar pressure and time. It indicates the temporal impact of flat feet on gait.

Test method

Prior to the test, the participants' height, weight, and other relevant information were measured. The test procedures were explained to the participants, and they were given the opportunity to walk multiple times to adapt to the testing environment, ensuring compliance with

Figure 3. Floor pressure zoning.

the test requirements. During the test, the participants removed their shoes and socks and walked naturally on the runway of the Cordewener plantar pressure test system at a speed (Traveling speed: 5 km/h) equivalent to their usual gait, performing the test at least three times. The three best foot images were selected for analysis, and the average values were calculated.

The collected data was processed using the software provided with the test instrument, which generated corresponding graphics and raw data. The plantar surface of the foot was anatomically divided into 11 regions: the first phalanx (TOE1, T1), the second to fifth phalanx (TOE2-5, T2-5), the first metatarsal (META1, M1), the second metatarsal (META2, M2), the third metatarsal (META3, M3), the fourth metatarsal (META4, M4), the fifth metatarsal (META5, M5), the medial arch of the foot (MM), the lateral arch of the foot (ML), the medial heel (HM), and the lateral heel (HL).

Main Observation Indicators

The maximum pressure peak, pressure impulse, and pressure area in various regions of the plantar foot.

Statistical analysis

All data statistics were processed using SPSS 22.0 software. Multiple comparisons were conducted using analysis of variance (ANOVA). The statistical results were expressed as mean±standard deviation (x±s), with a significance level of $P<0.05$ indicating a significant difference

Results

The basic data of the participants are shown in Table 1. The foot scanning images and pressure maps of the three

Table 1. Detailed data of participants.

Groups	Height (cm)	Weight (kg)	Age (years)	BMI (kg/m²)
Normal Foot	174.67±6.88	66.36±5.27	19.3±1.24	18.67±2.75
Flat foot	174.50±4.87	65.71±3.70	18.9±1.56	19.18±1.78
Flat feet with accessory navicular	174.77±8.65	65.33±4.53	19.1±1.12	18.91±1.97
P	0.89	0.25	0.06	0.09

SD: Standard deviation. ∗Significant difference (p<0.05) between normal and flat feet.

Figure 4. Plantar scan Fig.

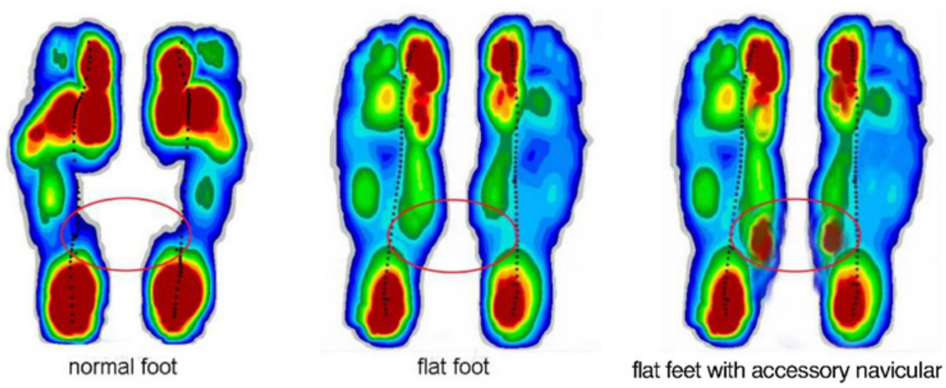

Figure 5. Plantar pressure map.

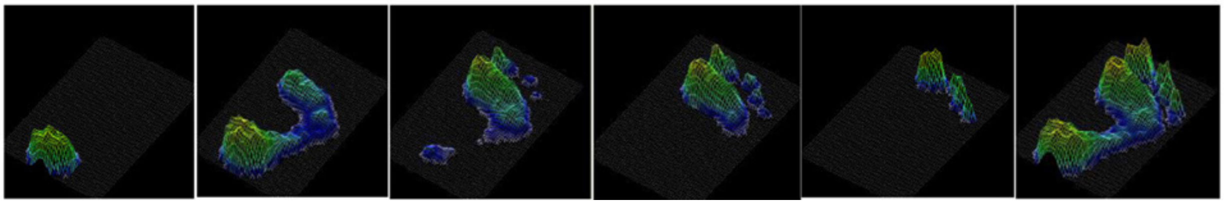

Figure 6. 3D plantar pressure maps at each moment of a normal bare foot.

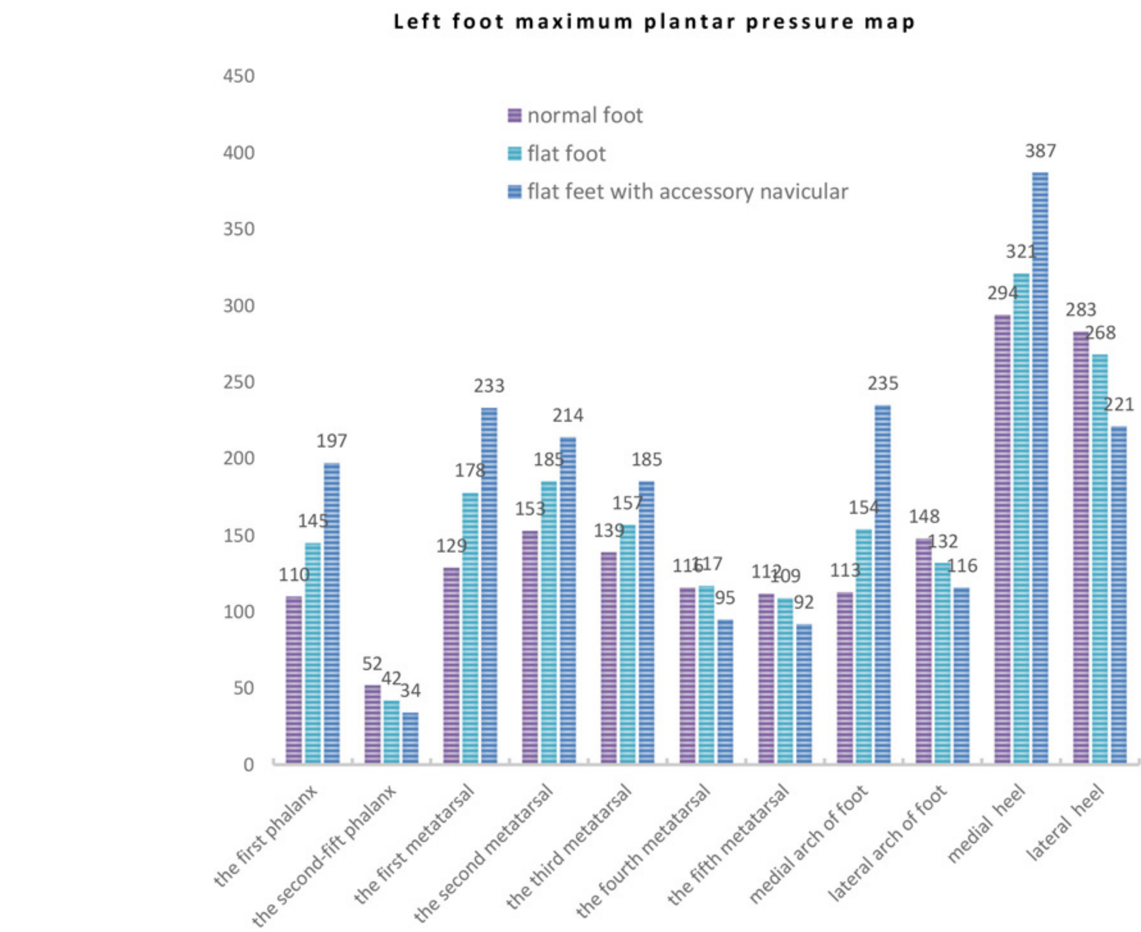

Figure 7. Left Foot Maximum Plantar Pressure Peak Contrast Column.

groups of patients were analyzed, including normal plantar pressure analysis, flat foot plantar pressure analysis, and accessory navicular plantar pressure analysis. The foot scanning images (Figure 4), plantar pressure maps (Figure 5), and 3D plantar pressure maps (Figure 6) of the three groups are presented below. In individuals with flat feet, there was an increase in plantar pressure on the medial side of the forefoot, as well as a significant increase in pressure on the medial side of the heel and arch. Conversely, there was a significant decrease in pressure on the lateral side of the heel and arch. In patients with painful accessory navicular, the medial pressure on the foot arch showed a further increase, while the lateral pressure on the foot arch exhibited a further decrease, indicating highly significant differences.

The maximum plantar pressure peak value and pressure impulse of Flat feet and accessory navicular bone in recruits increased in varying degrees compared with that of normal feet, and the appearance of accessory navicular bone further increased the pressure on the inner heel. The accessory navicular bone will impact the ground faster and more impulsively than the Flat feet in the same stress area, and the pain caused by the injury to the accessory navicular bone will be more obvious.

Differences in maximum plantar pressure peak among three groups

As shown in Table 2 and Figure 7, there are significant variations in the values of plantar pressure across different areas of the left foot in the three data sets. In terms of total pressure values, the highest pressure is observed in the medial heel. This is followed by the lateral heel, the medial arch, and the first metatarsal bone. However, in the case of the first metatarsal, the pressure in the normal foot and flat foot is higher than that in the medial arch, except for the flat feet with accessory navicular group. The pressure values then decrease in the following order: second, first toe, third metatarsal, fourth metatarsal, and fifth metatarsal. The lateral arch of the foot has the next highest pressure. The areas with the lowest pressure are the second to fifth toes.

As shown in Table 2 and Figure 8, the plantar pressure

Table 2. pressure contrast in normal feet, flat feet, flat feet with accessory navicular.

Target		Normal foot	Flat foot	Flat feet with accessory navicular
TOE1,T1	Left	110.33±20.14	145.21±19.53	197.63±5.97*
	Right	105.62±19.48	128.58±20.41	183.59±8.86*
TOE2-5,T2-5	Left	52.65±10.35	42.42±11.22	34.76±8.87*
	Right	50.57±11.35	41.51±8.37	33.44±9.47*
META1,M1	Left	129.65±27.76	178.57±17.36	233.66±25.92*
	Right	124.72±25.96	172.65±11.54	241.49±21.95*
META2,M2	Left	153.54±31.43	185.65±11.59	214.73±16.67
	Right	151.47±30.58	191.74±17.61	228.38±19.42*
META3,M3	Left	139.73±29.62	157.49±9.27	185.64±17.45*
	Right	132.81±28.64	161.22±18.93	181.75±16.77*
META4,M4	Left	116.77±37.56	117.82±25.33	95.54±11.37*
	Right	112.75±31.46	111.17±21.55	93.68±18.24*
META5,M5	Left	112.84±28.57	109.51±13.53	92.21±10.63*
	Right	110.59±23.98	108.62±16.74	91.58±14.87*
MM	Left	113.57±15.72	154.97±20.49	235.66±12.59*
	Right	108.64±21.55	160.54±18.62	237.59±13.43*
ML	Left	148.69±22.38	132.58±25.69	116.94±15.61*
	Right	142.67±18.73	137.35±21.42	119.43±20.47*
HM	Left	294.37±53.73	321.52±31.79	387.64±42.88*
	Right	291.52±49.33	333.61±28.84	384.32±35.84*
HL	Left	283.57±45.64	268.65±24.77	221.67±28.73*
	Right	276.62±40.55	262.32±18.65	232.51±27.59*

*SD: Standard deviation. *Significant difference ($p<0.05$) between normal and flat feet.*

values for the right foot data in the three groups exhibit a similar trend to that of the left foot. Similar to the left foot, the maximum pressure is observed in the medial heel, with minimal change compared to the left foot. This is followed by the lateral heel, and then the first metatarsal. However, unlike the left foot, the medial arch pressure follows a different pattern. The values then follow a similar order as the left foot: second metatarsal bone, first toe, third metatarsal bone, fourth metatarsal bone, and fifth metatarsal bone. The lateral arch of the foot has the next highest pressure. Similarly, the area with the lowest pressure is the second to fifth toes

Differences in plantar pressure impulse among three groups

As shown in Table 3 and Figure 9, the maximum pressure impulse in the normal left foot is observed in the medial part of the heel, followed by the lateral part of the heel, the medial part of the arch, the first toe, and then the first, second, and third metatarsal regions of the forefoot. The smallest pressure impulse is found in the second to fifth toe region. The sequence of pressure impulse distribution is as follows: medial heel, lateral heel medial arch of foot, first toe, lateral arch of foot, first metatarsal, second metatarsal, third metatarsal, fourth metatarsal, second to fifth toe.

In flat feet, the order of pressure impulse distribution in the left foot differs from that of normal feet. It follows this sequence: medial heel, (lateral heel = medial arch of foot=medial first toe=first metatarsal), second metatarsal, third metatarsal, fourth metatarsal, fifth metatarsal, second to fifth toe.

For flat feet with accessory navicular, the order of pressure impulse distribution in the left foot is as follows: medial heel, medial first metatarsal, medial arch of foot, second metatarsal, first toe, lateral heel, lateral third metatarsal, lateral arch of foot, fourth metatarsal, fifth metatarsal, second to fifth toe.

As shown in Table 3 and Figure 10, the trend of the maximum pressure impulse in the right foot is similar to that of the left foot. The maximum pressure impulse in the normal right foot is highest in the medial part of the heel (slightly smaller than that of the left foot), followed by the lateral part of the heel, the medial part of the arch of the foot, the lateral part of the arch of the foot, the first toe, and then the first, second, and third metatarsal regions of the forefoot. The smallest pressure impulse is observed in the second to fifth toe region. The sequence of pressure impulse distribution is as follows: medial heel >lateral heel >medial arch of foot >first toe >lateral arch of foot >first metatarsal >second metatarsal >third metatarsal >fourth metatarsal > second to fifth toe.

In flat feet, the order of pressure impulse distribution differs from that of normal feet in the right foot. It follows this sequence: medial heel >medial arch of foot >lateral heel

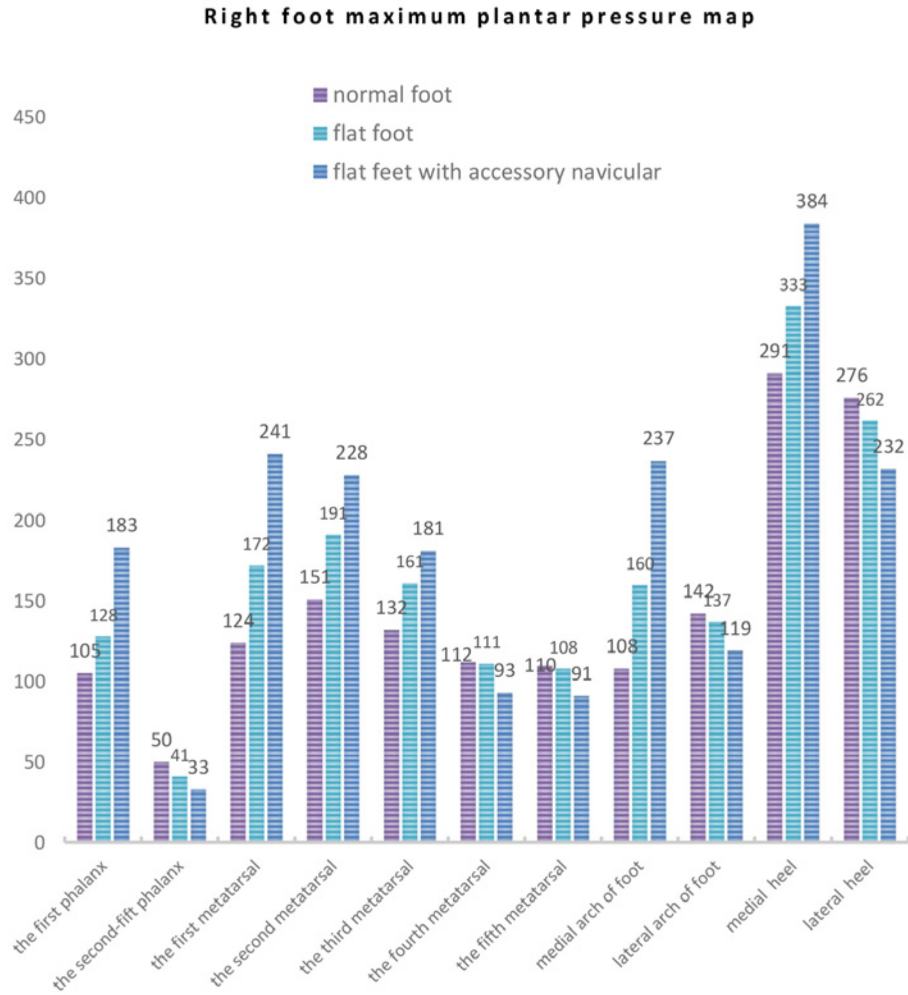

Figure 8. Right Foot Maximum Plantar Pressure Peak Contrast Column.

>lateral arch of foot >first metatarsal >first toe >second metatarsal >third metatarsal >fourth metatarsal >fifth metatarsal >second to fifth toe.

For flat feet with accessory navicular, the order of pressure impulse distribution in the right food is as follows: medial heel >(medial arch of foot=first metatarsal) >second metatarsal >first toe >lateral heel >third metatarsal >lateral arch of foot >fourth metatarsal >fifth metatarsal >second to fifth toe.

Discussion

Definitions and current status

The presence of the accessory navicular bone in the foot is a common cause of pain in the medial arch of the foot, with intermittent pain related to movement and activity as the main manifestation. Some patients present with local protrusions and tenderness at the accessory navicular node, and in severe cases, it can lead to the painful accessory navicular in the foot[6].The painful accessory navicular has been observed to be on the rise in military training settings and has garnered increased attention from professionals worldwide. Some modes of medical management and physiotherapy have been used for the therapy of symptomatic accessory navicular, such as nonsteroidal anti-inflammatory medication, steroid injection, footwear modification and custom orthotics, while for refractory cases, surgery will be more effective[7]. Various surgical methods are reported for symptomatic accessory navicular, including simple excision; percutaneous drilling; excision and relocation of the tibialis posterior tendon (the Kidner procedure) and fusion of the accessory navicular to the body of the navicular[8]. H. Rice et al. conducted a fundamental study on foot injuries among Royal Marine recruits and found that abnormal pressure distribution within the foot, both inside and outside, was a direct cause of foot pain[9]. Reviewing relevant literature[10-13], the causes of medial foot pain in painful accessory navicular can be summarized as follows: (1) Local

Table 3. Measurements of plantar pressure and impulse.

Target		Normal foot	Flat foot	Flat feet with accessory navicular
TOE1,T1	Left	27.15±15.96	36.23±8.77	41.42±7.84*
	Right	29.17±13.24	32.65±3.43	39.75±10.23*
TOE2-5,T2-5	Left	15.24±2.37	13.34±1.58	10.16±6.62*
	Right	17.42±3.58	12.26±5.63	9.53±2.98*
META1,M1	Left	25.63±19.69	36.45±11.58	56.73±15.33*
	Right	28.99±12.46	33.44±19.65	53.72±6.59*
META2,M2	Left	22.34±32.14	28.64±16.59	43.63±28.76*
	Right	22.77±21.65	29.59±18.92	46.33±19.75*
META3,M3	Left	21.37±6.38	27.85±8.93	28.82±11.68*
	Right	21.62±10.59	24.74±17.62	26.73±16.19*
META4,M4	Left	19.56±17.33	18.42±12.64*	17.64±8.52*
	Right	17.45±10.22	16.57±17.41	15.93±7.47*
META5,M5	Left	17.59±7.39	15.34±6.71*	13.48±7.61*
	Right	18.76±8.52	16.53±7.55	12.77±7.52*
MM	Left	28.62±12.55	36.69±9.76*	67.58±11.63**
	Right	33.54±19.71	39.47±16.57	63.25±10.17**
ML	Left	26.15±17.54	22.59±12.62	18.75±6.94**
	Right	31.45±8.92	25.77±5.33	19.39±10.28**
HM	Left	42.72±23.28	74.33±37.56	108.87±23.52*
	Right	39.52±22.64	73.58±42.75	113.17±20.53*
HL	Left	41.48±11.25	36.62±22.56	31.78±21.53*
	Right	38.68±7.53	34.78±17.95	30.69±31.57*

*SD: Standard deviation. *Significant difference (p < 0.05) between normal and flat feet.*

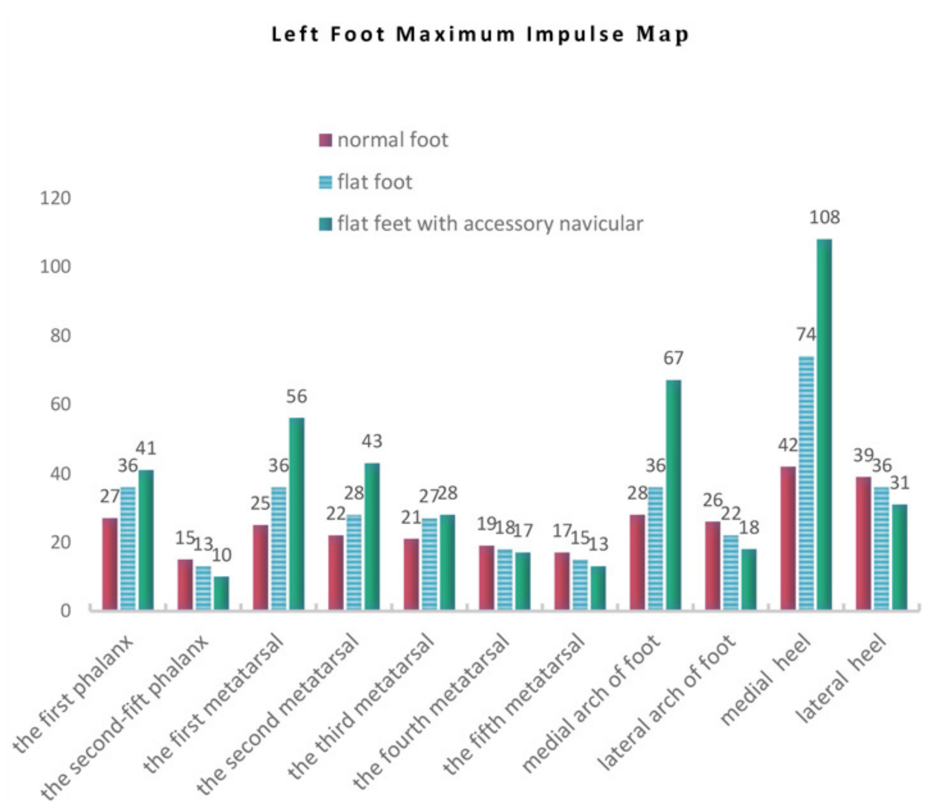

Figure 9. Left Foot Maximum Impulse Contrast Column.

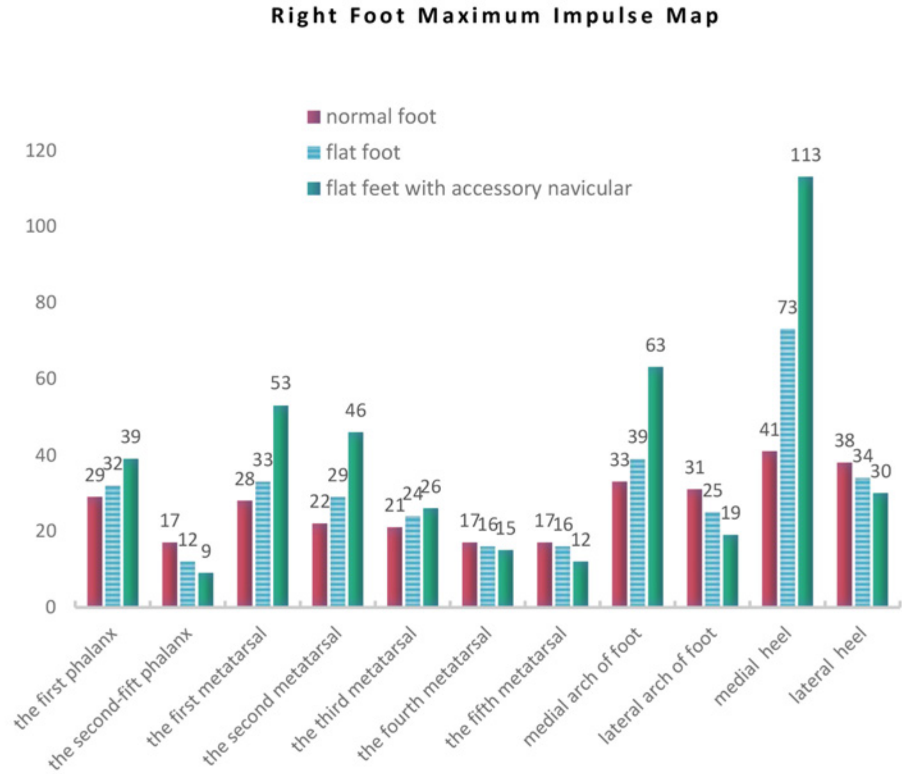

Figure 10. Right Foot Maximum Impulse Contrast Column.

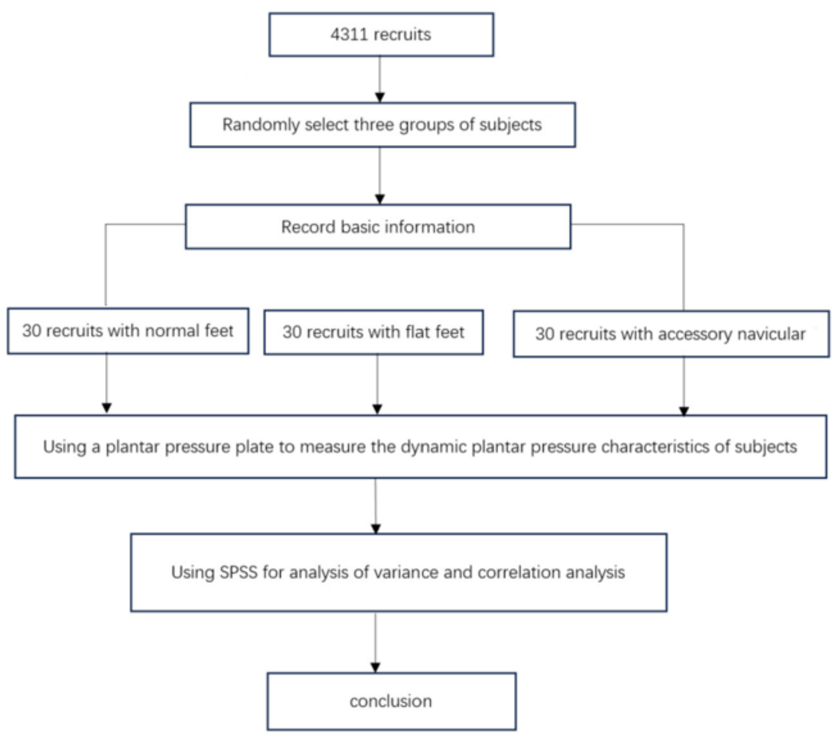

Figure 11. Test flow chart.

irritation of the medial accessory navicular process due to training shoes. (2) Structural changes in the posterior tibial tendon caused by the presence of the accessory navicular bone, leading to increased tension and subsequent tendinitis. (3) Bone pain resulting from bone marrow edema due to prolonged friction and strain on the accessory navicular joint surface of the foot.

The current training shoe system used in our army offers distinct advantages, including high uppers of shoes, strong support, and durable materials. However, these training shoes can further compress the medial foot area, making them unsuitable for long-distance operations and increasing the likelihood of soldiers experiencing accessory navicular pain syndrome. We observed a significantly higher incidence of pain in the medial accessory navicular region among soldiers wearing training shoes compared to other training participants after a 5-kilometer march or medium-distance running during training. During the training period, young soldiers engage in high-intensity exercises such as combat drills, long-distance runs, 400-meter obstacle courses, and jumping exercises on a daily basis. This often leads to acute sprains and chronic strain in their feet, highlighting the differences in training practices between young soldiers and adolescents in civilian life[14]. We also observed significant differences in plantar pressure after long runs in the general population[15].

In this study, we dynamically examined and analyzed the foot characteristics of recruits with accessory navicular in comparison to those with normal and flat feet for the first time. We recorded the maximum pressure peak and pressure impulse in specific areas of the foot for each group and identified the differences and connections among the groups.

The peak plantar pressure is a crucial parameter in analyzing plantar pressure distribution, making it a primary evaluation metric for plantar gait analysis[16]. Zhang Tengdan discovered that peak pressure changes were most significant in the medial heel and the area encompassing the second to fifth phalanges of the foot during walking among young college students. The time sequence for reaching peak pressure was observed as follows: heel <arch <metatarsal <toe. These findings provide a theoretical foundation for investigating and addressing cases using plantar pressure testing[17]. Based on the results of this study, normal feet exhibit the highest plantar pressure in the heel region, followed by the first and second metatarsals, and then the first toe. The second to fifth toes and the outer arch of the foot show the lowest plantar pressure. In flat feet, the sagittal pressure distribution resembles that of normal feet, but the plantar pressure on the medial malleolus (medial column) surpasses that on the lateral malleolus (lateral column). The pressure in the medial heel, medial arch, and the first, second, and third metatarsal bones is higher in flat feet compared to normal feet. However, the pressure on the lateral heel, lateral arch, and the second to fifth toes of the lateral ankle is lower than that on normal feet ($P<0.05$). This suggests that the overall plantar pressure in flat feet starts to shift inward on the frontal plane, deviating from the pattern observed in normal feet.

In flat feet with accessory navicular, the sagittal pressure distribution aligns with that of normal and flat feet. However, the pressure further increases toward the inner column on the frontal plane, while decreasing on the outer ankle. This phenomenon is observed in both the left and right feet, with the most notable changes occurring in the inside and outside of the arch. The pressure increase in the medial arch significantly differs from that in flat and normal feet ($P<0.001$), and the pressure decrease in the outer arch is also significantly different ($P<0.001$). These findings indicate that the presence of an accessory navicular significantly amplifies the pressure on the medial arch of flat feet. Impulse is a measure of the cumulative force applied to an object over time and reflects the plantar damage caused by chronic conditions. Regarding plantar pressure impulse testing, impulse is a measurement that represents the product of time and force. It reflects the local impulse on the sole of the foot during landing. The formula used is $Ft=MV$, where F is the average force, T is time, M is the weight of the human body, and V is the speed of plantar landing. In this study, the maximum impulse observed in normal feet, flat feet, and flat paracanoe feet was in the heel region, followed by the first and second metatarsals, the first toe, the third, fourth, and fifth toes, and the lateral arch of the foot. The lowest impulse was observed in the second and fifth toes, aligning with the regular distribution of plantar pressure. However, significant differences were found among the three groups in localized areas. The impulse in the medial arch of the flat paracanoe foot was significantly higher than that in flat feet and normal feet ($P<0.001$). There was also a significant difference between flat feet and normal feet ($P<0.05$). Furthermore, a decrease in impulse was observed in the fifth metatarsal, with statistically significant results ($P<0.001$). These findings indicate that both the accessory navicular and flat feet exhibit a faster and more impulsive impact on the ground within the same force area, and the resulting pain from the accessory navicular is more pronounced. In the future, improving symptoms can be achieved by increasing support and cushioning in this area, as well as reducing the contact speed.

Causes and Preventive Measures of Medial Foot Pain in Recruits with Accessory Navicular During Basic Training

Military training is a crucial activity for new recruits and a fundamental way to enhance the fighting capabilities of troops. The presence of an accessory navicular in the foot is often accompanied by local protrusion in the medial foot and a smaller or flat arch[18]. During walking, individuals with an accessory navicular experience increased pressure on the medial heel and arch of the foot compared to the same areas in individuals with normal feet or flat feet. This significant difference was observed through the analysis of experimental data. By examining the results of plantar pressure impulse tests, we observed that the maximum pressure impulse received by the foot during walking is in the heel area. In individuals with an accessory navicular, the impulse received by the medial part of the foot arch and the first metatarsal bone ranked second, which differs significantly from individuals with normal feet. These findings suggest that the pressure and pressure impulses in the medial foot arch of individuals with an accessory navicular are significantly increased compared to those with a normal foot arch. This fundamentally explains the cause of medial foot pain associated with the accessory navicular. Calvin et al. have previously reported on the design of foot support insoles and evaluated their orthopedic effects through gait analysis[19-21]. Building on the data from this study, we will design a supportive and protective orthotic insole specifically for painful accessory navicular. The design concept involves using special material shoe pads with a column support structure in the inner sole position. This design aims to improve the foot arch, reduce tension in the posterior tibial tendon, and enhance local blood circulation while mitigating the inflammatory environment. The inner part of the insole is connected with a cup-shaped protective ring to alleviate irritation from the inner upper of the training shoes on the bulge of the accessory navicular. By adhering to these design principles, the shoe pads effectively reduce the incidence of pain symptoms associated with the accessory navicular.

Conclusion

The peak plantar pressure and pressure impulse of the recruits with flat foot and accessory navicular of foot increased to varying degrees compared with the normal foot. The presence of the accessory navicular further increases the pressure on the inside of the heel. Patients with accessory navicular of foot are more likely to experience ground shocks and impulses compared to individuals with flat feet within the same force area. This serves as important evidence indicating that accessory navicular of foot is more likely to cause medial foot pain.

Authors' contributions

XP: Conceived and designed the study, and drafted the manuscript. LX, LJ, BL, and YtW: Collected, analyzed, and interpreted the experimental data. YZ, YW, and QK: Revised the manuscript for important intellectual content. All authors: Read and approved the final manuscript

Ethics approval

This study has obtained informed consent from all participants in accordance with the requirements of the Declaration of Helsinki.

The study protocol was approved by the Ethics Committee of the 980th Hospital of the Chinese People's Liberation Army with approval number: (2022-KY-128).

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