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Towel Curl and Short Foot Exercises on the Medial Longitudinal Arch in Children with Flat Foot: A Pre-Experimental Study

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Abstract

Introduction: Pes planus (flat foot) is a common condition in children characterized by a decrease in the medial longitudinal arch, which can affect balance, increase the risk of musculoskeletal injuries, and impact motor development. Towel curls and short foot exercises are believed to strengthen foot muscles and improve arch stability. This study evaluates the effectiveness of combining these exercises in children with flat feet.
Methods: A pre-experimental study with a one-group pretest-posttest design was conducted on 10 boys aged 6–8 years from SD No 3 Kuwum who met the inclusion criteria (flat foot in the right foot for standardized measurement, no lower limb injuries, good dynamic balance, and effective communication). The intervention lasted 20 weeks, with sessions three times per week. Evaluations were conducted using the wet footprint test and Clarke's angle measurement. Data analysis was performed using a paired sample t-test in SPSS 26.0.
Results: Post-intervention, there was a significant improvement in the medial longitudinal arch ($p = 0.001$; $p < 0.05$), with an average increase in Clarke's angle of 1.0 ± 0.67 degrees, compared to the normal range of 25°–42°.
Conclusion: The combination of towel curl and short foot exercises effectively improves the medial longitudinal arch in children with flat feet. This study supports these exercises as part of physiotherapy interventions, although further research with a controlled design is needed for stronger validation.

Keywords: Pes Planus, Towel Curl, Short Foot Exercise, Clarke's Angle, Wet Footprint Test.

Introduction

A flat foot, also known as pes planus, is characterized by a reduced or underdeveloped medial longitudinal arch in the foot. It is a common condition in children, with a prevalence ranging from 14% to 28% in elementary school-aged children. This condition is often associated with valgus deformity or pronated hindfoot, leading to a planovalgus condition. The medial longitudinal arch plays a crucial biomechanical role in supporting body weight and maintaining balance in a static stance and during dynamic activities.[1] Flat foot can impact overall biomechanics, affecting daily activities, increasing lower limb muscle fatigue during prolonged walking or standing, and impairing balance, ultimately reducing productivity.[2] Additionally, flat feet can lead to uneven weight distribution on the foot, which, over time, increases pressure on structures such as the plantar fascia, patella, and tibia. This can heighten the risk of developing conditions like patellofemoral pain syndrome, plantar fasciitis, and medial tibial stress syndrome, especially in physically active individuals.[3]

Physiotherapy intervention is a primary approach for managing flat feet, one of which involves a combination of towel curls and short foot exercises. The towel curl exercise is designed to strengthen intrinsic foot muscles using a towel as a prop to enhance ankle function and stability.[4] One of its advantages is that it is easy for elementary school-aged children to perform, as it requires only a towel. This exercise effectively trains toe grip strength, improving ankle stability during walking, running, and stair climbing.[4] Repetitive execution of this exercise can enhance intrinsic foot muscle strength and improve balance components.[5]

In addition, short foot exercise is a sensorimotor training method to activate intrinsic and extrinsic foot and ankle muscles to improve the medial longitudinal and horizontal arch.[6] While towel curl exercise focuses on intrinsic muscle strength, short foot exercise optimizes sensorimotor control. The combination of these two exercises is expected to have a synergistic effect, providing a more comprehensive improvement in the medial longitudinal arch compared to either exercise alone. Short foot exercise is particularly effective in significantly increasing the medial longitudinal arch and enhancing the function of the abductor hallucis muscle, which supports body weight during the push-off phase of gait. Moreover, this exercise strengthens the flexor hallucis brevis, which helps maintain the medial longitudinal arch during the terminal stance phase of the gait cycle.[7] Therefore, the combination of towel curl and short foot exercises is anticipated to synergistically rehabilitate children with flat feet.

Despite evidence supporting the effectiveness of towel curl and short foot exercises separately in improving the medial longitudinal arch, research on their combined effect remains limited. Previous studies have demonstrated the benefits of these exercises individually, but no study has specifically investigated their synergistic effect in children with flat feet.[8] Thus, this study aims to evaluate the effectiveness of combining these exercises in improving the medial longitudinal arch in children with flat feet at SD No 3 Kuwum.

This research holds significance in pediatric physiotherapy, which focuses on movement and function in children, including their growth and development. Children with flat feet often experience physical activity limitations, potentially affecting the biomechanical development of their feet. The findings from this study are expected to serve as a foundation for physiotherapists in designing more effective and easily implementable rehabilitation programs for children with flat feet, particularly in school or pediatric clinical settings.

This study hypothesizes that the combination of towel curl and short foot exercises will significantly improve the medial longitudinal arch compared to pre-intervention levels. The null hypothesis (H_0) states that there is no substantial improvement in the medial longitudinal arch following the intervention. In contrast, the alternative hypothesis (H_1) posits that these exercises effectively enhance the medial longitudinal arch in children with flat feet at SD No 3 Kuwum. Therefore, this study aims to evaluate the effectiveness of the combined towel curl and short foot exercises in improving the medial longitudinal arch in children with flat feet at SD No 3 Kuwum.

Methods

This study employed a pre-experimental design using a one-group pretest-posttest non-randomized trial. This design was chosen because it allows the evaluation of intervention effects within the same group before and after treatment without a control group. However, its limitation is the absence of comparison with a non-intervention group, making the results susceptible to external factors. The study utilized the same evaluator for all measurements to minimize bias and adhered to a standardized exercise protocol to maintain internal validity.

The study was conducted from August to December 2024 at SD No. 3 Kuwum. The population comprised first- and second-grade male students aged 6–8 years. Third-grade students were excluded as they did not meet the predetermined age criteria. A purposive sampling technique was used to select participants who met specific inclusion criteria relevant to the study's objectives instead of random sampling, which could yield a broader, less controlled sample variation. Ultimately, 10 participants were selected. Although the sample size was relatively small, it was deemed adequate based on effect size estimations from previous studies, with a significance level of 0.05 and a power of 80%. The intervention consisted of towel curl and short foot exercises performed three times per week over four weeks, from 9:00 AM to 10:00 AM WITA, in a designated school activity room adapted for the intervention.

The inclusion criteria were male children with unilateral flat feet on the right foot, as determined by Clarke’s Angle measurement, no lower limb injuries, dynamic balance impairments, and the ability to communicate effectively. The right foot was selected to reduce biomechanical variability and ensure consistency in outcome evaluation. Exclusion criteria included children with musculoskeletal disorders in the lower limbs, unhealed open wounds, genu valgum or genu varum conditions, and the use of arch-supporting footwear. The diagnosis of flat foot was based not only on Clarke’s Angle but also confirmed by a physiotherapist through additional clinical assessments to ensure diagnostic accuracy. Participants who were absent for more than three consecutive sessions, sustained injuries during training, or did not complete the post-test were dropouts.

The short foot exercise was performed in a standing position, where participants pulled their toes toward the heel without moving the ankle, holding the muscle contraction statically for 30 seconds across five sets. Meanwhile, the towel curl exercise was conducted in a seated position with feet flat on the floor, using a towel to grip and curl with the toes. This movement was performed with muscular contractions for five seconds, repeated five times per set, totaling five sets per session. A physiotherapist supervised each session to ensure the correct technique. Before engaging in independent training, participants received live demonstrations and an initial practice session to ensure proper movement execution. Weekly evaluations were conducted to monitor adherence and ensure exercises were performed according to protocol.

Measurements were conducted using the wet footprint test with Clarke’s Angle, calculated based on the angle formed between a line connecting the first metatarsal head to the heel and the foot's medial arch. This method is highly reliable in identifying flat feet in children, as supported by previous research indicating an intra-rater reliability coefficient above 0.85. The same evaluator took measurements to minimize inter-rater bias. Additionally, intra-rater reliability was tested by performing Clarke’s Angle measurements twice on a pilot sample before the study commenced.

Data analysis was conducted using SPSS version 26.0. A paired t-test was used for normally distributed data, while the Wilcoxon signed-rank test was applied to non-normally distributed data. Before hypothesis testing, the Shapiro-Wilk test was conducted to determine the appropriate analytical method. To address potential missing data, analysis was performed using a per-protocol approach. In this study, no participants were excluded from the analysis as all completed the intervention and post-test.

This study received ethical approval under clearance number 64/EA/KEP-UNDHIRA/2024, ensuring compliance with ethical research principles. In addition to parental consent, informed consent was obtained from participants in simplified language to ensure their understanding of the study’s objectives and procedures, which aligned with ethical research principles.

Results

Based on the research, the data presented reflects the effects of towel curl and short foot exercises on the medial longitudinal arch in children with flat feet at SD No. 3 Kuwum from August to December 2024. The research data is reported following the study procedure, which included pre-test and post-test assessments of the study sample. The

following flowchart illustrates the selection process and participant progression to clarify the number of participants at each study stage.

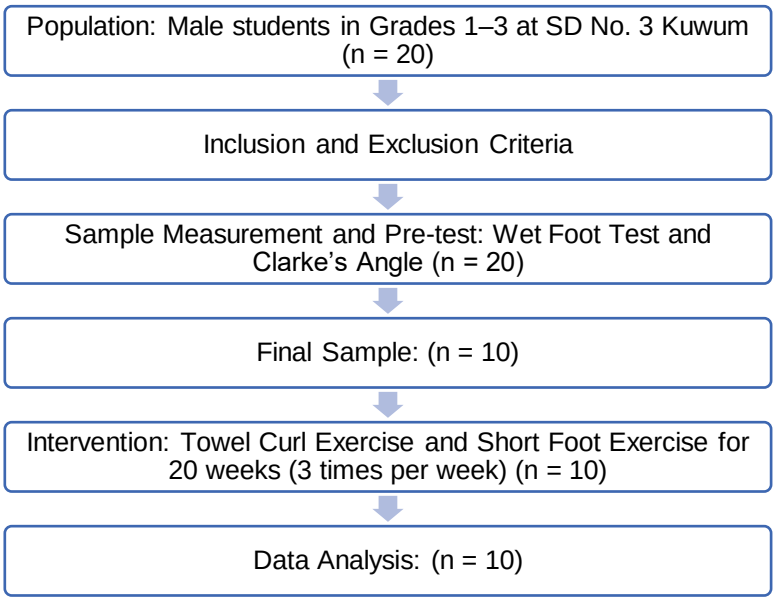

Figure 1. Participant Flowchart

At the initial meeting, parents were provided with informed consent forms as proof of their agreement for their child's participation in the study. Children whose parents consented were screened according to the inclusion, exclusion, and dropout criteria. In this study, no participants dropped out, allowing all eligible participants to complete the intervention.

As the first step, all first- and second-grade students at SD No. 3 Kuwum underwent assessment using the wet footprint test to determine the degree of their medial longitudinal arch. If the test indicated a child had flat feet, they were immediately included as a research sample. A total of 10 children were selected as participants and completed the study. Before receiving the towel curl and short foot exercises, vital signs were measured, and the intervention was carried out for 20 weeks, with training sessions conducted thrice weekly.

The towel curl exercise was performed in a seated position using a towel or cloth under the sole, while the short foot exercise was conducted in a standing position.

Table 1. Sample Characteristics

Category	Variable	Frequency (n)	Percentage (%)
Gender	Male	10	100%
Age (Years)	6	3	30%
	7	4	40%
	8	3	30%
BMI Category	Normal	10	100%

As shown in the table above, all participants in this study were male, aged between 6 and 8 years, and had a body mass index (BMI) within the normal range.

Table 2. Degree of Arch in the Right Foot Before and After Intervention (Mean ± SD)

Condition	Mean ± SD
Pre-test	4.00 ± 1.15°
Post-test	5.00 ± 1.05°

A mean increase of 1.0° in arch angle was observed after the intervention. Additionally, the data distribution is illustrated in the bar graph below to provide a more precise visualization of changes in arch angle before and after the intervention.

Table 3. Paired Sample T-Test Results

Comparison	Mean ± SD	95% Confidence Interval	t	df	Sig. (2-tailed)
Pre-test vs. Post-test	1.0 ± 0.67	-1.47690 to -0.52310	-4.743	9	0.001

The paired sample t-test results indicate a negative t-value (-4.743), signifying an improvement in the arch angle following the intervention. The p-value of 0.001 ($p < 0.05$) demonstrates that the difference between pre-test and post-test measurements is statistically significant.

Throughout the intervention, no adverse effects or complications were reported. All participants completed the training sessions without complaints or difficulties. Given that the study sample was homogeneous (all participants were male, aged 6–8 years, and had normal BMI), no additional subgroup analyses were conducted. However, future research should consider additional variables, such as baseline physical activity levels or the severity of flat feet, for a more comprehensive analysis.

Furthermore, the findings of this study align with previous research, which has shown that intrinsic foot muscle training, such as towel curls and short foot exercises, is effective in enhancing medial longitudinal arch support in

individuals with flat feet. These results support the implementation of similar interventions in rehabilitation programs for children with this condition.

Sample Characteristics

The study sample consisted of 10 male participants. This study focused on male children because they have twice the risk of developing flat feet compared to females. This is due to slower arch development and a lower medial longitudinal arch in boys. The prevalence of flat feet in male children reaches 60.8%, whereas in female children, it is 39.2%.[4]

The participants were between 6 and 8 years old, with the following distribution: three participants (30%) were six years old, four participants (40%) were seven years old, and three participants (30%) were eight years old. At ages 8–12, some children still experience flat feet because their bone and muscle structures are still developing. Studies have reported that the prevalence of flat feet is 57.4% at age six and decreases to 42.8% by age eight due to the development of the medial longitudinal arch.[9] Balance within this age range is crucial for motor development. Although children generally exhibit adequate balance at this stage, continuous training and improvement are necessary. The medial longitudinal arch undergoes significant improvements until around age six, then slows until age ten. Beyond ten years of age, substantial changes in arch structure are no longer observed.[6]

The combination of Towel Curl Exercise and Short Foot Exercise for Enhancing the Medial Longitudinal Arch

As shown in Table 5, the study assessed pre-test and post-test results using the wet footprint test, followed by Clarke's angle measurement. Clarke's angle is a widely used index in research, along with the Staheli Index and the Chippaux-Smiraux Index. A 2015 study on adults found that Clarke's angle had the highest specificity (90.7%) compared to the other indices. The likelihood of obtaining a negative result in individuals with flat feet was 0.11 times lower than in those with standard feet. This indicates that Clarke's angle is highly accurate for diagnosing flat feet.[7]

Table 3 presents the paired sample t-test results. Among the 10 participants, the analysis yielded a p-value of 0.001, where $p < 0.05$, indicating a significant difference between pre-test and post-test balance measurements. The effect of the intervention is also reflected in the average Clarke's angle, which increased by 1° from the pre-test to the post-test (effect size X). This finding supports the research hypothesis that the combination of towel curl and short foot exercise effectively enhances the medial longitudinal arch in children with flat feet at SD No. 3 Kuwum.

This result aligns with previous studies suggesting that strengthening exercises targeting toe muscles, including calf stretch, towel curl, and towel stretch, can improve balance. These exercises enhance muscle strength at the neuromuscular junction and within muscle fibers, supporting balance components.[10]

Combining towel curl and short foot exercise improves the medial longitudinal arch (MLA). Both exercises target intrinsic foot muscles, particularly the flexor digitorum brevis, abductor hallucis, and other supporting muscles. Towel curl exercise serves as a dynamic exercise to strengthen the toe flexors, whereas short foot exercise is an isometric exercise to improve stability and core foot strength. This combination provides a synergistic effect by enhancing both muscle strength and neuromuscular control, ultimately leading to structural and functional improvements in the medial longitudinal arch.[1]

Short foot exercise explicitly activates intrinsic and extrinsic foot muscles, helping correct both longitudinal and transverse arches while improving biomechanical stability. fiveClick or tap here to enter text. Short foot exercise enhances shock absorption capabilities and optimizes upper extremity biomechanics.[8] Proper technique is essential for targeting intrinsic foot muscles effectively. This ensures the activation of key intrinsic muscles such as the lumbricals, flexor hallucis brevis, flexor digiti minimi brevis, abductor hallucis, quadratus plantae, flexor digitorum brevis, and abductor digiti minimi, all of which contribute to MLA formation. Studies have shown that MLA improvement occurs more rapidly in children who exercise regularly than those who rely solely on natural development. Strengthening the flexor digitorum brevis, abductor hallucis, and lumbricals significantly enhances foot arch stability.[9]

This study has several limitations that should be considered when interpreting the findings. The small sample size ($n = 10$) may limit the generalizability of the results to a broader population, highlighting the need for more extensive studies to improve external validity. Additionally, selection bias may exist since only male children were included, meaning the findings may not apply to female or older age groups. The lack of a control group is another limitation, as the effectiveness of the intervention cannot be compared to a non-intervention group. Furthermore, the wet footprint test used in this study may have potential measurement biases, necessitating an evaluation of inter-rater reliability to ensure consistent results. Future studies with a control group are needed to establish more objective intervention effects.

This study was conducted exclusively on male children from a single elementary school, limiting the ability to determine whether similar effects would be observed in female children or children from different regions. Additionally, environmental factors, such as the availability of instructors, exercise facilities, and children's habitual physical activity levels, may influence intervention effectiveness. Other variables, including body weight, physical activity habits, and environmental conditions, could also impact training success and should be considered in future research. This exercise program can be implemented at home under parental supervision. However, for optimal effectiveness, initial guidance from a physiotherapist is recommended to ensure proper technique execution.

This study demonstrates the effectiveness of the intervention in improving the medial longitudinal arch. However, further research is needed to determine the long-term effects after training cessation. While no significant adverse effects were reported, some children experienced mild muscle fatigue, soreness, or difficulty performing the movements correctly. Proper supervision during training is essential to minimize the risk of injury.

Compared to previous studies, these findings are consistent with research demonstrating that intrinsic foot muscle-strengthening exercises can improve foot structure and balance. However, additional experimental studies with stronger

research designs must validate these findings. Moreover, long-term studies must evaluate whether MLA improvements persist or diminish after discontinued training.

Conclusion

Based on the findings of this study, the combination of towel curl exercise and short foot exercise, performed three times per week from 09:00 to 10:00 WITA over 20 weeks, was effective in improving the Medial Longitudinal Arch (MLA) in children with flat feet at SD No 3 Kuwum. The results indicated an average increase of 1° in Clarke's angle, suggesting structural improvement in the MLA following the intervention. This study involved 10 boys as the sample, making these findings preliminary and necessitating further research with a larger sample size before they can be generalized.

This study has several limitations. One major limitation is the lack of control over participants' daily activities, which may have influenced the results. Additionally, the flat foot assessment method did not include more precise techniques such as radiography or bone scans, which could provide more objective findings. Furthermore, these results cannot be generalized to a broader population, particularly girls or different age groups.

For future research, a longitudinal study design is recommended to evaluate the long-term effects of these exercises. Including a control group could also help compare the intervention's effectiveness. The use of more accurate diagnostic tools, such as radiography or bone scans, is advised to obtain more valid and objective data on MLA changes. Future studies could also explore the effects of these exercises on other parameters, such as balance, gait biomechanics, or foot muscle strength, and investigate variations in exercise frequency to determine their effectiveness under different conditions. Additionally, considering the clinical implications of these findings is essential, particularly for integrating these exercises into school-based or physiotherapy clinic intervention programs to support children with flat feet more comprehensively.

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