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Factors in Ergonomic Design of 6-to-18-month Baby Carriers for Elderly People

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ABSTRACT

The main objective of this study was to formulate an ergonomic design factor for 6-to-18-month baby carrier from simulated loading point data and physical parameters of an average Thai elderly person. The research steps were as follows: (1) reviewing the literature on 6-to-18-month baby carrier designs; (2) simulating the forces acting on a few selected baby carriers and on the body of an average Thai elderly person carrying them; and (3) synthesizing ergonomic design factors based on load-bearing data as well as the physical parameters of an average Thai elderly person. Four ergonomic design factors were synthesized: 1) their shoulder and hip posture while they are using the carrier, 2) the seat and backrest of the baby carrier, 3) the load-bearing points on the body of the carrying person, and 4) the type of baby carrier. Our findings may benefit designers of cushion seat and baby stroller.

Keywords: 6-to-18-month, baby carrier, ergonomic design

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INTRODUCTION

Traditional lifestyle of people in Thailand has been drastically changed, socially and economically, by modern advances in science, technology, and innovation. The changes have exerted tremendous impacts on families, the smallest unit of the society, in terms of family structure, size, and lifestyle as well as the relationships among family members (Photisita, 2009),

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especially on big families where grandparents and young children live together (Husserl, 1965). Boonkwang and Ayuwat (2017) stated that the movement of laborers from the country to big cities to work had resulted in isolation of members of the older generation. Many workers have also put their children into the sole care of their grandparents. This trend is expected to be ever increasing in the rural areas of Thailand.

Temporary childcare strongly affects the lifestyle of elderly people. Komjakkraphan and Chansawang (2015) found that currently, for many families in Thailand, childcare had been relegated solely to elderly members of the family. Moreover, they may also have to earn some auxiliary income for the family in addition to taking care of their own affairs. Jendreck (1993) stated that as elderly people took on the role of temporary parents; they were affected in four ways: (1) they became exhausted; (2) they lost their relationship with their friends; (3) they might have less time to spend with their family members; and (4) misunderstanding might occur between elderly people and their mates. To conclude, Thai elderly people among elderly populations of countries around the world, have a distinctive lifestyle of obligated to raise their grandchildren in a modern rural society. Thus, they need good tools that will help perform this task effectively and conveniently. An ergonomic baby carrier is one such tool for Thai elderly people.

World Health Organization has released the following statistics: one-third of the elderly population slips and falls at least once in a year, and the trend is that 28-35% of elderlies over 65 years of age will slip and fall in a year. This percentage increases to 32-42% for elderlies 70 years of age. As people grow old, they suffer calcium loss from bones, making them fragile. In combination with weaker muscles, their bones are easily broken from a physical (Atthawuttikul & Chavalkul, 2018). It is expected that Thailand will be faced with an aged society in 2021. This means that Thailand has a very short time to prepare a response to demographic change. Therefore, lifestyle and social restructuring, including collaboration of all sectors, will need to support the elderly society and relationship to a family this situation (Punyakaew et al., 2019).

A good relationship between parents and children, from infant to three years old, helps stimulate the children's development. It helps promote development of their physical abilities such as maintaining a good balance, making precise movement, practicing recognition by the sense of touch, coordinating the eyes and the hands to do certain activities, and developing gross motor skills (Elaine et al., 2017), as well as their mental abilities such as recognition, observation, and memorization of objects and their surroundings, analytical ability, and communication by physical actions (Thanatchang, 2007). Figure 1 shows three types of baby carriers for 0-to-36-month-old babies (Pollack-Nelson, 2000; Cirelli, 2014). Parents are instinctively attached to infants by nature, whereas elderly people taking the role of the parents are not by nature. Nevertheless, they provide love and care for the children as surrogate parents.

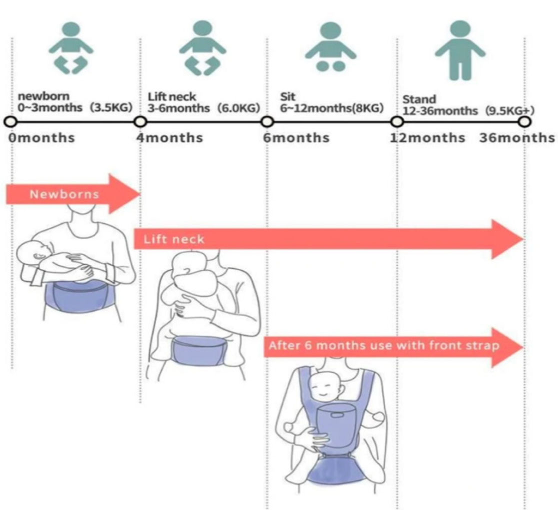


Figure 1. Three different types of baby carrier for 0-to-36-month-old babies. (Infantino Baby Carriers, 2020)

In taking care of small children and doing some activities together, oftentimes, elderly people need to carry the child or support its weight. A baby carrier is divided into 5 types: (1) stretchy wrap; (2) ring sling; (3) woven wrap; (4) Mei-tai; and (5) structured carrier (Dr. Sears Wellness Institute, 2019), as shown in Figure 2 and Table 1. The authors were interested in investigating the structured carrier which should be suitable for babies at 6 to 18 months of age and older till they reached a weight of 18-20 kg. For elderly people, this kind of carrier has a wide and padded hip belt that can distribute the weight of the baby to the hip and not to their shoulders. Andersson (2019) stated that a child should sit in an ergonomic posture, a frog posture, for the parent. Its weight should be supported by the pelvis and thighs of the parent. The back of the parent also supports the baby weight. A parent can place a baby in a tummy-to-tummy position or back-to-tummy position. Some carriers also let the parent place a baby on his or her hip. Structured carriers are among the most comfortable carriers, especially if one still intends to carry a child when it gets bigger and heavier.

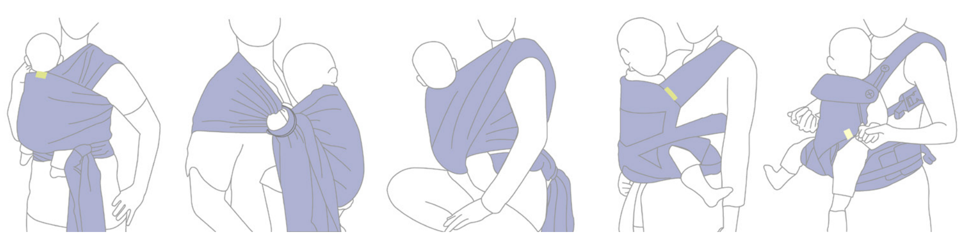


Figure 2. Five common types of baby carrier. (Andersson, 2019)

The physiological postures of child carrying are of 4 types; (1) front-carry (facing-in), (2) front-carry (facing-out), (3) back-carry, and (4) hip-carry, as shown in Figure 2. Baby carriers for these different postures are of different designs. Since a 6-18-month-old baby should have opportunities to be stimulated by its parent and the environment, the design of a carrier should allow a baby those opportunities, i.e., the carrier should have a padded frame that can support the baby for a long time without tiring it, and the carrier should let the baby face out toward the environment and away from the torso of the parent.

Table 1
References for types of baby carrier research

Type of baby carriers	References
1. Stretchy wrap	Fista et al., 2019
2. Ring sling	Fista et al., 2019
3. Woven wrap	Fista et al., 2019; Brown et al., 2018; Jones, 2017
4. Mei tai	Kim & Yun, 2013
5. Structured carrier	Bleah & Ellett, 2010; Fista et al., 2019; Brown et al., 2018; Lee & Hong, 2018

The structure of a baby carrier today has not been designed with the ergonomic of elderly people in mind because the shape of the carrier does not fit their body well (Bleah & Ellett, 2010). In addition, there is a relatively wide gap between the carrier and the person carrying the baby, hence it is possible that the baby may wriggle out of the cradle of the carrier and fall. This is especially dangerous for a small baby because it still cannot hold its posture tightly enough, and when it must put its weight on the seat of the carrier for a long time, it may wriggle or limp and fall. Today's carrier is also not so ergonomic for the elderly person carrying the baby because the weight of the baby is supported only by the torso of the elderly person. Moreover, for a young baby, its neck cannot be held rigidly by itself, so the elderly person carrying the baby may have some difficulties at handling the neck of the baby so that it does not grate with the side bands of the carrier, i.e., the baby may get injured, and it is difficult for an elderly person carrying it to prevent that.

Therefore, good design factors for a 6-18-month-old baby carrier for an elderly person play an important role in preventing baby's neck grating injury and breathing difficulty. The weight distribution of the carrier on the body of the elderly person carrying the baby is also needed to be aligned according to the ergonomic of the elderly person and anyone who may carry the baby. Finally, good design factors should enable a baby to fully develop, both physically and mentally.

The first main objective of this study was to determine, by computer simulation, high loading points of 4 baby carrier designs and loading points on a person carrying each one of them. The second was to use the obtained loading points and physical parameters of elderly people to synthesize ergonomic design factors of baby carriers for elderly people.

METHODS

Theoretical Consideration

Four types of 6-to-18-month baby carriers for elderly people were gleaned from Andersson, 2019 and considered in this study. Front-carry (facing-out) type was considered the best type because it allows the baby to observe and learn the world in front of it. Hence, the authors focused on the design of this type of baby carriers shown in Figure 3.

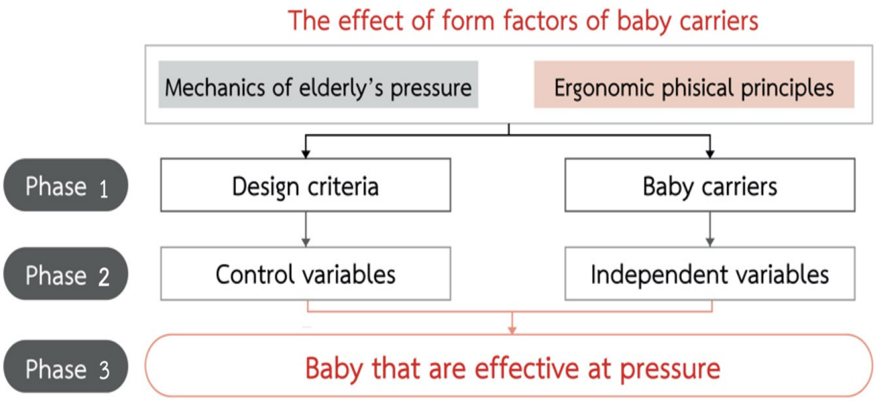


Figure 3. Methods theoretical framework.

Baby Carriers. Three front-carry baby carriers were purchased from a shop in Bangkok, Thailand. The three baby carriers: D1, D2, and D3 shown in Figure 4, were of different designs. All three were imported from England and rather quite expensive compared to other baby carriers that the shop was offering.

Figure 4. Infantino brand 6-to-8-month baby carrier. (Baby Best Buy in Thailand. 2020)

Sampling Method. A questionnaire survey was conducted on samples of a population of prospective consumers of baby carriers, a Thai border senior population-population of seniors with good physical conditions but still at risk of some disability, as defined by Okochi et al., (2005) in his classification of seniors. Samples were purposely selected from a senior care center in Ladkrabang district, Thailand. Living in a suburb of Bangkok Metropolitan, their viewpoints and attitudes on living and lifestyle were various. They were life-embraced elders as defined by Komjakkraphan & Chansawang (2015). The items in the questionnaire were questions on the participant's demographic information, on their use of baby carrier in everyday life, and on baby carrier usage issues that they encountered. Their responses to the questionnaire were crucial information for our synthesis of ergonomic design factors of baby carriers for elderly people.

Simulation. Three-dimensional models of baby carriers were constructed with 3D Studio Max software. The models were then inputted into ANSYS Engineering Simulation & 3D Design Software. ANSYS determined the load of a baby's weight on any point of the three-dimensional model of each carrier. The main purpose was to find the point on each carrier that bore the maximum load, which would be key data for synthesizing factors in ergonomic design. ANSYS is a force-simulation program used by many big corporations such as Toyota, Honda, and Hyundai to simulate the designs of their products.

Procedure. (i) The first step of this work was to consider all available choices of 6-18 months-old baby carriers reported in the research literature and commercial market to find several suitable carriers to test. In the end, three facing-out carriers were selected. They were the top three models, most popularly picked by Thai consumers according to a survey by a website called 'Baby Best Buy in Thailand (2020)'. They were also the three top-selling items.

(ii) Next is the construction of 3D models of the carriers. The models were constructed with 3D Studio Max software. Images of the models—D1, D2, and D3—are shown in Figure 5. They differed in the shape of the and the attachment locations of the shoulder straps. The dimensions and geometry of the models were identical to the real carriers, and all physical differences between the carriers were accurately incorporated into the models.

(iii) The three 3D models were imported into ANSYS force simulation software along with all necessary physical parameters such as earth gravity constant = ~9.600 N.m/s (Brown et al. 2018), stiffness = ~0.40 MPa., flexibility = ~0.26 MPa., and durability = 1.6 MPa. (Michael & Ash, 2007) against impact force.

(iv) The simulation software was run on a PC on Windows platform with an i5 CPU and 8 gigabytes of RAM. High and low loading points were represented by different colors

(1) D1 model (2) D2 model (3) D3 model

Figure 5. Dimensions and geometry of D1, D2, and D3 simulated baby carrier models**.**

in the simulated images of the models. The highest loading points are represented by red color, and the lowest loading points are represented by blue color.

(v) The nature of the loading-points of all 6-to-18-month carriers' baby from ANSYS force simulation results was analyzed, and the components of the carrier associated with low loading-points were included in the ergonomic design factors.

RESULTS AND DISCUSSION

Table 2 shows the results of our simulation experiment—simulated images of three baby carriers and their load-bearing points along with the materials and physical dimensions of their parts. It can be observed that D3 was able to support the highest load, while D1 supported the lowest load. The reason that D3 performed better than D1 and D2 is that it did not have as many weak points (areas supporting a high load) as the other two (Fista et al., 2019). Incidentally, the high load areas on the person wearing a carrier found from the simulation output were quite consistent with the responses to an item in the questionnaire that the participants have experienced pains in their shoulders, waist, and torso. Taking this simulation output into account, we synthesized factors in ergonomic design for Thai elderly people.

The four main factors in ergonomic design for elderly people were the following: (1) their shoulder and hip posture while they were using the carrier; (2) the seat and backrest areas discussed by Moore et al. (2012) as load-bearing points of baby carriers; (3) the load-bearing points on their body as investigated by Glover (2012); and (4) the type of baby carrier.

Regarding (1), from a survey by Punyakaew et al. (2019), eight elderly people 62 to 85 years of age (a mean of 70) offered their opinions that the carrier did not fit the baby well—the baby's head could not be positioned above the carrier's cover, and it might get suffocated. Another survey by Brown et al. (2018) reported an opinion that the shoulder strap of a baby carrier was not strong enough or did not fit the physique of elderly people well which made the elderly people fear that the baby might fall from the baby carrier.

Table 2
Simulated images and load-bearing points of baby carriers of 3 types (areas color-coded by load magnitude)

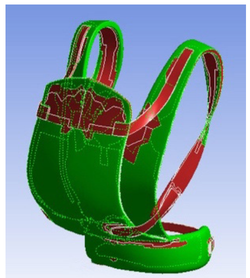
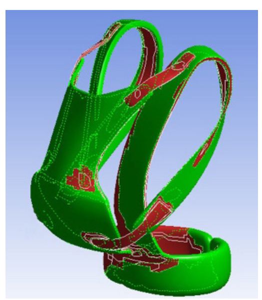
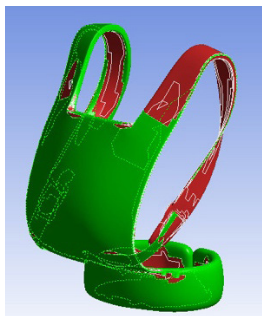
Item	Model	Material	Size (inch.)	Weight (g)	Load bearing-point
D1	 Green areas are areas of low load; red areas are areas of high load.	**Main materials:** 60% cotton and 40% polyester **Lining:** 100% cotton **Waist belt:** 100% polyester	- Waistband thickness 4” - Width of shoulder straps 3” - Main Body including waistband 18” tall, 13.5 wide - Hip Strap 28” to 53” with 27.5” of padding - Shortest possible length of shoulder straps 17” - Fit baby from 8-40 mm.	995	Shoulder, back, and pelvis belt
D2	 Green areas are areas of low load; red areas are areas of high load.	**Main material:** 50% cotton and 50% polyester **Lining:** 100% cotton **Waist belt:** 100% polyester	- Waistband thickness 4” - Width of shoulder straps 3” - Main body including waistband 21” tall, 19” wide - Hip Strap 28” to 32” with 12.5” of padding - Shortest possible length of shoulder strap 15” - Fit baby from 15-45 mm.	993	Shoulder, chest, and pelvis belt

Table 2 *(Continued)*

Item	Model	Material	Size (inch.)	Weight (g)	Load bearing-point
D3	 Green areas are areas of low load; red areas are areas of high load.	**Main material:** 40% cotton and 60% polyester **Lining:** 100% cotton **Waist belt:** 100% polyester	- Waistband thickness 4” - Width of shoulder straps 3” - Main body including waistband 15” tall, 18” wide - Hip Strap 28” to 32” with 12.5” of padding - Shortest possible length of shoulder strap 15” - Fit baby from 20-60 mm.	997	Shoulder and back belt

Additionally, another survey by Jones (2017) reported an opinion that the shoulder straps were too long and awkward so that the baby carrier was not convenient to use.

Regarding (2), seat and backrest were discussed by Moore et al. (2012) as load-bearing points of baby carriers. From our simulation, the D3 carrier (H-type baby) was the best at supporting a load. In our opinion, this was because the back-cushion seat of D3 was very large and wide compared to those of D1 and D2 (H-hip type). This finding is not in accordance with a report by Lee & Hong (2018) that X-type baby carriers were able to support a load well, especially the shoulder straps.

Regarding (3), Glover (2012) investigated load-bearing points on the body of elderly people and reported that the dimensions of the soft slings used for shoulder attachment were not ergonomic for elderly people carrying a baby. From out simulation, the high loading points (the red areas in the simulated image in Table. 1) on an average Thai elderly person were at his or her shoulder, back, and hips which might cause the person sedhoulder, back, and hip pain.

Finally, regarding (4), Bleah and Ellett (2010) reported that a structured carrier compressed the chest area of the baby, making it difficult for it to breathe, but helps it to learn and remember the environment better than other types of baby carriers. They went on and stated that the main issue with an elderly person carrying a baby was that he or she was likely to feel pain at the shoulder and waist. Some may even get cuts at their forearm and wrist from scraping the edge of the shoulder straps as they are trying to maneuver a baby into the carrier.

We had expected that the findings from this study would help considerably in the design of these types of baby carriers. However, the findings did not give us conclusive evidence for either positive or negative effect of the design of the current face-out-baby-carriers on the ergonomic for elderly people or their posture. The evidence for a positive effect of a type of baby carrier was not definite, only suggestive, and the lack of reproducibility of the results prevented a firm conclusion from being drawn. Similarly, the results of the three simulation studies investigating the factors in ergonomic design of 6-18-month baby carriers for elderly people were inconclusive. No design provided decisively better ergonomic factors than the other two. Nonetheless, the investigation provided an interesting basis for further study. The simulations pointed out causal relationships between the types of baby carrier, ergonomic design principles, and elderly people's loading points at their chest, shoulder tip, back, knee, and ankle in their standing posture.

CONCLUSION

Our main objective was to investigate by simulation the load-bearing points of several types of baby carriers and the load-bearing points on the body of an average Thai elderly people. Mainly based on the simulation results, we synthesized four factors in ergonomic design of baby carriers for Thai elderly people. We obtained valuable information on loading points of the baby carriers and on the body of an average Thai elderly person, which to a certain extent, helped us to synthesize these factors. According to these factors, out of the three baby carrier designs that we investigated, the facing-out, H-type baby carrier design was the best ergonomic design for an average Thai elderly people. A good baby carrier design should have straps that fit a baby snugly, a large, but with good fit, back-cushion seat, and not-too-long shoulder straps. Our findings may directly benefit designers of baby carrier, car seat, and baby stroller in their effort to make their design ergonomic. Future studies should investigate the ergonomic design of cushion seat of baby carriers for elderly people as well as the of back-cushion seat, waist belt, and shoulder straps of baby carriers.

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