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Article

Study on the Effect of Three-Dimensional Reconstruction Technique Based on Human Gait Plantar Transient Data on Rehabilitation of Patients with Abnormal Foot Arch

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Abstract: This research employs non-contact plantar 3D data scanning and gait analysis methodologies to establish a rehabilitation assistance system tailored for foot arch anomalies. The system utilizes a non-contact plantar 3D data model to mitigate dysfunctions within the plantar skeletal-muscular system. Its objectives include facilitating personalized remote diagnosis of foot arch anomalies, enabling patients to monitor their rehabilitation progress, and supporting at-home rehabilitation efforts. A dataset comprising 124 cases of physiological foot arch anomalies in adults aged 18 and above was collected and analyzed. The findings demonstrate the system's flexibility, high spatial resolution, personalization, and innovation. Notably, the system achieves real-time measurement of positive pressure and shear force distribution at the plantar interface, facilitates the construction of accurate geometric models, and yields high-quality plantar three-dimensional coordinate data. This research contributes theoretical and technical underpinnings for the application of footwork anomaly diagnosis and correction.

Keywords: arch abnormality; physical model; 3D scanning; gait recognition

1. Introduction

The foot arch constitutes a pivotal anatomical structure within the human body, serving as a critical element in supporting static and dynamic weight-bearing activities such as standing and walking. Its primary role is the attenuation of ground pressure, cushioning, and equitable dispersion of loads across the plantar surface, thus ensuring the integrity and well-being of the foot. Extant literature [1] underscores the prevalence of foot arch anomalies in the demographic of children and adolescents, particularly within the age bracket of 3 to 10 years. This occurrence is characterized predominantly by "soft physiological flat feet" (commonly known as pseudo-flat feet), with a considerably minor occurrence of "pathologic flat feet". It is noteworthy that a significant proportion of young children exhibit an innate predisposition toward flat feet, albeit with the expectation of spontaneous development of normative arches before the age of 10 [2,3].

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Additionally, research has indicated that detection rates of flat feet and high-arched feet among children aged 10–13 years stand at 19.1% and 14.6%, respectively [4–6]. In the adolescent age group spanning from 10 to 18 years, Wang Yuxia et al. conducted a study in a Tianjin middle school, detecting 254 cases of flat feet among 468 students aged 13–16 years, yielding a detection rate of 54.27% using the footprint method [7]. Moreover, in the examination of adolescent flat feet within the age range of 13–18 years, conducted by Zhang Lihua et al., a marked gender disparity was discerned. The detection rate among boys stood at 37.50%, a substantial contrast to the 23.47% rate observed among girls [8].

In the adult population, arch abnormalities are widespread on a global scale. Data from the U.S. National Health Survey demonstrates a correlation between the prevalence of flat feet in adults in the United States and factors such as age, gender, body mass index, occupation, and health status. Male flatfoot cases outnumber their female counterparts, with the elderly experiencing more severe instances of flat feet than younger individuals, manifesting an average age of 44.20 ± 17.16 years and a prevalence rate of 2.3% [9]. In China, there has been a 20% rise in the number of patients with arch abnormalities between 1960 and 2000. Over the past two decades, coinciding with China's rapid economic growth, the average duration of physical activity and exercise among adults has notably decreased, leading to a consistent upward trajectory in the number of affected individuals [10].

Arch abnormalities in adults are predominantly characterized as "acquired" arch abnormalities (AADF) [11]. Conversely, arch abnormalities in children predominantly arise from the foot's inability to undergo growth and development sufficient to accommodate the stresses imposed by the child's foot movements [12]. However, owing to the high plasticity inherent in the foot during this developmental stage, arch abnormalities can be mitigated as the foot undergoes maturation and training. Despite the availability of advanced measurement techniques facilitating precise dynamic quantitative analysis of activities and stresses on various anatomical regions during walking, limited attention has been directed towards evaluating the plantar pressure transient measurement [13], a dynamic technique developed in recent years.

This innovative approach has previously found application in orthotic foot rehabilitation for athletes, enabling the detection and characterization of pressure magnitude and distribution on the plantar surface during activity. Nevertheless, scant research has explored the application of this technique within the population afflicted by foot arch abnormalities. The commercial viability of such a flexible and customized assistive system remains unclear, leading to a paucity of attention in this domain [14].

Given the substantial population in China, the application of this technology assumes paramount importance. Yet, there is a dearth of essential studies guiding and assisting patients in planning and scientifically intervening in the diagnosis and rehabilitation of foot arch anomalies. This paper seeks to harness this technology to establish a theoretical and practical foundation for understanding foot arch abnormalities, providing a reference framework for clinical diagnosis, efficacy assessment of foot-related diseases, and informing physical exercise protocols [15].

2. Literature Review

2.1. Methods of Detecting Foot Arch Abnormalities

The methodologies for detecting foot arch abnormalities can be broadly classified into two categories: traditional detection methods and intelligent detection methods. Traditional detection methods encompass medical assessments predominantly reliant on footprint analysis and imaging examinations. Physical examination predominantly relies on the identification of flat feet based on clinical symptoms and signs, constituting the most commonly utilized clinical diagnostic approach for flat feet. Specifically, there are mainly the following six methods:

One such modality is Footprint Analysis, wherein the diagnosis is indirectly derived through expedient measurement of the patient's ambulatory footprints. This process, characterized by simplicity, expeditiousness, and cost-effectiveness, serves as a fundamental diagnostic approach (Figure 1) [16].

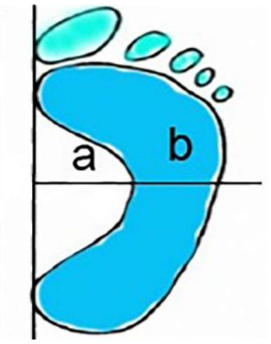


Figure 1. Footprint analysis method.

The Scribing Method entails the delineation of the inner arch's tangent line, denoted as the first line, alongside a line drawn from the third toe's center to the midpoint of the heel, designated as the second line. The intersection of these lines engenders an angle, from which an equidistant line is drawn to form the third line. These tripartite demarcations categorize the footprint into medial, medial, and lateral regions. The normal foot exhibits an inner arch within the lateral portion, whereas mild and moderate flat feet manifest in the middle and medial portions, respectively. In severe cases, the inner arch surpasses the medial portion. This method predominantly finds utility in the archival of laboratory data (Figure 2) [17].

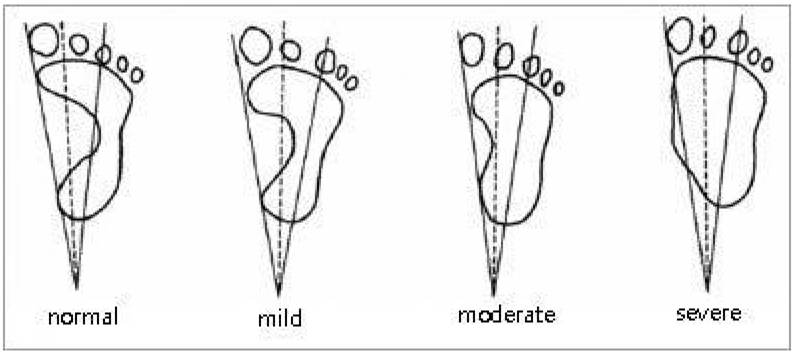


Figure 2. The scribing method.

The Visualization Copying Method involves the placement of light sources at both ends of a glass apparatus, positioned atop an elastic pad. As the foot makes contact with the elastic pad, light undergoes total reflection within the glass, generating a distinct foot imprint. The luminous intensity of the imprint corresponds proportionally to the applied pressure. This differential luminosity facilitates the identification and quantification of plantar pressure across various foot regions [18].

The application of Force Plate and Force Table methodologies builds upon transducers and sensors dedicated to plantar pressure measurement systems. These systems detect and differentiate plantar pressure distribution between normal and flat feet. Furthermore, automated analysis through accompanying software, exemplified by the German Nover Emid force plate and Swiss Kistler force table, amplifies their utilization.

Force Measuring Shoes and Insoles represent a paradigm wherein sensors are embedded within footwear or insoles. Leveraging pressure conversion pads on the soles, these systems facilitate multifaceted gait and temporal measurements. Prominent examples encompass the Belgian FootScan insole and Peder insole, emblematic of contemporary widespread adoption (Figure 3) [19].

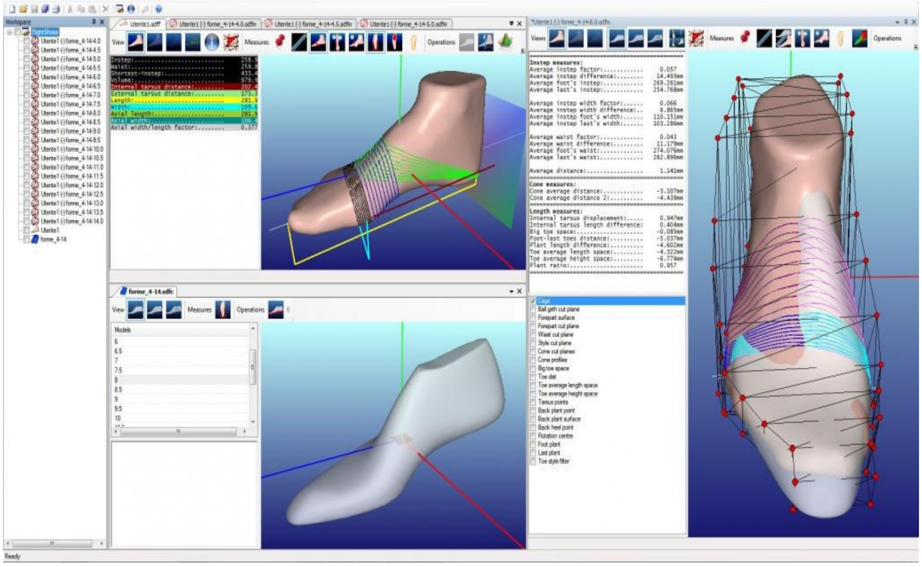


Figure 3. Force measuring shoes.

Imaging examinations, including radiography and ultrasonography, are characterized by high precision, providing intuitive and reliable results. However, their application in large-scale clinical surveys is limited due to the associated high costs, primarily serving as confirmation tools for diagnosis and surgical planning [20].

In contrast, less common methods of intelligent inspection are those based on intelligent inspection through computerized measurement techniques such as AI and 3D scanning. Plantar 3D scanning detection entails the acquisition of three-dimensional stereo morphology, structural attributes, and color images of the plantar foot through 3D scanners, ultimately yielding three-dimensional stereo models of plantar landmarks. Foot 3D scanning detectors predominantly rely on three measurement methodologies: laser scanning, structured light measurement, and computer vision-based non-contact measurement (Table 1) [21].

Table 1. Comparison chart between traditional methods.

Methodology	Advantages	Disadvantages
Mark method	Simple and convenient, low cost	Because some patients are due to plantar soft tissue hypertrophy, rather than arch collapse, imprinting can only do more rough detection, the accuracy is low
Drawing lines	Easy to operate, small consumption	Rough judgment
Visualization	The imprint is clear, the operation is simple and the cost is low	It is impossible to judge the force of each part
Force plate	It can judge the stress of each part of the foot	The operation is complicated, the cost is high, it is not conducive to dynamic research, and it is impossible to evaluate the force of "foot-shoe interface"
Force shoe	Because the shoe or insole is attached to the sole, the continuous parameters of the pressure at the "foot-shoe interface" can be measured, and the pressure of multiple gait phases during the march can be continuously recorded for real-time monitoring and feedback	The cost is slightly higher and the operation is more complicated

Magnetic resonance	The main structure and shape of the foot can be accurately reproduced, and the deformed foot that cannot be detected by other methods can be detected more accurately	The cost is high and the post-processing is complicated

Each of the above methods is used to detect or explain the characteristics of flat feet from the outside through various forces or phenomena, and cannot capture the dynamic features of the plantar foot, while for the purposes of this study, the experiments were conducted using a computer vision-based non-contact plantar 3D scanner [22].

2.2. Gait Recognition Diagnostics

Gait recognition diagnosis entails the utilization of visual sensors for the collection of human gait data. This process relies on convolutional neural networks, which operate at a depth sufficient to extract the spatial coordinates of 20 key skeletal joints in the human body (Figure 4). These skeletal joint positions are determined by assessing the distances from each sampling point to their central reference positions, thus generating a set of sampling variables. Deviations in these distances are examined to detect anomalies in the skeletal joint positions, enabling the creation of a comprehensive gait model. Subsequently, through the patient's gait and the comparison of the gait of a normal person to determine whether there is an abnormality of the patient's gait and then diagnose whether there is an abnormality of the foot arch. Then we can diagnose whether the foot arch is abnormal by comparing the patient's gait with that of a normal person (Figure 5).

Figure 4. Gait recognition process.

Figure 5. 3D recognition modeling.

In the context of this research, the primary visual sensors employed are Kinect sensors, a product introduced by Microsoft. These sensors encompass both 3D cameras and infrared sensors. The 3D camera concurrently captures human depth images, color information, and skeletal structural data. The infrared sensor, conversely, is employed for the acquisition of 3D depth information. Leveraging the principles of infrared emission and reception, objects in closer proximity to the camera exhibit brighter coloration, while those farther away appear darker, thus facilitating precise depth perception.

3. Composition and Function of Foot Arch Abnormality Rehabilitation Aid System

3.1. Components of the Rehabilitation Aid System for Foot Arch Abnormalities

The foot arch abnormality rehabilitation system is based on computer vision technology and utilizes plantar 3D scanning technology and gait recognition diagnostic technology to achieve non-contact foot arch abnormality diagnosis, realize auxiliary support for the rehabilitation process, and improve the rehabilitation effect of patients. The system can be mainly divided into two major parts: the server side and the detection terminal, of which the server side includes three parts: patient database, remote diagnosis server, and privacy matching server, and the detection terminal includes mobile detection terminal and cell phone APP (Figure 6).

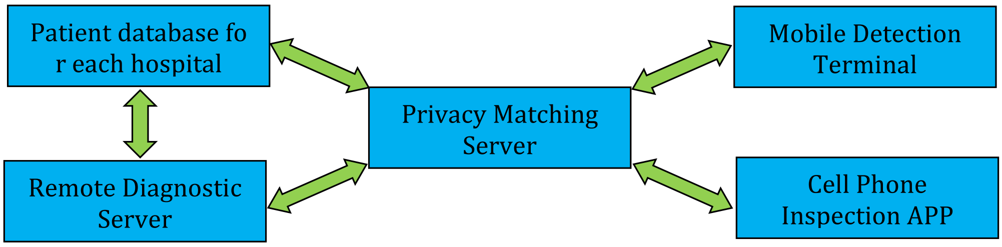


Figure 6. Schematic diagram of foot arch abnormality rehabilitation assistance system.

3.2. Arch Abnormalities Rehabilitation Aid System Function

Each hospital's patient database primarily serves as a repository for organizing and housing comprehensive outpatient records, treatment data, medical histories, historical diagnostic reports, and previous models pertaining to individual patients [23]. Securing patient data within the hospital's dedicated database, where the patient's diagnosis is established, offers maximal protection of patient privacy during remote diagnostic procedures and public network transmission [24].

The primary function of remote diagnostic servers is to furnish remote diagnostic services focused on identifying foot arch abnormalities. These servers facilitate remote diagnosis by evaluating a patient's current condition through a comparative analysis of their historical data, archived within the patient database, and the fresh data gathered via mobile detection terminals or cellular application interfaces.

The privacy matching server assumes the role of a central relay station within the system. Its principal duty involves decrypting the encrypted information transmitted by all involved parties. This includes the encrypted personal information (e.g., name and ID number) conveyed by the mobile detection terminal or mobile application, along with the patient case number furnished by the hospital's patient database [25].

Mobile detection terminals predominantly encompass portable plantar 3D scanners designed for large-scale and extensive screening. These devices offer screening services within community healthcare facilities, educational institutions, and other public locations.

The mobile detection application (App) handscan-300 primarily serves patients and their families during the home-based rehabilitation phase. This facilitates not only a reduction in patient burden, both psychologically and financially but also diminishes the health risks associated with in-person visits. These advantages contribute significantly to the overall success of the system. The mobile application for testing on smartphones is geared towards patient and family use during the home-based rehabilitation phase, thereby mitigating psychological and financial burdens and enhancing patient rehabilitation outcomes (Figure 7) [26].

Figure 7. Patient-side App.

3.3. Treatment Process of Foot Arch Anomaly Rehabilitation Assistance System

The treatment process of the foot arch anomaly rehabilitation aid system comprises two primary phases: the initial diagnosis stage and the rehabilitation stage. The initial diagnosis stage primarily involves the process of patient detection and the diagnosis of foot arch abnormalities, with the progression outlined as follows: patient's report of foot discomfort → remote or outpatient assessment for foot arch abnormalities → establishment of a three-dimensional model of the plantar foot → construction of a gait model → preservation of both models in the diagnosing hospital's database → transmission of the patient's case number to the privacy matching server → issuance of verification text message to the patient → linking the patient's case number with their mobile phone number [27].

To ensure the accuracy of the gait modeling, the system creates 2D charts displaying the following foot dimensions: length, width, internal bone distance, and shortest instep, under the operation of the physician. Data were collected and organized in charts (Figure 8). Displays confidence intervals and predictions. Display the slope of the regression line. It is possible to set the increment of the displayed measurement on the X-axis to automatically calculate the increment of the displayed measurement on the Y-axis (Figure 9).

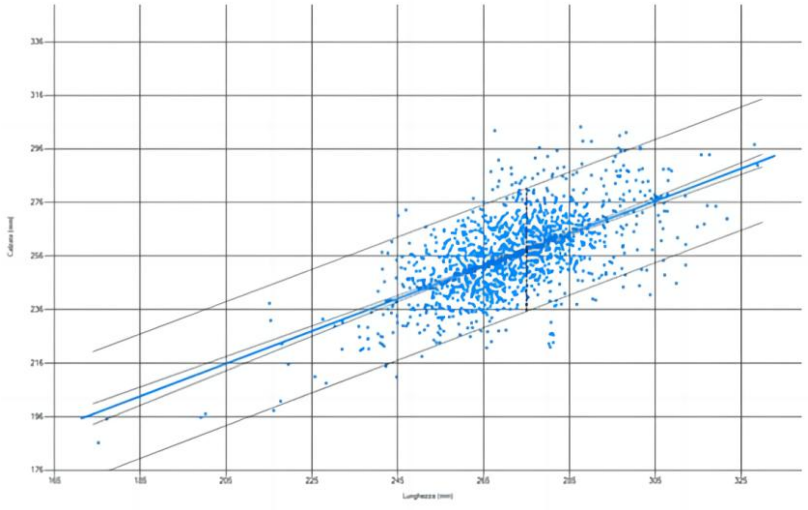


Figure 8. Creates 2D charts and filters.

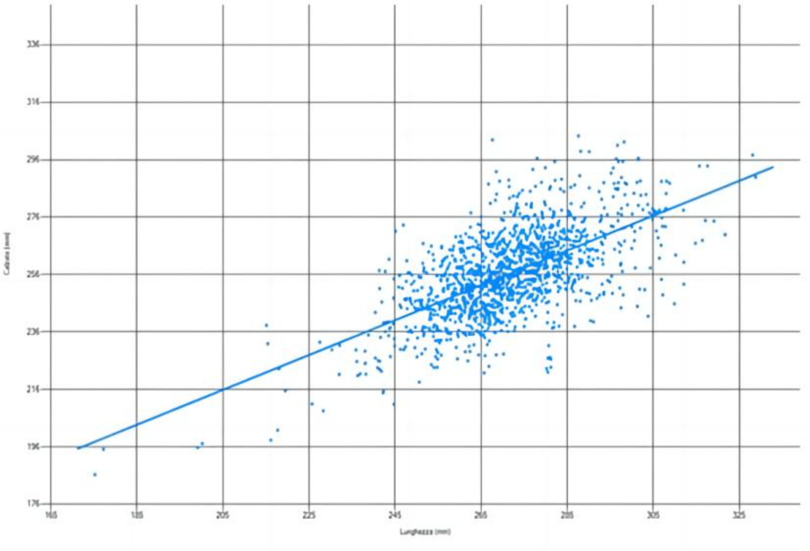


Figure 9. Displays statistical data.

The rehabilitation phase primarily represents a series of patient assessments conducted during the rehabilitation process, and the sequence unfolds as follows: the patient utilizes the designated mobile application (App) handscan-300 for testing → the mobile device submits photos and videos to the privacy matching server → the privacy matching server conducts identity verification with the hospital database → the hospital database validates the patient's information → the privacy matching server forwards the patient's new data and case number to the remote diagnostic server → the remote diagnostic server retrieves historical model data from the hospital database using the patient's case number → the remote diagnostic server performs a comparative analysis and diagnostic assessment → the remote diagnostic server transmits the newly acquired model data, diagnostic outcomes, and rehabilitation recommendations to the hospital database → the hospital database conveys this information for approval by the attending physician → the hospital database communicates the attending physician's approval status to the privacy matching server → the privacy matching server disseminates this information to the patient's mobile application [28].

The rehabilitative process serves to ameliorate the spatial encumbrance attributed to superfluous data preservation, alleviate the communication lacunae between medical practitioners and patients in the course of rehabilitation, and expeditiously depict the authentic status of patients' rehabilitation. This modality operates with efficacy, expediency, and convenience. It concurrently assumes a palliative role in mitigating psychological stressors encountered by patients throughout the rehabilitation trajectory, engendering a salutary impact. Moreover, the procedural sequence instills a profound sense of confidence within the patient, thus abating preexisting biases against the physician's therapeutic regimen. Nevertheless, it is noteworthy that elderly patients evince a proclivity towards the conventional doctor-patient communicative paradigm.

4. Experimental Comparison of Research Methods and Application of Rehabilitation Assistive Systems

From October to December 2020, a cohort of 124 patients, drawn from Binzhou Medical College and its affiliated hospitals, were meticulously selected to partake in this study. In adherence to stringent inclusion criteria, eligible participants were stipulated to be above the age of 18 and exhibit physiological abnormalities in the arches of their feet. The participants' body mass indices (BMI) ranged between 18.5 and 23.9 kg/m^2. Concomitantly, exclusion criteria were meticulously applied, eliminating individuals who had undergone professional sports training, those afflicted with foot disorders such as trauma, neuroma, flat foot, or high-arched foot, individuals manifesting bony deformities of the foot, those with a history of foot or leg amputation, those with mental aberrations, and those experiencing walking dysfunction attributable to other pathological conditions.

Following the judicious application of the inclusion and exclusion criteria, the cohort was stratified into two groups, namely the experimental group and the control group, each comprising 62 subjects, with a gender distribution of 44 males and 80 females.

This investigation employed the Creaform plantar pressure test analysis system (Creaform, Canada) to scrutinize plantar pressure-related indices. The accompanying plate test system facilitated both static and dynamic plantar pressure testing, enabling the assessment of gait during multiple walking cycles, with a testing frequency ranging between 50 and 100 Hz.

The test apparatus encompassed a force plate replete with complementary facilities and analysis software. The force plate, boasting dimensions of 500 mm × 500 mm and equipped with 45 sensing elements measuring 9 mm × 9 mm, was seamlessly interfaced with a computer through a USB cable. Geomagic Studio software was employed for data processing, partitioning the plantar foot into nine distinct zones for comprehensive analysis (Figure 10).

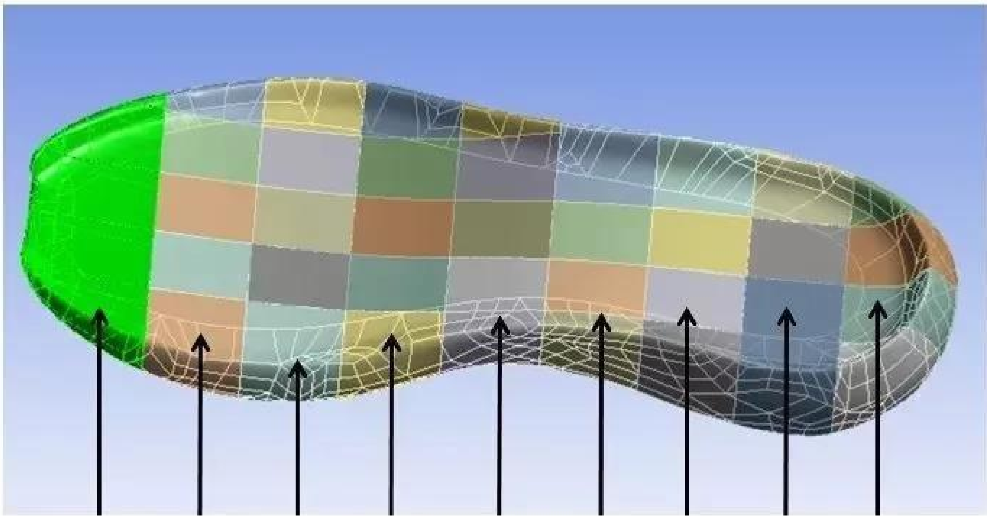


Figure 10. Definition of plantar zones.

All participants removed their footwear and socks, assumed their customary stance on the platform for approximately 10 seconds, and underwent three successive measurements of static plantar parameters for both feet, with a 1-minute interval between each assessment. Subsequently, dynamic plantar parameters of both feet were assessed during the subjects' habitual walking patterns, involving three traversals of the platform with a 1-minute interval between each traversal. Preliminary trial walks were administered to ensure subjects' acclimatization to the testing environment.

To assess the efficacy of the rehabilitation assistance system, data entry and analysis were performed using SPSS 24.0 statistical software. The study enrolled adult patients afflicted with foot arch abnormalities. The experimental cohort underwent intervention in their rehabilitation process through the utilization of the foot arch abnormality rehabilitation assistance system, while the control group underwent traditional rehabilitation methods for comparative purposes. Subsequently, a comparative analysis was conducted on self-care, anxiety, depression, and exercise conditions between the two groups before and after the patients' rehabilitation processes.

4.1. Comparison of the General Conditions of Patients in the Experimental Group and the Control Group

The test was used Chi-squared test to compare the demographic information of the two groups of patients such as gender, marital status, place of residence, cultural level, occupation, caregiver, etc., and the results showed that the difference was not statistically significant (P > 0.05), indicating that the general information of the two groups of patients before the experiment was balanced, and the detailed results are shown in Table 2.

Table 2. Comparison of demographic information of the two groups of patients.

Project		**Experimental group (n = 62)**		**Control group (n = 62)**		χ^2	***P***
		n	**%**	***n***	**%**		
1.Gender	Male 0	38	61.29	36	58.06	0.134	0.714
	Female 1	24	38.70	26	41.93		
2.Marital status	Married 0	49	79.03	52	83.87	0.395	0.530
	Unmarried 1	1	1.61	0	0.00		
	Divorced 2	12	19.35	10	16.12		
3.Occupation	Retiree 0	11	17.74	15	24.19	0.869	0.351

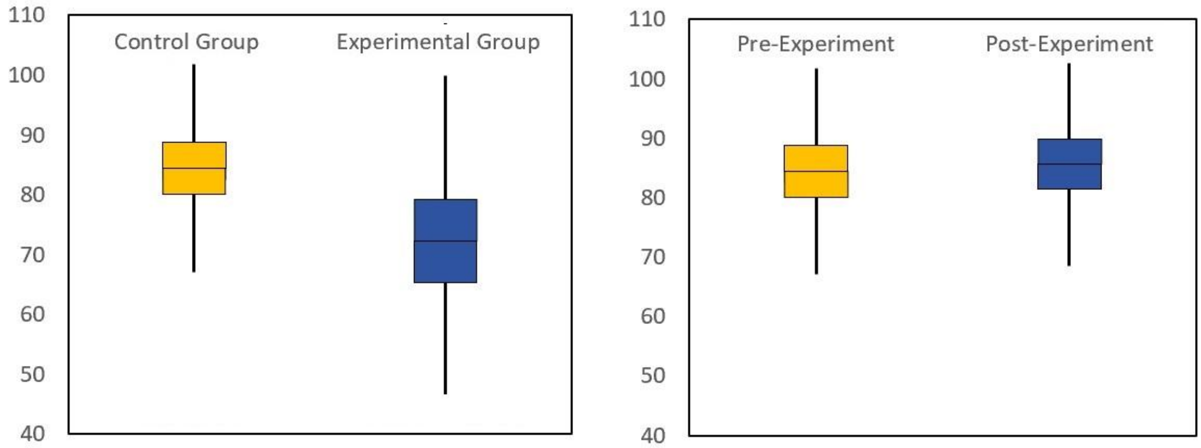
	Workers 1	4	6.45	8	12.90		
	Peasants 2	41	66.12	36	58.06		
	Others 3	6	9.67	3	4.83		
4. Education	Illiteracy 0	7	11.29	21	33.87	3.965	0.056
	Primary school 1	16	25.80	9	14.51		
	Junior high school 2	17	27.41	14	22.58		
	High school 3	18	29.03	15	24.19		
	Professional 4	4	6.45	3	4.83		
5.Income	< 1000 1	22	35.48	27	43.54	0.223	0.637
	1000–3000 0	7	11.29	5	8.06		
	3001–5000 2	13	20.96	15	24.19		
	> 5000 3	20	32.25	15	24.19		
6.Household registration	City 1	45	72.58	38	61.29	1.785	0.181
	Countryside 0	17	27.41	24	38.70		
7.Payment method	Medical insurance 1	44	70.96	37	59.67	1.110	0.292
	NACP 0	18	29.03	24	38.70		
	Self-funded 2	0	0.00	1	1.61		
8.Caregiver	Spouse 0	29	46.77	28	45.16	0.056	0.813
	Children 1	31	50.00	33	53.22		
	Others 2	2	3.22	1	1.61		

4.2. Comparison of Self-care Index BI Scores between the Two Groups Before and After the Experiment

A two-sample independent t-test was employed to assess and compare the experimental self-care index BI (Barthel Index) scores between the two patient groups. Pre-rehabilitation, the self-care index BI scores for patients in the experimental and control groups were (72.26 ± 27.68) and (84.44 ± 17.35), respectively, with no statistically significant differences observed ($P > 0.05$). Following the experimental intervention, the self-care index BI scores for the experimental group and the control group were (80.81 ± 20.61) and (85.65 ± 17.05), respectively, with statistically significant differences being evident ($P < 0.05$). Detailed statistical findings are presented in Table 3, and Figure 11 provides a graphical representation of these results.

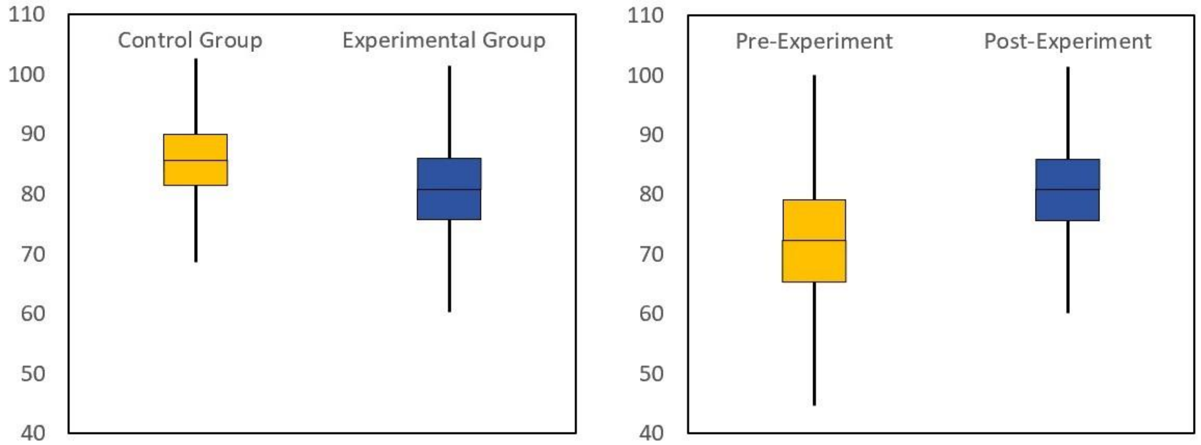
Table 3. Intergroup comparison of self-care index BI scores between the two groups of patients before and after the experiment ($\overline{x} \pm$ SD).

Project	***n***	**Pre-Experiment**	**Post-Experiment**
Experimental group	62	72.26 ± 27.68	80.81 ± 20.61
Control group	62	84.44 ± 17.35	85.65 ± 17.05
t		3.515	2.617
P		0.070	0.043



(a) Pre-experiment.

(b) Control Group.



(c) Post-experiment.

(d) Experimental Group.

Figure 11. Changes in the total self-care index BI score before and after rehabilitation in both groups. (**a**) Pre-experiment; (**b**) Control Group; (**c**) Post-experiment; (**d**) Experimental Group.

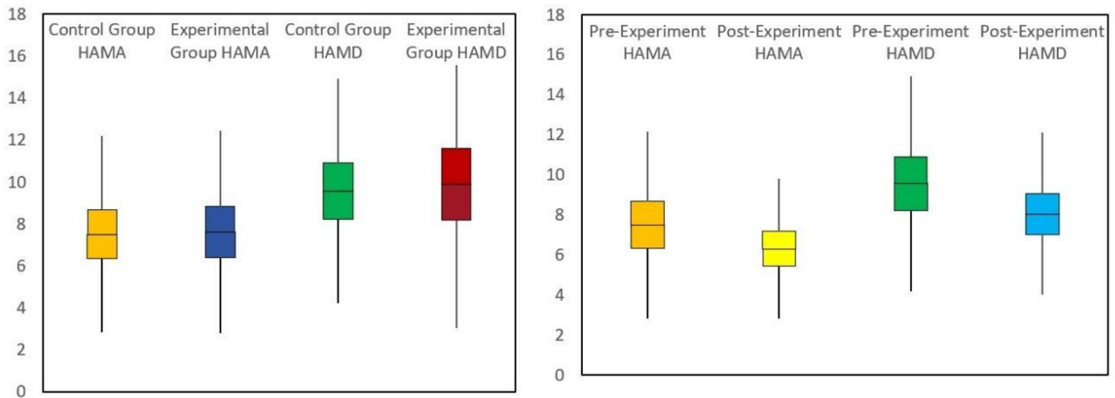
The self-care index BI of the two groups showed that patients using the arch abnormality rehabilitation assistance system recovered their self-care rapidly, but due to the large difference in the prehabilitation BI scores between the two groups, an absolute difference between the two groups could not be demonstrated.

4.3. Comparison of the Results between Hamilton Anxiety Scale in the Two Groups of Patients Before and After the Experiment (Hamilton Anxiety Scale, HAMA) and Hamilton Depression Scale (Hamilton Depression Scale, HAMD)

Two independent samples mean t-test was used to compare the HAMA and HAMD scores of the two groups of patients in the experiment. Before the experiment, the HAMA scores of the patients in the experimental group and the control group were (7.62 ± 4.82) and (7.51 ± 4.67), respectively, and the results were significant ($P < 0.05$); the HAMD scores of the patients in the experimental group and the control group were (9.89 ± 6.86) and (9.57 ± 5.36), respectively, and the results were significant ($P < 0.05$). The HAMA scores of the patients in the experimental group and the control group were (3.67 ± 2.41) and (6.31 ± 3.50), respectively, and the results were significant ($P < 0.05$); the HAMD scores of the patients in the experimental group and the control group were (3.49 ± 2.51) and (8.05 ± 4.05), respectively, and the results were significant ($P < 0.05$). Detailed results are shown in Table 4 and Figure 12.

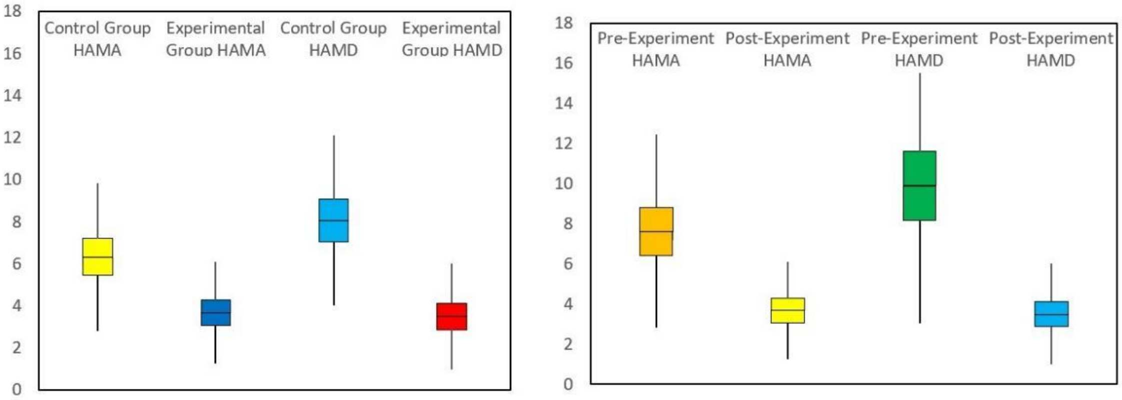
Table 4. Intergroup comparison of HAMA and HAMD scores between the two groups of patients before and after the experiment ($\overline{x} \pm SD$).

Project	*n*	HAMA		HAMD	
		Pre-Experiment	Post-Experiment	Pre-Experiment	Post-Experiment
Experimental group	62	7.62 ± 4.82	3.67 ± 2.41	9.89 ± 6.86	3.49 ± 2.51
Control group	62	7.51 ± 4.67	6.31 ± 3.50	9.57 ± 5.36	8.05 ± 4.05
t	—	0.598	0.448	0.686	0.518
P	—	0.012	0.009	0.014	0.010



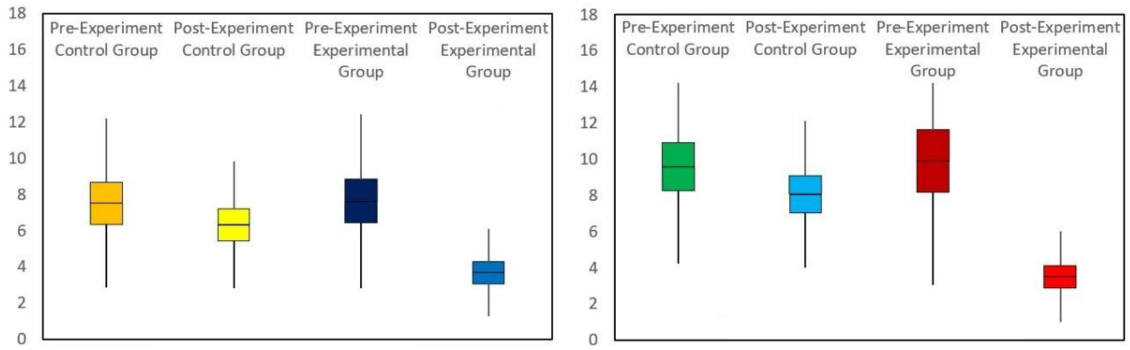
(a) Pre-experiment.

(b) Control Group.



(c) Post-experiment.

(d) Experimental Group.



(e) HAMA.

(f) MAMD.

Figure 12. Changes in HAMA and HAMD scores before and after rehabilitation in the two groups of patients. (**a**) Pre-experiment; (**b**) Control Group; (**c**) Post-experiment; (**d**) Experimental Group; (**e**) HAMA; (**f**) MAMD.

The experimental findings pertaining to the HAMA (Hamilton Anxiety Rating Scale) and HAMD (Hamilton Depression Rating Scale) scores of both patient groups revealed the presence of anxiety and depression among participants prior to the intervention. The utilization of the foot arch abnormality rehabilitation assistance system enabled patients to engage in the rehabilitation process, fostering a self-directed and quantifiable experience of recovery. This approach satisfied the inherent need for self-motivation and self-confidence, leading to a significant amelioration of psychological anxiety and depression symptoms.

4.4. Comparison of Total Motor Function Rating Scale Index Scores between the Two Groups of Patients Before and After the Experiment (Fugl-Meyer Motor Function Assessment, FMA)

Two independent samples mean t-test was used to compare the total motor FMA index scores of the two groups of patients in the experiment. Before the experiment, the total motor FMA index scores of the patients in the experimental group and the control group were (69.26 ± 20.67) and (71.20 ± 21.67), respectively, and the results were not statistically significant (P > 0.05). The total motor FMA index scores of the patients in the experimental group and the control group were (87.87 ± 13.26) and (79.26 ± 17.05), respectively, and the results were significant (P < 0.05). Detailed results are shown in Table 5 and Figure 13.

Table 5. Intergroup comparison of exercise FMA index total ratings in the two groups of patients before and after the experiment ($\overline{x} \pm SD$).

Project	***n***	**Pre-Experiment**	**Post-Experiment**
Experimental Group	62	69.26 ± 20.67	87.87 ± 13.26
Control Group	62	71.20 ± 21.67	79.26 ± 17.05
t		2.774	2.183
P		0.055	0.044

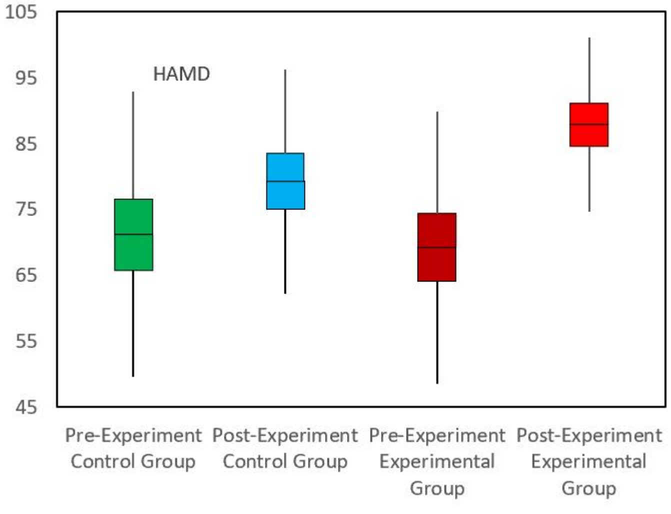


Figure 13. Changes in total exercise FMA index scores before and after rehabilitation in both groups of patients.

The comprehensive motor FMA (Fugl-Meyer Assessment) index scores for both cohorts demonstrated that the implementation of the arch abnormality rehabilitation assistance system yielded more favorable rehabilitation outcomes for the patients. This can be chiefly attributed to the fact that the rehabilitation protocol adopted by the control group remained static and unalterable, resulting in a comparatively lower level of efficiency. In contrast, the experimental group's rehabilitation program exhibited a dynamic quality, characterized by gradual adjustments tailored to the patients' evolving rehabilitation progress, thereby enhancing overall efficacy.

5. Discussion of Results

The intricate biomechanics inherent in the normal human body present a formidable challenge in reconciling disparate research outcomes from various scholars and research institutions. Concurrently, the diverse array of plantar pressure measurement equipment contributes to pronounced discrepancies in measurement outcomes among different instruments, precluding facile inter-comparisons. This paper, however, furnishes insights into the distribution patterns and dynamic plantar pressure characteristics within a delimited population. Nevertheless, a notable lacuna in this study is the absence of a comparative analysis of the clinical rehabilitation efficacy pertaining to biological characteristics. This deficiency underscores the imperative for advancements in this system from an applied perspective.

Presently, surgery stands as the acknowledged pinnacle in achieving orthopedic outcomes; nevertheless, it introduces biomechanical modifications that can impact patient functionality. Given the varying developmental stages of the human body, surgical interventions are not recommended, advocating instead for correction through physical exercise and corrective insoles [28]. While the amelioration of flatfoot deformity through corrective insoles may manifest a gradual improvement in aesthetic appearance, their efficacy in enhancing foot force dynamics and cushioning status is noteworthy, resulting in a reduction of associated injuries. The escalating demand for flatfoot deformity correction, driven by aesthetic considerations, underscores the exigency for further research to delineate effective, safe, and comfortable modalities for rectifying flatfoot deformities.

6. Conclusions

Leveraging plantar 3D scanning technology and gait recognition techniques, the foot arch anomaly rehabilitation assistance system furnishes a rehabilitative milieu that enables patients to recuperate within the confines of their homes while facilitating remote diagnosis. This approach ensures the continuum of care for patients with foot arch anomalies, laying the foundation for a swift enhancement of their quality of life. Simultaneously, the foot arch abnormality rehabilitation assistance system exhibits enhanced adaptability, extending its utility to encompass large-scale screenings for foot arch conditions in educational settings, including kindergartens and primary and secondary schools, thereby offering valuable support for the maintenance of optimal foot health among children and adolescents in China.

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