

A Human-Machine-Environment Interaction Analysis on the Washing and Changing of Toddlers' Caregivers

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Abstract: Newborn babies usually have 8-10 diaper changes daily. Repeating inappropriate movements may injure caregivers. By understanding the limitations of the product, environment and the interactions among them, a comfortable and efficient washing and changing environment may be developed. The research includes three stages: 1) interviewing and collecting the information about the caregivers' physical and psychological burdens of washing and changing for toddlers; 2) analyzing the procedure and movements of washing and changing by photographing; 3) conducting a human-machine-environment analysis according to the recorded clips. The analysis results are as follows. 1) Human/machine/environment: the location of washing and changing affect the distance that the caregiver walking while carrying a toddler. The caregiver needs to keep the toddler safe on the wash stand with one arm and uses the other arm to complete the washing/changing. The bounds of caregivers' arms are heavy. 2) Human/machine: the length, width, and height of a wash stand would affect the weight of caregiver's upper body and arms, as well as the location of toiletries and the safety of toddlers. 3) Human/environment: the location of washing or changing items would affect caregivers' immediate access and their movements. The location also affects the smoothness of repetitive movements of caregivers. The environment may influence toddlers' concentration and consequently affects 'movements.

Key words: *toddler caregiver, changing diapers, human-machine-environment interaction analysis, Analysis on process and action*

1. Introduction

With limited autonomous action ability, babies require physical assistance of the caregiver in the daily life demands from bathing, feeding to sleeping. Therefore, the fulltime babysitters are often heavily loaded and do work with arms frequently. In case of improper working gesture, it may easily injure the muscles and bones. If this condition lasts for a long time, with high frequency or serious pains, it will impact the health status of the caregiver and the care quality [2]. In the first month after birth, the toddlers need to change diaper every hour, and then every three or four hours. When they grow up to 18 months, they could be trained to defecate and urinate [5]. Therefore, the diaper period lasts for about 18 months, during which the health of the caregiver may be overburdened due to the improper gesture or muscle overuse caused by the factors of product or environment. Thus, if it could learn the changing and washing operation and analyze the process and action of the caregiver, and

find out the problems to provide reference for the medical staff, caregivers and related designers in further study, it will be expected to propose a more comfortable and effective changing and washing product and environment. The purposes of this study are listed as below: (1) Learn the physiological and psychological status of the caregiver in the changing and washing task. (2) Analyze the problems of human-machine-environment interaction in the changing and washing task.

2. Literature

2.1 Physiological injury of caregiver

During toddler caring, the caregiver may be usually in improper gesture or body overuse, which may result in physiological injury and exhaustion if accumulated for a long time. The news often reports the caregiver has pains in elbows, wrists, shoulders, waist and back [9]. The muscle and bone injury takes up the high proportion of occupational injury all the time, among which one third is on the shoulders and upper limb. The full-time caregivers in this study mainly take care of toddlers and do housework, so they frequently use the arms and wrists. If they work with an improper gesture or do heavy works for a long time, it may cause injury or disease to the muscle, tendon, bones and other body parts, resulting in Cervical-shoulder Syndrome, internal humeral epicondylitis (Also known as Golfer' s Elbow), De Quervain's disease (Also known as Washerwoman' s Sprain), which may be so serious to affect life quality [4,6,8].

2.2 Human-Machine -Environment Research

The human-machine-environment system is defined and developed from ergonomics. That is, the human-machine system is added with the environment factor to form a single system [2]. It mainly considers three factors, (1) General situation or condition of humans; (2) Activities, including the facilities or equipment's needed; (3) Environment of the activities [1,3]. For example, the human-machine system consists of the caregiver and the changing and washing platform. If added with the environment, it becomes a human-machine-environment system, as shown in Figure 1. In addition to the individual requirements and limitations of these three factors, the human-machine-environment research also takes their interaction into consideration, so as to achieve dynamic balance [7].

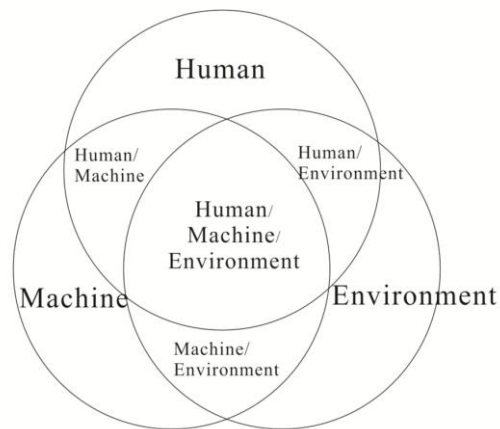


Figure 1. Human-machine-environment architecture diagram

3. Method

The methods of this study include interview, participatory observation, motion analysis and human-machine-environment interaction analysis. The Department of Health of Executive Yuan defines the toddlers as 0 to 3 years old babies. Therefore, the study subjects are the caregivers who are caring 0 to 3 years old babies, with the interview and observation period from Aug. 27 to Aug. 29, 2012 in a family restaurant in Taipei.

3.1 Interview

A total of three participator are interviewed for 30 minutes respectively. The interview is composed of the participator's basic information and care burden.

3.1.1 Data of participator

- (1) Gender and age of caregivers.
- (2) Age of toddlers.
- (3) Relationship between caregivers and toddlers.

3.1.2 Care burden of participator

- (1) Symptoms, body parts and reasons of physiological burdens.
- (2) Symptoms and reasons of psychological burdens.

3.2 Participatory observation

In the participatory observation, the cameras were set up in three directions: front, left and right side of the caregiver. It mainly researches and observes the caregiver when changing and washing the babies in the family restaurant.

3.2.1 Participator

Six persons include three participator and their babies.

3.2.2 Observation place

A family restaurant in Taipei.

3.2.3 Observation content

It mainly observes the way caregivers use their limb and trunk, the process and action of changing and washing, and the human-machine-environment interaction means.

3.3 Analysis on process and motion

The process and motion are analyzed by the human-machine-environment architecture. The changing and washing action of the caregiver is divided into three steps, namely, preparation, cleaning and finishing. In each step, it conducts motion analysis based on the caregiver, baby, changing and washing platform and environment.

3.4 Analysis on problems of interaction between humans and machine

It conducts analysis on the changing and washing steps based on the results of action analysis, and lists the problems of human-machine-environment interaction in the table. By dividing them into human/machine interface, human/environment interface, machine/environment interface and human/machine/environment interface, it

collects and sorts out the problems of the caregiver when changing and washing toddlers. The analysis content is as shown in Figure 2.

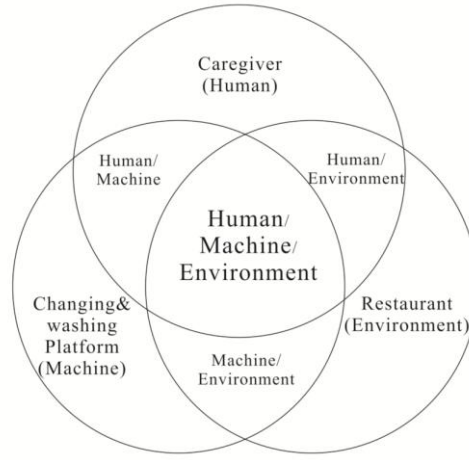


Figure 2. Human-machine-environment relationship for the changing and washing action of caregiver

4. Results

4.1 Interview results

4.1.1 Basic data

- (1) Caregivers: All are females with the average age of 35.
- (2) Toddlers: The average age is 21 months, with the standard deviation of 2.45.
- (3) Relationship between the caregiver and toddlers: Mother and child.

4.1.2 Caregiver's physiological and psychological burdens and their causes

- (1) Physiological burdens: The caregivers' physiological burdens are mainly in shoulders, neck, limb (Upper arm, forearm, wrist and elbow) and waist, with the symptoms of pain and paralysis. The major reasons are that the caregivers apply force for a long time or frequently (such as helping the toddlers bath and change diaper), or adopt improper gestures (such as bending, bowing, turning, and leaning).
- (2) Psychological burdens: During toddler caring in daily life, the toddlers are active and distracted easily, so caregivers need to change and clean clothes and environment frequently, which are main reasons for the caregivers to have psychological burdens. It may make the caregiver frustrated or anxious.

4.2 Results of analysis on process and motion

Based on the data observed and recorded by the camera, it divides the caregiver's changing and washing motion into three steps, preparation, cleaning and finishing. In each step, it conducts motion analysis based on the human (caregiver) and machine (changing and washing platform and stuff), as shown in Table 1:

Table 1. Process and motion analysis of human-machine-environment architecture

Motion \ Factor			Human		Machine	Environment
			Caregiver	Toddlers	Tank, platform, tap, garbage can	Family restaurant
Preparation	1	Caregiver carries the toddler onto the washing table for	Caregiver carries the toddler and the bag by two hands, heading	Toddler is held by the caregiver, with the body lifted and seated	The bag contains clothes, towel and other washing stuff.	In front of the washing room in the restaurant.

Cleaning		changing and washing.	towards the washing table.	on one arm of the caregiver.		In the changing room of the restaurant.
			Put the toddler on the table.	Stand on the table.	There is a washing table, with the tank on it. In front of the tank, there is a tap.	
			Take out the towel, wet it by tap water.		Open the tap, wet the towel, and place it on the table.	
	2	Caregiver takes off the trousers of the toddler.	Take off the trousers and put them into the bag.	Put hands on the shoulder of the caregiver and lift one leg to take off the trousers with the support of the caregiver.	Put the trousers into the bag.	
			Get the clean diaper ready, and put it into the bag.	Stand on the table.	Unfold the clean diaper and place it under the bag.	
	3	Caregiver removes the dirty diaper for the toddler.	Unfasten the dirty diaper, and wipe the buttocks of the toddler with the edge of dirty diaper.	Stand on the table.	Dirty diaper is removed from the buttocks of the toddler.	
			Fold the dirty diaper and discard it into the garbage can.	Turn around with the support of the caregiver, and stand on the table by holding caregiver's hand.	Dirty diaper is discarded into the coverless garbage can aside the washing table.	
	4	Caregiver washes the buttocks for the toddler.	Carry the toddler by one hand, and use the other hand to clean the buttocks and thighs by tap water.	Toddler is held by the caregiver, and one leg is lifted. The toddler is placed into the tank, with the buttocks close to the tap, and hands on the edge of the tank.	Open the tap.	
			Close the tap, and carry the toddler away from the tank.	Get out of the tank, stand on the table.	Close the tap.	
			Carry the toddler by one hand, and take towel in the other hand to wipe buttocks and thighs of the toddler.	Stand on the table, lean forward, play the tap and move on the table.	Towel is taken from the table.	
Finishing	5	Caregiver carries the toddler into the changing room.	Carry the toddler, take the bag, and go into the changing room.	Toddler is held by one hand of the caregiver, with the buttocks seated on the other hand.	Take the bag.	
			Place the toddler down on the changing table, take out the clean diaper, towel and trousers from the bag, and place them aside the toddler.	Toddler is held by one hand of the caregiver, seated on the changing table.	The soft pad provided on the changing table, towel, clean diaper, and trousers in the bag are placed on the changing table.	
			Wipe the buttocks and thighs of the toddler by towel.	Stand on the soft pad, and play the toys on the wall.	Diaper pad is provided on the changing table, and toys are provided on the wall.	
			Place the toddler down on the back; get the cream, life the thighs by one hand to apply the cream.	Toddler lies down on the changing table, with one leg lifted to apply the cream.	Unmovable changing table	
	6	Caregiver changes the clean diaper for the toddler.	Life the thighs by one hand to expose the buttocks. Fix the clean diaper under the toddler.	The thighs are lifted, and the clean diaper is placed under the toddler.	Clean diaper is fixed under the toddler.	

			Put down the thighs gently, put on the clean diaper to the waist and fasten it securely.	The thighs are put down, with the body lying down on the changing table.	Clean diaper covers the buttocks of the toddler.	
			Lift one leg of the toddler by one hand, adjust the diaper position, and do it on the other leg.	One leg is lifted, with the body lying down on the changing table.	On the changing table.	
	7	Caregiver puts on the trousers for the toddler.	Put the trousers on.	Stretch the leg to put on the trousers.	Trousers are put on the body of the toddler.	
			Get the toddler dressed.	Get up from the changing table.	Clothes are dressed well.	

4.3 Results of analysis on the problems of human-machine-environment interaction

Based on the analysis results shown in Table 1, it divides the changing and washing process of the caregiver into 7 steps in sequence, and lists the problems of human-machine interaction in each step, as shown in Table 2:

- (1) Step1: Caregiver carries the toddler onto the washing table for changing and washing.
- (2) Step2: Caregiver takes off the trousers of the toddler.
- (3) Step3: Caregiver removes the dirty diaper for the toddler.
- (4) Step4: Caregiver washes the buttocks for the toddler.
- (5) Step5: Caregiver carries the toddler into the changing room.
- (6) Step6: Caregiver changes the clean diaper for the toddler.
- (7) Step7: Caregiver puts on the trousers for the toddler..

Table 2. Problems of human-machine interaction

Changing and washing process		Problems of human-machine interaction	
Step1.	Caregiver carries the toddler onto the washing table for changing and washing.	(1)	The length, width, height and material of the table affect the caregiver's burden on trunk and upper limbs, as well as the safety of the toddler when standing.
Step2.	Caregiver takes off the trousers of the toddler.	(2)	The facilities affect the convenience and action of the caregiver to take all stuff once only, and further impact the caring convenience of caregiver.
Step3.	Caregiver removes the dirty diaper for the toddler.	(3)	The facilities distract the toddler's attention, and further affect the action of the caregiver.
Step4.	Caregiver washes the buttocks for the toddler.	(4)	When holding the toddler and cleaning in the tank, the burdens on caregiver's trunk and arms are heavy.
Step5.	Caregiver carries the toddler into the changing room.	(1)	When carrying the toddler into the changing room, the caregiver's burden on upper limb is affected.
Step6.	Caregiver changes the clean diaper for the toddler.	(2)	The length, width and height of the changing table affect the burdens on caregiver's trunk and upper limbs, as well as the comfortable degree of the toddler when lying on the back.
Step7.	Caregiver puts on the trousers for the toddler.	(3)	The facilities affect the convenience and action of the caregiver to take all stuff once only.
		(4)	The safety design of the changing table affects the safety of the toddler and psychological burden of the caregiver.

By observing the caregiver's changing and washing action in toddler caring, the study collects above problems of human-machine interaction and works out the following points:

- (1) Factor of changing and washing platform: The length, width, height and material of washing table and changing table both affect the gesture of trunk/upper limb, cleaning efficiency, convenience of placing/getting stuff in terms of the caregiver, as well as the safety and comfort in terms of the toddler.
- (2) Factor of toddlers and changing and washing products: The facilities distract the toddler's attention, and further affect the changing and washing process of the caregiver. It exerts negative impacts on the efficiency of changing and washing and the safety of the toddler.
- (3) Factor of caregiver and toddler: The caregiver's changing and washing habits, the toddler's emotion and action reaction all affect the changing and washing process and efficiency.

5. Conclusions and Discussion

- (1) The study results show, when changing and washing the toddler, the caregiver is often affected by the length, width, height and material of washing table or changing table, which may result in low efficiency, improper gesture and physiological burdens, such as trunk, neck bending, and arm burden. Therefore, when designing the changing and washing platform in the future, it may take the human factor of caregiver and toddler into consideration, so as to relieve the burden on the trunk and upper limb of the caregiver and avoid the improper gesture. Besides, the design of changing and washing platform should lay emphasis on the safety of toddler to prevent accident, such as using non-slip or non-drop materials.
- (2) This study mainly researches the problems of human-machine interaction in the family restaurant. The cleaning is done on the washing table, while the diaper changing is done on the changing table, so the caregivers need to carry the infant walking place to place. The future design of the related changing and washing platform could combine these two into one place and one product, so as to relieve the physical burden of the caregiver while carrying the toddler.
- (3) The toddler is too active and distracted because of their curiosity and disturbed, which further negatively impacts the psychological burden of the caregiver and the changing and washing process. The future design of the related changing and washing platform could make the toddler concentrate. In this way, the toddler won't become excited or move about when staying in the strange environment or surroundings, which may affect the psychological burden of the caregiver and the changing and washing process.

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