

Development of a baby walker with an integrated speed-limiting system to enhance safety and support infant motor skill development



Islamiyati Islamiyati^a  | Sadiman Sadiman^a  | Yoga Tri Wijayanti^a  |
Kusumawardhany Airlangga Rijanti^b  | Huminsa Ranto Morison Panjaitan^c  | Riza Muhida^d  |
Muhammad Riza^d 

^aProgram Studi Kebidanan Metro Poltekkes Kemenkes Tanjung Karang, Lampung, Indonesia.

^bRSUD Jendral A. Yani Metro Lampung, Indonesia.

^cRSUD Sukadana Lampung Timur, Indonesia.

^dDepartment of Mechanical Engineering, Universitas Bandar Lampung, Kota Bandar Lampung, Indonesia.

Abstract The use of baby walkers to promote infant motor skills is widespread, but safety concerns remain due to the risk of falls and accidents. This study aims to develop a baby walker with an integrated speed-limiting system to enhance safety while supporting motor development in infants aged 9 to 15 months. The walker incorporates a braking mechanism activated by an optical encoder sensor when the speed exceeds 0.3 meters per second. The prototype was tested with ten infants, and results demonstrated its effectiveness in maintaining safety and fostering motor skills. Expert feedback affirmed the design's suitability, emphasizing the importance of technological integration in enhancing product safety. Future improvements could include additional safety features like anti-collision sensors.

Keywords: baby walker, infant motor skills, speed-limiting system, safety control, anthropometric design

1. Introduction

Motor skill development is a fundamental aspect of infant growth, with early walking being a critical milestone in achieving independence (Yaghini et al., 2020). Baby walkers have become popular tools among parents to stimulate walking motor skills, especially in infants with delayed motor development. However, the safety of baby walkers has been widely debated due to the risk of accidents such as falls, which often occur because of the accelerated speed of the walker compared to an infant's natural walking speed (Nunes et al., 2022). In fact, studies have shown that many injuries are linked to the lack of anti-collision mechanisms and inadequate speed control in traditional baby walkers (Dogan et al., 2009; Grivna et al., 2015).

Despite these concerns, baby walkers remain widely used, particularly in developing countries where parents seek to enhance their children's motor development while managing household responsibilities (Albarrak et al., 2021). Research indicates that while 92% of parents believe in the benefits of baby walkers for improving their child's walking abilities, only a small proportion are aware of the associated risks (Albarrak et al., 2021). Consequently, there is a pressing need for safer designs that integrate advanced control systems to mitigate these risks.

To address this issue, this study presents the development of a baby walker prototype with an integrated electronic safety control system. The proposed design incorporates a speed-limiting mechanism using sensors and actuators to ensure that the walker operates within safe speed parameters, thereby reducing the likelihood of accidents (Fan et al., 2018; Wu et al., 2023). Anthropometric data were utilized to tailor the walker dimensions to the physical characteristics of infants aged 9 to 15 months, ensuring both ergonomic suitability and safety.

Figure 1 illustrates two main types of infant walkers available on the market: the push walking mode and the sitting mode. In the sitting mode, infants sit within the walker and move while seated, which pediatricians generally discourage as it limits the use of leg muscles necessary for walking or standing. In contrast, the push walking mode encourages infants to use their legs to propel the walker, promoting muscle development. Given the preference for push walkers among pediatricians, this study focuses on developing a baby walker in push walking mode.

This research aims to provide a safer alternative to traditional baby walkers by leveraging technological innovations to enhance safety while promoting motor skill development. The findings offer valuable insights into product safety standards and have the potential to inform future advancements in child mobility aids (Casman et al., 2021).

2. Literature Review





Figure 1 Types of baby walkers available on the market: (a) push walking mode and (b) sitting mode.

The use of baby walkers as tools to promote early motor development in infants has been both widely adopted and critically examined in recent years. While baby walkers are popular for their perceived benefits in stimulating walking skills, research has raised concerns about their safety and developmental impacts (Melike et al., 2019). Several studies have identified the risks associated with baby walkers, including falls, collisions, and delays in independent walking skills due to over-reliance on the device (Nunes et al., 2022; Remec et al., 2023).

One of the primary safety concerns with traditional baby walkers is the lack of speed control, which can lead to accidents when the walker moves faster than an infant can manage (Feng et al., 2013; Sharov et al., 2018). The American Academy of Pediatrics has strongly discouraged the use of baby walkers, recommending instead that parents focus on natural walking practices and safer alternatives (Dogan et al., 2009; Grivna et al., 2015). These recommendations are supported by data indicating a significant number of injuries related to baby walker use, particularly in households with stairs or uneven flooring (Rodgers & Leland, 2005).

Despite these risks, the use of baby walkers remains prevalent, particularly in regions where access to safer alternatives may be limited. In a study conducted in Saudi Arabia, 90% of surveyed families reported using baby walkers, with most parents unaware of the potential developmental delays or safety hazards (Albarrak et al., 2021). The continued use of baby walkers in these contexts underscores the need for improved designs that mitigate safety risks while retaining their developmental benefits.

Recent technological advancements have sought to address these safety concerns through the integration of electronic control systems in baby walkers. Research by Nanda et al. (2023), Fan et al. (2018), and Wu et al. (2023) highlights innovations such as speed limiters, braking mechanisms, and alarm systems designed to enhance safety. These studies demonstrate that incorporating sensors, microcontrollers, and actuators can significantly reduce the risk of accidents, making baby walkers safer for infants while preserving their intended benefits.

Moreover, the integration of anthropometric data into the design of baby walkers can further enhance safety and usability. By tailoring the dimensions of baby walkers to the specific physical characteristics of infants, researchers have shown improvements in both ergonomic fit and developmental outcomes (Indonesia Ministry of Health, 2020). The use of such data ensures that baby walkers are appropriately sized for the target age group, thereby reducing the risk of injury and promoting proper motor development (Lu et al., 2016).

The current study builds on this body of work by developing a baby walker with an integrated speed-limiting system and other safety features. This approach seeks to combine the developmental benefits of baby walkers with enhanced safety measures, providing a viable solution for parents and caregivers seeking to support their infants' motor skill development in a secure environment.

Recent studies emphasize not only the physical but also the psychological and developmental impacts of baby walkers on infants. Prolonged use of walkers may limit an infant's opportunity for natural exploration, which is crucial for both motor and cognitive development (Bezgin et al., 2021). Furthermore, a lack of interaction with natural walking environments can affect spatial awareness and problem-solving skills (Chagas et al., 2020). These findings underline the need for designing walkers that allow safe usage while fostering an environment for developmental milestones.

It is essential to address gaps in current research by providing safe baby walker designs that not only focus on preventing accidents but also promote balanced developmental outcomes. The present study contributes to this by integrating a speed-limiting mechanism and using anthropometric data to ensure the walker supports natural motor functions while maintaining safety standards (Wu et al., 2023). This combination aims to mitigate the identified psychological risks and promote overall development in infants.

3. Methods

The development of the baby walker with a speed-limiting system was conducted in several phases: design, prototyping, and testing. This methodology aimed to ensure that the walker meets safety standards while supporting infant motor development.

3.1. Design Phase

The design phase began with a review of existing baby walkers to identify safety gaps and areas for improvement. Anthropometric data from infants aged 9 to 15 months, collected according to the standards set by the Indonesian Ministry of Health (2020), were used to determine the optimal dimensions of the walker. Key measurements included body height, shoulder width, arm length, and stride length, ensuring the walker’s ergonomic fit for the targeted age group.

The walker was designed to include a speed-limiting mechanism, incorporating an optical encoder sensor to measure the walker’s velocity. This sensor relays data to an Arduino Nano microcontroller, which regulates the servo motor-based braking system. When the walker’s speed exceeds 0.3 meters per second, the system triggers the brakes, ensuring the walker’s speed remains within safe limits.

3.2. Prototyping Phase

A prototype of the baby walker was constructed using the designed specifications as shown in Figure 2. The prototype included a frame, wheels, a speed sensor, and a braking system. The frame was built to provide stability and ease of use for infants. The braking system utilized rubber clamps powered by a servo motor to halt the walker when necessary, as depicted in Figure 3. Materials for the prototype were chosen based on their durability, weight, and safety, ensuring the walker could support an infant’s weight while being easy to maneuver.

The material selection was a key consideration for ensuring the walker’s durability and safety. Lightweight yet durable materials such as high-density polyethylene (HDPE) or Soft Wood were chosen for the frame to support the weight of infants and resist wear from repeated use. HDPE offers a favorable strength-to-weight ratio, ensuring the walker remains easy to maneuver while withstanding long-term use (Verma et al., 2022). The wheels were constructed from thermoplastic elastomers, providing both flexibility and resistance to abrasion, ensuring smooth movement across different surfaces.

Additionally, durability testing was performed to assess the walker’s lifespan under simulated real-world conditions. The walker underwent repeated loading tests to ensure the frame and wheels could withstand extended use without compromising safety.

Figure 4 shows a flowchart of the automatic braking mechanism for the baby walker. The flowchart illustrates the process by which the optical encoder sensor detects wheel speed, the microcontroller evaluates whether the speed exceeds 0.3 meters per second, and the servo motor activates the braking system to halt the walker’s motion, ensuring safe operation. The braking mechanism of the baby walker. The flowchart outlines the following steps:

1. Sensor Detection: The optical encoder sensor continuously monitors the speed of the walker’s front wheels.
2. Speed Evaluation: The speed data is sent to the Arduino Nano microcontroller, which compares the current speed with the preset limit of 0.3 meters per second.
3. Brake Activation: If the speed exceeds this limit, the microcontroller signals the servo motor to activate the brake.
4. Braking Action: The servo motor rotates, causing the rubber brake clamps to engage the front wheels, halting their motion.
5. Feedback Loop: The system continuously checks the speed and adjusts the brake position to maintain safe operation.

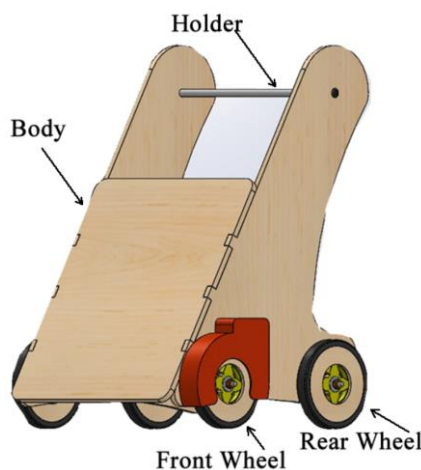


Figure 2 A prototype of the baby walker.

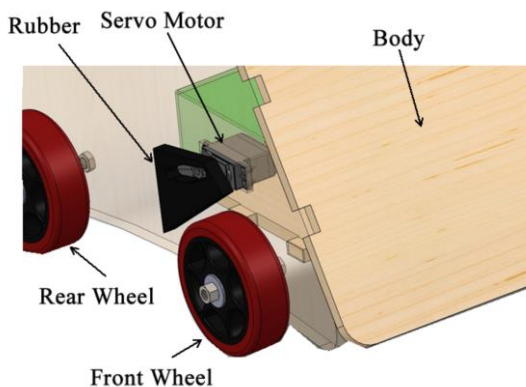


Figure 3 A brake mechanism of baby walker.

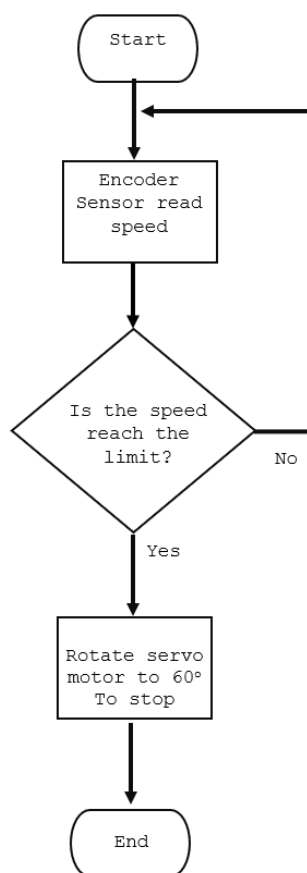


Figure 4 Flowchart of the automatic braking mechanism for the baby walker.

3.3. Testing Phase

The prototype was evaluated through a series of tests with ten infants aged 9 to 15 months. The tests were conducted in a controlled environment, ensuring the safety of all participants. Each infant's interaction with the walker was observed, focusing on their ability to push, stand, and walk using the walker. The speed control mechanism's effectiveness was assessed by monitoring how the braking system responded when the walker's speed exceeded 0.3 meters per second.

In Figure 5 shows an infant using the baby walker equipped with a speed limiter system. The figure shows an infant interacting with the baby walker, demonstrating the effectiveness of the speed-limiting mechanism. As the infant pushes the walker, the optical encoder sensor monitors the speed. When the walker's speed approaches the safety threshold of 0.3 meters per second, the braking mechanism engages, ensuring the walker slows down or stops. This visual representation confirms the walker's ability to maintain a safe speed, promoting both safety and motor skill development in infants.

Video recordings were used to capture the infants' behavior and the walker's performance. Key metrics included the distance walked, the speed of the walker, and the infant's ability to use the walker effectively and safely. Feedback from

pediatricians and medical rehabilitation specialists was also collected to assess the walker's design, size, shape, material, color, and safety features.



Figure 5 An infant using the baby walker.

3.4. Data Analysis

Data collected from the testing phase were analyzed to evaluate the performance of the baby walker's speed-limiting system and its impact on infant motor development. Descriptive statistics were used to summarize the infants' behavior and the walker's performance. Feedback from experts was synthesized to identify areas for further improvement and to validate the walker's safety and usability.

4. Results

4.1. Speed Control System Performance

The baby walker prototype's speed-limiting system was tested with ten infants aged 9 to 15 months. The optical encoder sensor effectively measured the walker's speed, and the braking mechanism activated promptly when the speed exceeded 0.3 meters per second. Figure 6 illustrates that the walker consistently stopped within safe speed limits, confirming the reliability of the speed control system.

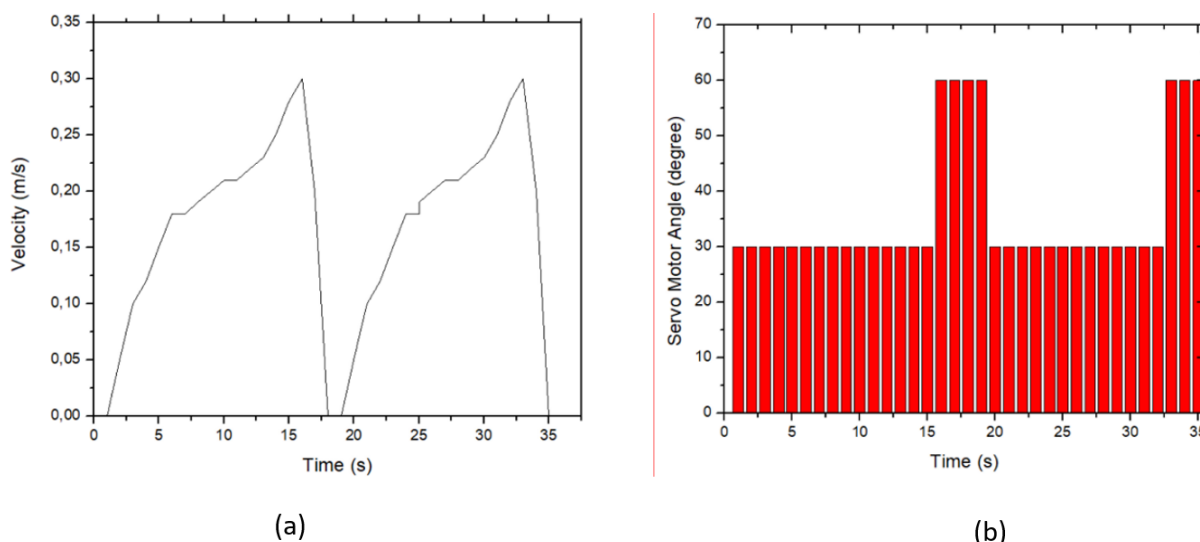


Figure 6 Performance of the baby walker's speed control system: (a) Velocity change over time, showing braking at 0.3 m/s; (b) Servo motor angle adjustment during braking from 30 to 60 degrees to activate the brake and ensure safety.

4.2. Infant Interaction and Motor Development

Observations showed that infants quickly adapted to using the walker. Initially, many infants required assistance to use the walker, but within three days, a marked improvement in their ability to stand and walk independently was noted (Table 1). The number of steps taken by the infants increased significantly over the testing period, indicating enhanced motor skills facilitated by the walker.



Table 1 Observations of Infant Behavior During Baby Walker Use.

Process	Conditions Before Trial	Conditions After Testing
First trial		
Ability to stand alone	Can not	5 seconds
Ability to walk	Can not	1-2 steps
Second trial		
Ability to stand alone	60 seconds	3 minutes
Ability to walk	10-15 steps	30-45 steps
Third trial		
Ability to stand alone	3 minutes	5 minutes
Ability to walk	50-60 steps	65-70 steps

4.3. Expert Feedback on Walker Design

Feedback from pediatricians and medical rehabilitation specialists affirmed the walker’s effectiveness and safety. Experts rated the walker highly for its design, size, shape, material selection, color, and safety features, emphasizing the importance of the speed-limiting mechanism in preventing falls (Table 2). They recommended the walker as a safe and effective tool for promoting motor development in infants aged 9 to 15 months.

Table 2 Expert Evaluation of Baby Walker Design: Feedback from Medical Rehabilitation Specialists and Pediatricians on Design, Shape, Size, Material, Color, and Safety Features.

No	Point of Evaluation	Reviewer 1 (medical rehabilitation specialist)	Reviewer 2 (pediatricians specialist)
1	Tool Design	Very Good	Good
2	Tool Shape	Very Good	Good
3	Tool Size	Very Good	Very Good
4	Material	Good	Very Good
5	Color	Very Good	Very Good
6	Safety System	Good	Very Good

5. Discussion

The results of this study demonstrate the effectiveness of integrating a speed-limiting system into a baby walker to enhance safety while promoting motor skill development in infants aged 9 to 15 months. The speed control mechanism, activated by an optical encoder sensor, successfully restricted the walker’s speed to a maximum of 0.3 meters per second, preventing falls and accidents. This finding aligns with previous studies that emphasize the importance of safety features in baby walkers to mitigate risks (Nunes et al., 2022; Wu et al., 2023).

5.1. Enhancement of Motor Skills

The observed improvements in infants’ ability to stand and walk independently suggest that the baby walker effectively supports motor development. Infants quickly adapted to the walker’s use, and their confidence and motor abilities increased significantly over a short period. This result supports earlier research that suggests well-designed baby walkers can facilitate motor learning and physical development when used appropriately (Casman et al., 2021; Melike et al., 2019).

5.2. Importance of Ergonomic Design

The use of anthropometric data to design the walker ensured that it was appropriately sized for the target age group, enhancing both safety and usability. This ergonomic approach is crucial for infant products, as improper sizing can lead to discomfort or injury. The design’s positive reception by medical professionals further underscores the importance of tailoring baby products to specific user needs, as emphasized by the Indonesian Ministry of Health (2020).

5.3. Limitations and Future Directions

While the study shows promising results, several limitations should be addressed in future research. The sample size was relatively small, which may limit the generalizability of the findings. Future studies should include a larger and more diverse sample to validate the results further. Additionally, incorporating additional safety features, such as anti-collision sensors, could further enhance the walker’s safety profile. Future research should also explore the long-term impact of using such devices on infants’ motor development.

5.4. Implications for Product Design and Safety Standards

The findings from this study have significant implications for the design and safety standards of baby walkers and other infant mobility aids. The successful integration of a speed-limiting mechanism into the walker highlights the potential for



technological innovations to improve product safety. These insights can inform the development of new safety standards and guidelines for baby walkers, ensuring they provide developmental benefits while minimizing risks.

6. Conclusions

This study presents the development of a baby walker equipped with a speed-limiting system designed to enhance safety while supporting the motor development of infants aged 9 to 15 months. The integration of an electronic safety control mechanism effectively restricted the walker's speed to a safe threshold, reducing the risk of falls and accidents. The findings demonstrated that the walker not only aids in developing infants' walking skills but also provides a safer alternative to traditional designs, as confirmed by positive feedback from pediatricians and rehabilitation specialists.

The use of anthropometric data ensured an ergonomic design tailored to the specific needs of the target age group, contributing to the walker's comfort and usability. The study highlights the importance of integrating technological innovations in baby walkers to address safety concerns, offering a viable solution for parents seeking safe and effective tools for their children's motor development.

Future work should focus on expanding the sample size and incorporating additional safety features, such as anti-collision sensors, to further enhance the walker's safety and functionality. This research contributes to the ongoing efforts to improve child safety products and underscores the potential for innovative designs to support infant development in a secure environment.

Acknowledgment

The authors would like to thank Poltekkes Kemenkes Tanjung Karang, Direktorat Jenderal Tenaga Kesehatan Kementerian Kesehatan RI for providing funds in conducting this research. This research was partially funded by the Direktorat Jenderal Tenaga Kesehatan Kementerian Kesehatan RI under scheme Penelitian Terapan Unggulan Perguruan Tinggi 2023 Program.

Ethical considerations

Not applicable.

Conflict of interest

The authors declare no conflicts of interest.

Funding

This research did not receive any financial support.

References

- Albarrak, Y. A., Algwaiz, A. F., Sharaf, A. M., Alahmari, A. A., Albadi, K. A., & Almutairi, A. M. (2021). The reasons and associated injuries related to baby walkers use among children in Riyadh, Saudi Arabia. *Cureus*. <https://doi.org/10.7759/cureus.17122>
- Bezgin, K., Uzun Akkaya, S., Çelik, H. İ., Duyan Çamurdan, A., & Elbasan, B. (2021). Evaluation of the effects of using a baby walker on trunk control and motor development. *Turkish Archives of Pediatrics*, *56*(2), 159–163. <https://doi.org/10.14744/TurkPediatriArs.2020.48742>
- Casman, C., Pursitasari, I., Wijaya, A., & Helfiyanti, Y. (2021). Efek stimulasi dini menggunakan baby walker dan balance bike pada perkembangan motorik anak. *Jurnal Bahana Kesehatan Masyarakat*, *5*(2), 72–77. <https://doi.org/10.35910/jbkm.v5i2.526>
- Chagas, P. S. C., Mancini, M. C., Tirado, M. G. A., Megale, L., & Sampaio, R. F. (2020). Effects of baby walker use on the development of gait by typically developing toddlers. *Gait & Posture*, *76*, 231–237. <https://doi.org/10.1016/j.gaitpost.2019.12.013>
- Dogan, D. G., Bilici, M., Yilmaz, A. E., Catal, F., & Keles, N. (2009). Baby walkers: A perspective from Turkey. *Acta Paediatrica*, *98*(10), 1656–1660. <https://doi.org/10.1111/j.1651-2227.2009.01397.x>
- Fan, Z., Zhao, H., & Liang, Z. (2018). Design of smart baby carriage based on MCU. In *Proceedings of the ACM International Conference* (pp. 286–289). <https://doi.org/10.1145/3305275.3305332>
- Feng, Y. Q., Yin, Y., Zhang, X. R., & Xiao, J. J. (2013). Testing and evaluation of baby walkers based on product injury data. *Advanced Materials Research*, *834–836*, 1628–1631. <https://doi.org/10.4028/www.scientific.net/AMR.834-836.1628>
- Grivna, M., Barss, P., Al-Hanaee, A., Al-Dhahab, F., Al-Kaabi, F., & Al-Muhairi, S. (2015). Baby walker injury awareness among grade-12 girls in a high-prevalence Arab country in the Middle East. *Asia Pacific Journal of Public Health*, *27*(2), NP1507–NP1516. <https://doi.org/10.1177/1010539513498766>
- Indonesia Ministry of Health. (2020). Regulation of Minister of Health Republic of Indonesia No 2/2020 about standard of children anthropometry. Jakarta. Retrieved from <https://peraturan.bpk.go.id/Details/152505/permenkes-no-2-tahun-2020>
- Lu, R. J., Feng, Y. X., Zheng, H., & Tan, J. R. (2016). A product design based on interaction design and axiomatic design theory. *Procedia CIRP*, *53*, 125–129. <https://doi.org/10.1016/j.procir.2016.07.061>
- Melike, M., Gonca, K., & Gülbün, G. (2019). Baby walker use and child development. *International Journal of Pediatric Research*, *5*(1). <https://doi.org/10.23937/2469-5769/1510051>
- Nanda, I. G. P., Udayana, M. I. A., & Putu, K. S. (2023). Rancang bangun smart baby walker berbasis mikrokontroler Arduino Mega. *Magnetika*, *7*(2), 71–78.
- Nunes, P. P., Guimarães, C. C. A., De Oliveira, C. L. A., & De Oliveira, L. L. (2022). Baby walker use: Injuries and developmental delay behind practicality. *Brazilian*

Journal of Development, 8(4), 27768–27776. <https://doi.org/10.34117/bjdv8n4-327>

Remec, N., Eckersley, W., & Smith, B. A. (2023). Commentary on 'Association between baby walker use and infant functional motor development.' *Pediatric Physical Therapy*, 35(2), 242–242. <https://doi.org/10.1097/PEP.0000000000001003>

Rodgers, G. B., & Leland, E. W. (2005). An evaluation of the effectiveness of a baby walker safety standard to prevent stair-fall injuries. *Journal of Safety Research*, 36(4), 327–332. <https://doi.org/10.1016/j.jsr.2005.06.010>

Sharov, A. N., Krivova, A. V., Rodionova, S. S., & Zakharov, V. P. (2018). Damage associated with the use of baby walkers. *Pediatric Traumatology, Orthopaedics, and Reconstructive Surgery*, 6(4), 48–58. <https://doi.org/10.17816/PTORS6448-58>

Verma, S., Singh, R., & Pant, K. K. (2022). Comparative performance of high-density polyethylene composites: A durability analysis. *Polymer Engineering & Science*, 62(3), 923–934. <https://doi.org/10.1002/pen.25803>

Wu, Y., Chiu, Y.-J., Deng, T.-H., & Shih, Y.-H. (2023). Design of intelligent baby walker. In *Proceedings of the Conference* (pp. 239–249). https://doi.org/10.1007/978-981-99-0848-6_18

Yaghini, O., Goodarzi, M., Khoei, S., & Shirani, M. (2020). Effect of baby walker use on developmental status based on ages and stages questionnaire score (ASQ). *Iranian Journal of Child Neurology*, 14(1), 105–111.