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ORIGINAL RESEARCH

The Effect of Anthropometric Shoes on Lactic Acid Reduction in Nurses: A Mixed-Methods Study from Indonesia

Nita Fitria[1,*], Putri Karisa[2,*], Tertianto Prabowo[3,*], Ahmad Kharisma Ramadhan[4,*], Muhamad Gustaf Al Fajar[2,*], Setiawan[5,*], Kusman Ibrahim[6,*], Aditya Salya[7,*], Raini Diah Susanti[8,*]

[1]Department of Fundamental Nursing, Faculty of Nursing, Universitas Padjadjaran, Sumedang, West Java, 45363, Indonesia; [2]Professional Nursing Student, Faculty of Nursing, Universitas Padjadjaran, Sumedang, West Java, 45363, Indonesia; [3]Department of Physical Medicine & Rehabilitation, Hasan Sadikin General Hospital, Bandung, West Java, Indonesia; [4]Department of Design Product, Faculty of Art and Design, Bandung Institute of Technology, Bandung, West Java, Indonesia; [5]Department of Basic Medical Science, Faculty of Medicine, Universitas Padjadjaran, Bandung, West Java, 40132, Indonesia; [6]Department of Medical-Surgical Nursing, Faculty of Nursing, Universitas Padjadjaran, Sumedang, West Java, 45363, Indonesia; [7]Department of Management, Faculty of Economic and Business, Universitas Padjadjaran, Sumedang, West Java, 45363, Indonesia; [8]Department of Community Health Nursing, Faculty of Nursing, Universitas Padjadjaran, Sumedang, West Java, 45363, Indonesia

*These authors contributed equally to this work

Correspondence: Nita Fitria, Department of Fundamental Nursing, Faculty of Nursing, Universitas Padjadjaran, Bandung, West Java, 40132, Indonesia, Tel +62 811-2015-188, Email nita.fitria@unpad.ac.id

Background: The mobilization characteristics of nurses' work, such as standing, walking, and transferring patients for a long time, can increase the risk of musculoskeletal disorders. Repetitive activities nurses perform can cause foot problems such as discomfort and insecurity, characterized by increased lactic acid levels. Anthropometric shoes are specifically designed to reduce complaints on nurses' feet.

Purpose: This study aimed to determine the effect of individual anthropometric shoes on lactic acid levels in nurses at the hospital.

Methods: This study used a mixed-method study design. This study involved 71 nurses in the quantitative study and 15 nurses in the qualitative study. Nurses in Emergency Room, Central Surgical Installation, Inpatient Room, Intensive Care Unit, and Outpatient Installation were randomly selected using a stratified random sampling technique. The instruments used were the Accutrend Lactacyd tool, demographic questionnaire and interview questionnaire. Bivariate data analysis was using Statistical Package for Social Sciences (SPSS) and qualitative data analysis using thematic analysis.

Results: This mixed-method study shows that anthropometric shoes can reduce nurses' lactic acid levels. In the quantitative study; there was a significant difference in lactic acid levels of nurses before and after using anthropometric shoes with the average results of measuring lactic acid levels, namely pre-test (22.48 mg/dL) and post-test (16.27 mg/dL), with a p-value (0.000). The qualitative study data revealed positive results related to increased nurse knowledge, positive views on the effect of shoes on nurse performance, and the impact of using anthropometric shoes in providing comfort and safety, such as decreased muscle fatigue and pain.

Conclusion: The findings of this study highlight the effect of individualized anthropometric shoes on lactic acid levels in nurses in Indonesian hospitals. It is essential to conduct further research and evaluate the results in a broader setting to ensure that anthropometric shoes can directly affect lactic acid levels.

Keywords: anthropometric shoes, lactic acid, nurses, Indonesia

Introduction

Work-Related Musculoskeletal Disorders (WRMDs) due to work is a health disorder that often occurs in service workers such as nurses.[1] Nursing is the occupation with the highest prevalence rate of WRMDs globally.[2] The prevalence of foot and ankle pain in nurses was 55.4% in the Intensive Care Unit, 44.4% in the Emergency Room, 40.5% in the Outpatient installation, and 38.1% in the Inpatient Room.[3] A study from Krishnan et al revealed that nurses complained of work-related pain in the lower

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back (86.7%), ankles (86.7%), neck (86.0%), shoulders (85.0%), lower legs (84.7%) and upper back (84.3%).[4] WHO states that the condition will worsen when the nurse's work activity becomes dense.[5]

Shoe selection is very important for nurses as a solution to improving their performance and quality of life.[6] Previous studies revealed that to adjust the use and fit of footwear can, anthropometric shoes should be used.[7,8] Anthropometric shoes are shoes that are specially designed according to the anthropometry of the user's feet. Anthropometric shoes are one of the best solutions in improving foot health, especially related to workload. Improper selection of footwear can cause pain and foot health problems, and reduce the comfort of movement and the ability to carry out daily activities.[9–12] The choice of footwear depends on the needs tailored to the type of work for safety while working.[13] The characteristics of shoes use by nurses include high comfort, light weight, anti-slip, environmentally friendly and good durability.[14] This is related to the characteristics of nurses' jobs that require walking and standing for a long time, so footwear is not only seen based on physical descriptions but functionally to reduce stress on the foot area.[15]

Continuous muscle contraction activity causes anaerobic metabolic activity resulting in increased lactic acid.[16] Lactic acid becomes a biomarker of muscle fatigue and increases the risk of WRMDs.[7,17] WRMDs in nurses can cause a decrease in quality of life and performance which has an impact on burnout.[18,19] Previous studies have revealed that the high work mobility of nurses can cause pain in the feet and ankles, thus interfering with performance and quality of service.[3,11–13] In addition, reports state that foot pain in 60% of women and 30% of men is caused by shoe use.[20] Thus, it can be said that the use of inappropriate footwear can increase the risk of WRMDs characterized by increased lactic acid levels. Therefore, the use of anthropometric shoes can be a solution that needs to be considered.

Various studies reveal the importance of having anthropometric shoes associated with the fit, safety and comfort of the feet when using shoes. The results of a recent study in surgical nurses recommended that the selection of footwear that is comfortable and conforms to the shape of the foot is an important factor to be considered in relation to WRMDs and foot health due to continuous contraction of the foot muscles.[21] However,[22] evidence regarding the effect of anthropometric shoes is limited, especially in the nursing population.[12] In Indonesia, research on anthropometric shoes in nurses has never been conducted. Therefore, this study aimed to determine the effect of individualized anthropometric shoes on lactic acid levels in nurses at the hospital.

Materials and Methods

Study Design

This study used a mixed-methods study design. We conducted two separate quantitative and qualitative studies. Outcome data collected in both studies were integrated to address the research objectives and understand the evidence base.[23] This design was relevant to the subject of the study and provided detailed data to guide the intervention.

The first stage of the pre-experimental method was conducted by testing the effect of anthropometric shoes using the lactic acid test before and after using anthropometric shoes. Meanwhile, the second stage was conducted with qualitative face-to-face interviews to explore nurses' experiences in using anthropometric shoes.

Sampling and Participant Recruitment

The population of this study was nurses of Dr. Hasan Sadikin Central General Hospital Bandung, Indonesia. The study was conducted from June to December 2022. A total of 135 nurses were selected based on the assessment of group work with a high activity level. One hundred nurses were determined based on calculations using the Slovin formula with a significance level of 0.05. We selected 71 nurses who met the inclusion criteria to be surveyed in the quantitative study. In addition, a random selection of participants obtained 15 people (21.12%) to be interviewed in the qualitative study. There was no control group in this study.

The inclusion criteria in this study are nurses willing to wear anthropometric shoes while working for three weeks; not planning on leave or retiring during the study period; not planning or currently taking a job other than as a nurse; and nurses working in Emergency Room, Central Surgical Installation, Inpatient Room, Intensive Care Unit, Outpatient Installation. We excluded participants if they had the following criteria: medical treatment for musculoskeletal problems in the legs, they suddenly participated in activities outside the main duties.

Study Variables, Materials and Instrument

Anthropometric Shoe Development

Anthropometric shoes are designed to improve the shoe's functional aspect toward the foot muscles' health. Foot measurements are taken individually using a 3D foot scanner to ensure the shoe fits the user. An ill-fitting shoe size (too loose or tight) can cause discomfort during use. The 3D scanning method is a recently developed method that can provide all foot dimensions clearly, including length, width, height and circumference.[24,25]

To address the issue of shoe modelling, we consider three aspects that affect shoe fit: user activity level, user profile, and style. These characteristics were determined to obtain a shoe that suits the user, and we defined four shoe models: men's lace-up shoes, women's lace-up shoes, men's slip-on shoes and women's slip-on shoes (Figures 1 and 2). In determining the shoe components, we analyzed several elements that affect the use of shoes:

1. A naturally shaped wide toe box with enough space for the toes to spread out. This way, the toes are not forced to point inward and can work on stabilizing the entire body. This shape we developed differs from typical shoes that restrict the foot's natural posture and function, causing pain and misalignment.
2. Zero drops to restore natural upright posture. When wearing shoes with a high heel, the entire body will shift out of alignment. Wearing shoes with chronically raised heels can shorten the calf structure and reduce the ankle range of motion and pain in the Achilles tendon. Zero-drop shoes provide the best base for a natural, upright posture.
3. Flexible insoles allow the foot to move naturally. When walking, the foot will dynamically perform dynamic movements such as bending, twisting and balancing, which requires insoles that can adapt to the foot's shape.
4. The insole is adapted to the function of the foot structure based on joint movement to support improved performance and maintain energy efficiency. The insole is made using an invention technique, namely an insole concept based on individual anthropometric measurements and continued with foot size mapping so that the insole made supports a foot structure that can reduce fatigue, soreness, and pain while working. The insole is arranged based on the foot's width, the arcus arch's shortest width, the raised arcus's width, and the arcus curvature's height.
5. Each foot has nerve endings that provide sensory feedback when stepping on something. A thinner sole allows the user to feel the surface and the foot to adapt appropriately. Sensory feedback is important in postural stability and dynamic gait patterns.

In the quantitative study, lactic acid was measured using the Accutrend Lactacyd device with the market brand The EDGE and a demographic characteristics questionnaire that included gender, place of work, age, and length of work. In the qualitative study, structured interviews were conducted using a questionnaire containing topics: Nurses' knowledge about anthropometric shoes, the advantages and disadvantages of anthropometric shoes, and the impact of using anthropometric shoes.

Data Collection

Evaluation of the effectiveness of anthropometric shoes was carried out in two ways. In the quantitative study, the nurses measured lactic acid levels before and after using the shoes within three weeks. Lactic acid measurement was chosen to indicate muscle fatigue as the end product of the anaerobic glycolysis process produced by red blood cells and active muscle cells (Bal et al, 2015). Lactic acid measurements were made using the Accutrend Lactacyd device with The EDGE market brand, a type of device that can measure lactic acid levels in a person's blood. Measurements were made by taking 0.05 cc of blood at the fingertip of the sample using blood lancets, then the blood was dripped on a lactate strip and checked using accutrend lactate (lactate meter). Lactic acid measurements were taken before and after participants wore shoes. Scheduling of measurements was carried out simultaneously after participants completed the service according to their respective schedules. All participants were able to know their lactate acid results after they completed the study and lactate acid sampling after the intervention.

The qualitative study was collected using interview guidelines. The primary researcher conducted open-ended inquiry and structured interviews to find out the knowledge and experience in using anthropometric shoes related to the perceived advantages and disadvantages and the impact of using anthropometric shoes. After obtaining informed consent, each

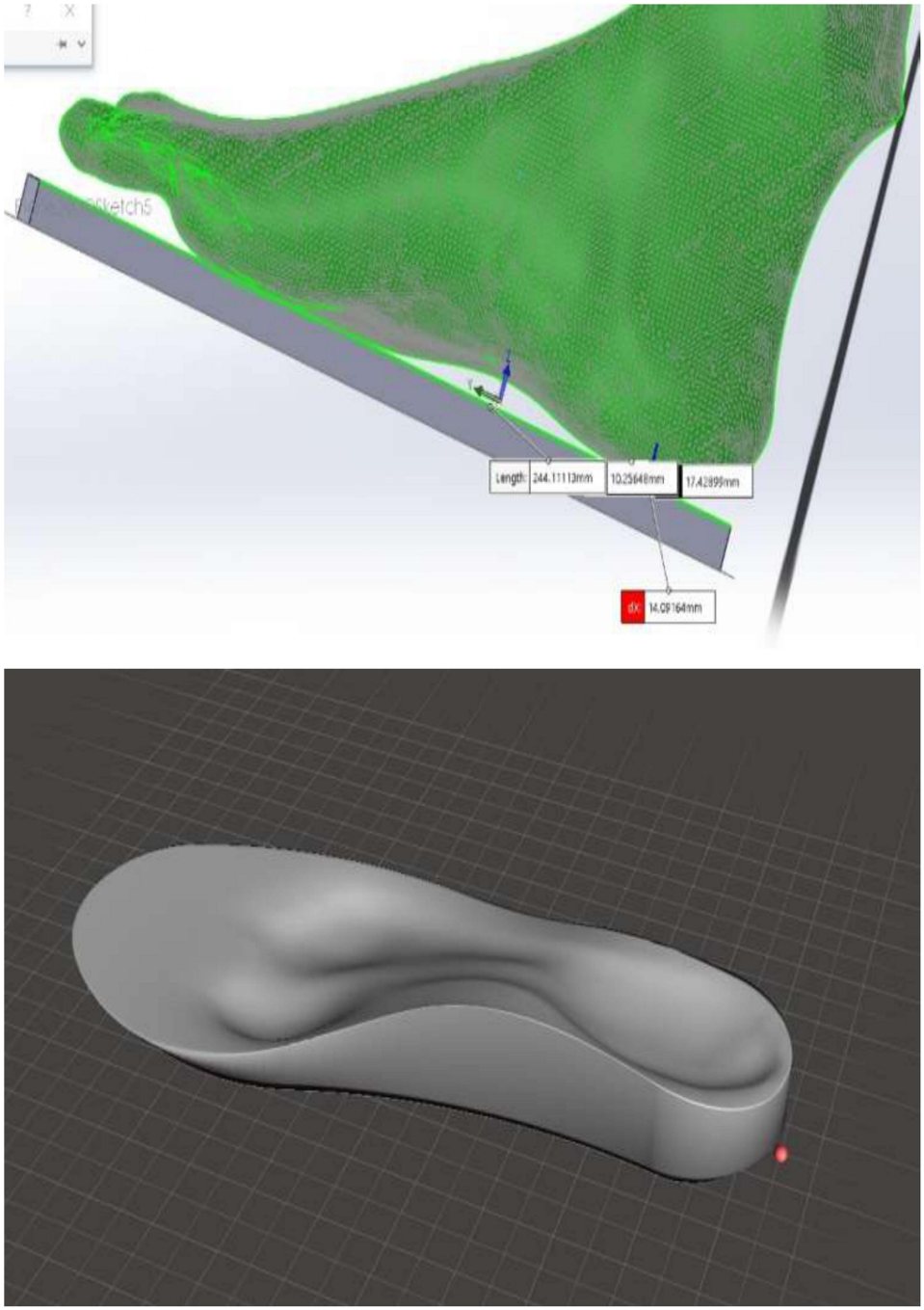

Figure 1 3D scan of foot anthropometry model measurement.

interview lasted 20 to 30 minutes in Bahasa Indonesia, using a voice recorder and written notes. The following questions were asked during the interview: "What do you think is the importance of wearing shoes while working for nurses?"; "What do you know about anthropometric shoes?"; "Have you heard of, owned, or used anthropometric shoes before?"; "What do you feel when using anthropometric shoes?"; "What do you think distinguishes anthropometric shoes from regular shoes?"; "Do you feel pain or soreness when using anthropometric shoes? If so, on which days did they occur?"; "Did you find out the cause of the pain or soreness, and what did you do about it?". All personal information was anonymized, and participants were given initials or codes.

Figure 2 Individual anthropometry shoe design.

Data Analysis

Quantitative Data Analysis

Bivariate data analysis was performed using the Statistical Package for Social Sciences (SPSS) Version 23. Pre and post-test values were looked at to determine the increase or decrease in lactic acid levels before and after work using anthropometric shoes using a paired *t*-test for significance. A p-value (<0.05) is the threshold for statistical significance. In addition, the statistical demographic data of the participants were displayed as frequencies and percentages.

Qualitative Data Analysis

In qualitative data analysis, we used thematic analysis to collect, transcribe, cite, code and examine the data. Both studies were evaluated and prioritized according to the convergent parallel design to accommodate qualitative and quantitative data. Then, the findings of the study were integrated and interpreted. Summary of methods is shown in Table 1.

Ethical Consideration

This study has been approved and exempted from ethics by the health research ethics committee of Universitas Padjadjaran (1063/UN6.KEP/EC/2022). This study also adheres to the Five Rights of Human Subjects in Research.[26] All information from research participants is kept confidential, and each participant's data was anonymized. The participants informed consent was implied upon completion of the survey and included publication of anonymized responses.

Results

Quantitative Study

Overall, 71 people were involved in the quantitative study. The majority of participants were female (56.3%), aged 36–45 years (50.7%), worked in the inpatient room (59.2%), and 16–20 years of work (28.2%). Descriptive statistics for each item are given in Table 2.

Based on the measurement results, there was a significant difference in lactic acid levels of nurses before and after using anthropometric shoes with the average measurement results of lactic acid levels, namely pre-test (22.48) and post-test (16.27). The results of the independent *t*-test showed a significant difference in p-value (0.000) between the measurement results before and after using the shoes, so it can be concluded that there is an effect of using individual anthropometric shoes on lactic acid levels as an indicator of muscle fatigue in nurses (Table 3).

Table 1 Summary of Methods

Study	Quantitative	Qualitative
Research design	Pre-experimental	Explorative
Sampling	Stratified random sampling	Stratified random sampling
Data collection method	A demographic questionnaire and accutrend lactate (lactate meter)	Structured interview
Participants	71	20
Recruitment	Nurses who have high activity-level jobs	Nurses who have high activity-level jobs
Inclusion criteria	• Willing to wear anthropometric shoes while working for three weeks • Not planning or currently taking leave or retirement during the study period • Not planning or currently taking other jobs other than working as a nurse • Emergency Room Nurse • Central Surgical Installation Nurse • Inpatient Room Nurses • Intensive Care Unit Nurse • Outpatient Installation Nurse	• Willing to wear anthropometric shoes while working for three weeks • Not planning or currently taking leave or retirement during the study period • Not planning or currently taking other jobs other than working as a nurse • Emergency Room Nurse • Central Surgical Installation Nurse • Inpatient Room Nurses • Intensive Care Unit Nurse • Outpatient Installation Nurse
Research setting	Hospital	Hospital
Study variables	• Demographic characteristics • Lactic acid levels	• Demographic characteristics • Nurses' knowledge of anthropometric shoes • Advantages and disadvantages of anthropometric shoes • Impact of using anthropometric shoes
Data analysis	• SPSS Version 23 • *t*-test	Thematic analysis

Table 2 Quantitative Participants' Characteristics (n=71)

Domain	Frequency (f)	Percentage (%)
Gender		
Male	31	43.7
Female	40	56.3
Age (years)		
26–35	17	23.9
36–45	36	50.7
46–55	18	25.4
Place of Work		
ER	6	8.5
CSI	9	12.7
IR	42	59.2
ICU	11	15.5
OI	3	4.2
Length of work (years)		
Less than 5	2	2.9
5–10	13	18.3
11–15	14	19.7
16–20	20	28.2
21–25	12	16.9
26–30	7	9.8
More than 30	3	4.2

Abbreviations: Emergency Room, ER; Central Surgical Installation, CSI; Inpatient Room, IR; Intensive Care Unit, ICU; Outpatient Installation, OI.

Table 3 Lactic Acid Levels Before and After the Use of Individual Anthropometric Shoes

Measurement	Pre Test (Mean)	Post Test (Mean)	p-value
Lactic acid	22.48	16.27	0.000

Note: 4.5 −19.8 mg/dL, (Normal lactic acid values).

Qualitative Study

We interviewed 15 nurses and coded each nurse according to the room, including Emergency Room (ER), Central Surgical installation (CSI), Inpatient Room (IR), Intensive Care Unit (ICU), and Outpatient installation (OI). The majority of interviewees were female (60%), aged between 26–35 years (60%), worked in the inpatient room (30.33%), and had 5–10 years of work (40%) (Table 4).

Qualitative data from the study questionnaire yielded three overarching themes to identify nurses' perspectives on individualized anthropometric shoes from a functional perspective: nurses' knowledge about individualized anthropometric shoes, shoe models and the impact of shoe use on nurses' performance and musculoskeletal system complaints. The following are the themes and codes from the interviews:

Theme 1: Nurses' Knowledge of Individual Anthropometric Shoes

This theme aims to determine nurses' understanding of individualized anthropometric shoes, including nurses' knowledge of the benefits and functions of individualized anthropometric shoes, how to measure them, and the elements within them. Most nurses reported that they know that the shoes they choose affect the quality of their performance because it makes it easier for nurses to perform client mobilization and transfer activities. In addition, a good model will increase nurses' confidence while working. Examples of anthropometric shoe function responses include:

Table 4 Qualitative Participants' Characteristics (n=15)

Code of Participant	Gender	Age (Years)	Place of Work	Length of Work (Years)
ER.1	Male	35	ER	21
ER.2	Female	43	ER	20
ER.3	Female	35	ER	22
CSI.1	Male	42	CSI	16
CSI.2	Male	45	CSI	20
OI.1	Female	30	OI	8
OI.2	Female	27	OI	1
ICU.1	Male	37	ICU	11
ICU.2	Male	31	ICU	5
ICU.3	Female	33	ICU	5
IR.1	Male	38	IR	9
IR.2	Female	44	IR	20
IR.3	Female	33	IR	6
IR.4	Female	31	IR	8
IR.5	Female	34	IR	12

Abbreviations: ER, Emergency Room; CSI, Central Surgical Installation; IR, Inpatient Room; ICU, Intensive Care Unit; OI, Outpatient Installation.

When working nurses do need footwear or shoes that can support work, such as light and comfortable. (ER.1)

The footwear worn can support nurses' performance and confidence in terms of modern and comfortable shoe models. (ICU.1)

Only a few nurses knew how to measure the elements of anthropometric shoes. Some nurses had seen videos or photos in the medical rehabilitation department or on the internet, but most only currently knew how to take comprehensive foot measurements. However, some nurses had customized shoes according to foot size and mapping.

To measure feet usually only know about the length of the foot, never measure other parts of the foot. (CSI.1)

When buying shoes, only based on the universal size based on the shoe number, not custom. (ER.3)

The medical rehabilitation department has taken foot measurements to make shoes, but only for clients, not for us. (OI.1)

I have shoes that are customized according to foot shape and size, but not many because they are expensive. (CSI.2)

Theme 2: Advantages and Disadvantages of Individual Anthropometric Shoes

We explored nurses' perceptions of the advantages and disadvantages of shoes. Nurses had a positive view of the effect of shoes on nurse performance due to comfort and safety.

The anthropometric shoes tested had advantages and disadvantages. In terms of material, nurses revealed that the material used is flexible, easy to clean, feels light, has strong laces, is anti-slip, and the inner insole feels soft. Nurses reported that, when using the shoes, they felt safe and comfortable.

In addition, some nurses revealed the shortcomings of anthropometric shoes: the cushioning element at the arcus is uncomfortable, and the base is parallel to the surface, especially for nurses who are used to wearing shoes with heels. Nurses who have never used leather shoes feel that the shoes are too stiff. Nurses who experienced weight gain reported hot feet because the shoes lacked ventilation. Some responses to the advantages and disadvantages of individualized anthropometric shoes are:

The shoes are comfortable to feel, not slippery and light. However, it seems too thin, and the cushion in the middle makes the foot feel something is blocking because this is the first experience of using shoes like this. (ICU.1)

The shoes are soft and light but have not yet adapted to the cushioning in the shoe insole. A few days later, I got used to it and was comfortable. (ER.1)

I am used to wearing shoes that have heels, so it feels strange because these shoes are flat to the surface. (OI.1)

I have gained weight, so the shoes feel hot and sweat easily on the instep because the size is too narrow. (IR.3)

Theme 3: Impact of Using Individual Anthropometric Shoes

Participants expressed their experiences in using shoes, both favorable and unfavorable impacts. The cushioning element in the shoe insole to support the arcus of the foot was highlighted by many nurses. The majority of nurses stated that cushioning can increase foot comfort. The findings of this theme show that using anthropometric shoes affects muscle fatigue and reduces foot pain, which indicates that the shoes excel in providing comfort and safety.

The protruding cushion on the insole makes me more comfortable because the entire sole is like flat with the surface. (ER.1)

The cushioning of the foot inside the shoe is more comfortable when walking because it feels like the foot is balanced and not afraid of sprains. (ER.3)

The size of the cushion is appropriate because the measurements are quite complex, so it is comfortable. (IR.1)

Anthropometric shoes are designed to improve nurses' performance by reducing the risk of musculoskeletal disorders. We found that some nurses reported pain and soreness while using anthropometric shoes because they were not used to it and it was not the correct size. However, nurses revealed they felt comfortable if they were used to it.

On the first to the third day, I felt pain due to the adjustment to the new shoe model with the arcus cushion. But on the fourth day onwards, it felt comfortable. (ER.2)

I felt pain during the first week of using the shoes because the size was not appropriate. Like there was an error in making shoes that did not fit the size. (IR.2)

I think these shoes are comfortable But if we pull the laces too tight, it feels painful. (CSI.1)

When the activities in the room are not too busy, I don't have any complaints. But when the activity is busy with a lot of patient transportation to the operating room, I feel sore feet. (IR.4)

For surgery activities with complex operations, I feel uncomfortable using shoes because I have to stand for a long time. In addition, in the room, we are used to using special slippers, so I am not used to using shoes. (CSI.2)

On the fifth day, I felt pain because the shoes were too thin for me, who was used to wearing thick shoes. (IR.5)

The decreasing lactic acid value evidences the success of using anthropometric shoes. Nurses expressed happiness when lactic acid levels in their bodies decreased after using anthropometric shoes. The group that experienced an increase in lactic acid reported that the increasing workload in the room influenced it.

I am happy that lactic acid can decrease because these shoes are comfortable compared to the shoes I have. (ER.1)

My lactic acid level increased because the work in the room was busy, and I didn't have time to sit at all today. (IR.3)

Discussion

This study reported several findings. In the quantitative study, there were significant results on the lactic acid levels of nurses before and after using anthropometric shoes. This is in line with data from the qualitative study, which revealed positive outcomes related to increased nurse knowledge, positive views regarding the effect of shoes on nurse performance, and the impact of using anthropometric shoes in providing comfort and safety, such as decreased muscle fatigue and pain.

The choice of footwear is very important for individuals to prevent symptoms of musculoskeletal disorders in carrying out daily activities.[27] Shoes are made for reducing pain, facilitating maximum foot function, preventing musculoskeletal disorders and injuries, and improving the quality of life of individuals, including nurses.[28,29] Therefore, comfort, safety and quality are the main things individuals consider when choosing shoes.[30] Shoe comfort and safety are assessed based on benefits and functionality.[13] Misuse of shoes will risk several problems, namely loss of ankle range of motion, peripheral neuropathy, balance and gait.[31–33] The risk of slipping, tripping, and falling injuries is also possible.[34]

The results of our qualitative study show that nurses are aware that shoe selection affects the quality of performance, positive views regarding the use of individualized anthropometric shoes that we developed with the characteristics of a "toe box made with enough space width, Zero drops, Flexible sole, insole with invention technique, and thin sole" on the comfort and safety of nurses such as decreased muscle fatigue and reduced pain. However, it still has shortcomings due to other factors such as weight and experience. Wang et al revealed that supportive shoes can reduce leg muscle fatigue.[35] Meanwhile, using unstable shoes results in pain and fatigue in the leg muscles.[36,37] The cushioning of the heel in the shoe affects energy expenditure so that optimal cushioning has an impact on reducing muscle activity.[38] Using leather shoes with a light mass shows lower muscle activation than heavy shoes.[39] In addition, shoe soles that are too flexible or flexible and rigid also cause higher levels of muscle fatigue.[40]

Nurses' work characteristics have a high activity load, which affects the increase in lactic acid levels in the body. The workload in each room is different depending on the characteristics of the job.[41,42] The findings of this study highlight that anthropometric shoes designed explicitly for nurses can provide comfort and safety to nurses' feet, as evidenced by decreased lactic acid levels. A person's activities will cause the body's physiological response to increase lactic acid; the intracellular pH will decrease, and the muscles will experience fatigue.[16] Therefore, to prevent an increase in lactic acid and reduce the amount of ATP turnover,[43] using the right shoes is very important to help prevent increased lactic acid.

Strength and Limitations

This study still has several limitations, including a small sample size and only one hospital, and the study did not include a control group, so there is a tendency for one hospital work culture, which may cause bias. In addition, the different work schedules and workloads each day and the situational nature of the room made the results more diverse. To our knowledge, this is the first mixed-method study in Indonesia to investigate the effect of individualized anthropometric shoes on lactic acid levels in nurses in hospitals conducted in five ward settings. In addition, the mixed methodology can provide in-depth information regarding the measurement results of individualized anthropometric shoes on lactic acid levels in nurses.

Conclusion

The findings of this study highlight the effect of individualized anthropometric shoes on lactic acid levels in nurses in Indonesian hospitals. Through a mixed method study, it is known that individualized anthropometric shoes can decrease lactic acid, decrease leg muscle fatigue, and increase safety and comfort while working, which impacts optimal work in care.

Our findings show the potential to be developed and applied in other room settings, health services, and other health workers such as doctors, pharmacists, midwives, therapists, and others. Furthermore, the future plan of this study is to develop a shoe model. In addition, it is important to conduct further research and evaluate the study's results in a broader setting to measure the level of nurse performance and foot health after using anthropometric shoes to ensure that anthropometric shoes can have a meaningful effect.

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Disclosure

The authors report no conflicts of interest in this work.

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