Comparison of absorption based on the location of seam of cloth diaper

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Abstract

A necessity for infants, diapers are not only used over long durations, but are also in direct contact to the infants’ skin, making the choice of diaper to be of utmost importance. Current interest in cloth diapers is rapidly increasing because of issues concerning the baby’s health, green environment, and economy. However, previous researches on cloth diapers are limited to simply investigating the form and material of commercial cloth diapers. There are few in-depth researches for the optimal cloth diaper development. This is therefore a fundamental research for the development of optimized cloth diapers, and analyzes the difference in absorption depending on the placement of seam line (liner, darts, and I pattern), the locations of liquid spraying (1 cm and 8 cm ahead of the center), and the amount of liquid capacity (10 and 20 ml). Currently, the development of diaper patterns considers the crotch shape of the infants and the skin length deformation. As a result, in the case of the I-pattern, the horizontal seam line prevents water from spreading to the front and back, thus reducing the absorbed area. This result was more clearly visible when water was sprayed at the center. The effect of the seam line became more obvious when there was more water (20 ml): also, when water was sprayed at the center, more leakage was observed. Using the results of this research, implementation of horizontal seam is expected to prevent the upward spread of urine.

Keywords : cloth diaper, absorption of water, location of seam, locations of liquid spraying

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I. Introduction

Diaper, a necessity for infants, is not only used over long terms but also directly contacts the infants’ skin making the parents’ choices of diaper be of utmost importance. Until recently, disposable paper diapers were popularly used due to superior absorption and convenience of not having to do the laundry. Also, much study has been performed about these disposable paper diapers (Han, Kim, Shin, Chung, Chung, & Chae, 2000; Lee & Koo, 2010). Disposable diapers utilizing various materials and antimicrobials to suppress rash have been developed and studies have been mainly on verifying this (Campbell, Seymour, Stone, & Milligan, 1987; Hong, Kang, & Oh, 2004; Park, Jho, Yoon, & Lee, 2001; Shim & Lee, 1995). A representative example of study by Park et al. (2001) compares the effect of before and after applying bamboo extracts that function as natural antimicrobials on the surface of diapers to suppress rash which is considered the greatest problem of disposable diapers. Also, Hong et al. (2004) suggested an improved diapers with enhanced comfortability by researching the touch and moisture characteristics between skin and non-woven by selecting several currently commercial non-woven. However, as negative perception on disposable diapers increased due to infant’s health, green environment, and economic issues, interest in cloth diaper grew (Lee, Han & Koo, 2011a). Also, interest in cloth diapers was further increased (EBS news, 2015; babynews, 2015) following the proposals that various dyes, strong absorbent gels, and bleach papers used in disposable diapers can critically damage the skin and health (Prasad, Srivastava, & Verma, 2004; Shin, Yoon, Park, & Ahn, 2004). This movement of encouraging cloth diaper has been progressing at a national level. In 2011, Seoul city, municipal assembly, and NGO related businesses developed models to expand the usage of cloth diapers (Asia Economy News, 2011), and claims that the government should encourage cloth diapers over disposable diapers in the ‘Low-income group diaper-powdered milk support demonstration project’ to relieve environmental problems and dermatitis problems from disposable diapers in the parliamentary inspection in 2015 (Babynews, 2015). Simultaneously, Babyan Inc. is selling high quality organic cotton material and Bamboo–bebe Inc., Mom’s Nature Inc., and Agaddong Inc. is selling cloth diaper made from bamboo, and many enterprises specializing in infant products are releasing diverse cloth diapers utilizing environment-friendly materials (Lee et al., 2011a; Money Today, 2016). Large rectangular foldable diapers were used in the past, but recently cloth diapers of diverse shapes and designs with baby’s body type in consideration are being released, including peanut type, underpants type, and cover integrated type (AVING global news, 2012). Therefore, most studies on cloth diapers are on shapes or materials of currently commercial cloth diapers (Lee, Han & Koo, 2011b). Notably, as peanut shape diapers are gaining popularity, factual survey on shape, material and composition of these are being performed frequently (Lee, Han & Koo, 2011a; Lee & Koo, 2010). Lee & Koo (2010) analyzed that organic cotton and bamboo material are popularly used by investigating peanut shaped cloth diapers from various local enterprises. Also, Lee et al. (2011b) provided information by comparing the shapes and pattern of currently commercial peanut shaped diapers. However, as mentioned
beforehand, this is limited to research on present conditions and research on the development of a new product can be hardly found. On the other hand, there have been studies on the effects of cloth diapers’ and disposable diapers’ wetness on dermatitis (Wilson & Dallas, 1990; Kanimozhi & Sasikala, 2016) and on temperature–humidity and wearing sensation of disposable diapers (Shim & Lee, 1995; Zimmerer, Lawson, & Calvert, 1986). However, studies on the wearing sensation of cloth diapers and internal temperature–humidity upon wearing them are lacking. Also, there have been almost no studies on the development of cloth diapers’ shape or absorption according to seam placement and shape. Therefore, to reflect the shape of infants’ crotch and prevent dermatitis from contact when diapers are wet simultaneously, study on a diaper pattern that can decrease contact area by creating space between the body and diaper is required. To develop such a pattern, 3D pattern connected by seam lines is required and ultimately the method of effectively placing seam lines must be taken into consideration.

Consumers are highly interested in cloth diaper as its numerous merits have been reported. However, due to urine leaking to the side, problems occurring from prolonged contact with the skin, and inconvenience of having to do the laundry, cloth diapers are not used very much. Due to this, annual usage of disposable diaper is two thousand million and the size of the market is approximately 60 billion won (Babynews, 2015; Han et al., 2000). Also, the ranking of cloth diaper among 80 diapers in Naver shopping ranking is also at the 54th and 59th, which is low (NAVER Shopping ranking of Korean market, 2016). Therefore, this study considers the infants’ groin shape to perform a fundamental study for the development of cloth diapers that apply ergonomics and are comfortable upon wearing. Specifically this study analyzes the difference in water absorption according to seam placement, location of water spraying, and spray amount to provide basic data for the development of cloth diaper that leaks less to the side and has high comfort ability upon wearing. By developing new cloth diapers based on this study, the usage of cloth diapers can be increased which will lead to environmental benefits as well.

II. Experimental methods

1. Design of infants’ diaper pattern

Diaper pattern was designed with the shape of the infants’ crotch in consideration and three different patterns were composed with the same crotch shape but different seam placement. Firstly, two dimensional replica parts obtained from three dimensional female human body data were combined to design a two dimensional human body part by connecting the front and back replicas, as can be seen in Figure 1 (a)–(c). Diaper pattern was developed by contracting the ratio to fit infants’ size (12 months or less) and adjusting the width and length according to standard commercial S size (length: 40 cm, front width: 15 cm, back width: 18 cm). The purpose of this study is to compare absorption according to placement of seam, so the length and width of the diapers were set to match the size of currently commercial diapers. Body weight difference was 0.6 (± 0.1) kg and the height difference was 1.6 (± 0.3) cm according to infant gender (WHO, 2006). In addition, cloth diapers are
currently sold without sex distinction, so in this study, cloth diapers were not designed separately. After setting the diaper’s size, the width of inguinal region for 5 infants were measured to make the width of the center of diaper, which applies to the perineum region, cover the body and contact the inguinal region.

Table 1 shows the body measurements of 5 infants (3 girls, 2 boys) who were measured. The skin deformation dimensions and crotch width were measured when infants’ legs were spread at 60° and 120°. The width length of spread legs at 120° was 5.4(±0.3) cm, and this was reflected in the pattern (Figure 1 (d)).

| Subject      | WHO(4~12 months) |   |   |   |   |   |
|--------------|-------------------|---|---|---|---|---|
| Sex          | Girl  | Boy  | Girl | Boy | Girl | Boy | Girl |
| Height       | 63.0  | 68.0 | 68.2 | 73.0 | 76.0 | 69.6(±5.0) | 70.3(±4.0) | 68.5(±4.0) |
| Weight       | 6.4   | 7.9  | 8.0  | 9.2  | 10.0 | 8.3(±1.4)  | 8.5(±0.9)  | 7.8(±0.8)  |

Figure 1. 3D Design Method of Infants’ Diaper Pattern
The 3D prototype of the diaper pattern was designed by using the method mentioned above. And the pattern was adjusted to maintain good fit on the inguinal region and to maintain gap between perineum area and the diaper to reduce discomfort from contact when the diaper is wet. In order to make a crotch shape and gap between perineum area and the diaper, sewing lines (seams) or darts must be inserted. Therefore, in this study, in order to select the most efficient sewing line with the same diaper shape, the following three pattern variables were selected. Linear-pattern was designed by inserting 7 cutting lines at the center of prototype basic cloth diaper and spreading by 0.3 cm to each side from the outer line, as can be seen in Figure 2 (a). Darts-pattern and a pattern with seam line in a different location were designed by manipulating the linear-pattern which can be seen in Figure 2 (b) and (c). In other words, the three patterns are the linear-pattern, with vertical seam through the center of diaper, the darts-pattern, with 6 darts in the crotch part, and the I-pattern, with two horizontal seams at the 4.5 cm forward and 6 cm backward from the center of diaper and a vertical seam between two horizontal seams.

2. Experiment variables

This study compared water absorption according to three variables. The first variable is the three patterns with different seam line placements, the linear-pattern, the darts-pattern, and the I-pattern. The second variable is the location of liquid spraying, with is set as 1 cm and 8 cm forward from the center of diaper pattern for baby boys and baby girls respectively (Figure 3). The third variable is the amount of liquid. The amount of liquid is set as 10 ml and 20 ml, which are the amount infant and newborn baby urinate respectively (Mom&enfant magazine, 2011). The 20 ml of liquid is sprayed over 10 seconds to keep the rate of spraying constant. For precise measurement of the absorption, liquid used in the experiment is water with watercolor as 96~99 % of urine is composed of water (Park & Shin, 2013).

3. Measurement of water absorption

To compare water absorption according to the variables, 12 diapers, four per each pattern, were produced. The cloth diapers have been made
Figure 3. Locations of liquid spraying, considering Babies of Both Gender (Variable 2)

Table 2. Characteristics of Materials used in Diapers

| Material          | Fabrics (weaving methods) |
|-------------------|---------------------------|
| Inside part       | bamboo 100 %              |
| (part touching the infants skin) | (rayon 60 %, cotton 40 %) |
| Outside part      | cotton 100 %              |
|                   | flannel fabrics           |

in total double layers, and the characteristics of the materials are in Table 2. The cloth diaper material used in the experiment was certified by the company as "Oeko-Tex standard 100" and is currently on sale.

Experiment protocol is as in Figure 4. Firstly, the location of liquid spraying was marked, the weight of diaper prior to being sprayed was measured, and front and back of diaper were hung on a metal bar. This is to keep it in a shape similar to its shape when an infant is wearing the diaper, and the front and back widths of the diaper were both approximately 20cm. Secondly, water was sprayed at a constant rate at the designated location. Thirdly, the weight immediately after absorbing water was measured and photographed from 40cm distance after being placed on a plastic board with a square ruler (50 cm x 25 cm) on it. Also, the diaper was photographed and its weight was measured in the same method after 5 minutes progressed. To measure the precise absorbed area using the photograph taken immediately after spraying and after 5 minutes progressed, the area of square ruler (50 cm x 25 cm) was extracted and saved with identical pixels. Then utilizing the YUKA CAD program (Youth Hitech, corp.), the area of absorption was measured as can be seen in Figure 5. Finally, the vertical length H in which water has spread after 20 minutes progressed was measured.

As the amount of water absorbed differed according to the type of pattern (seam line placement), location of spraying, and amount of water sprayed, the absorbed area and vertical length were compared according to the amount of liquid absorbed. The formula used is in Table 3. SPSS statistics 21.0, t-test, and one-way ANOVA method were used to compare the differences in water absorption, absorbed area per 1 ml, and absorbed vertical length per 1 ml according to the experimental variables.
Table 3. Formula for the Amount of Water Absorbed, Absorbed Area per 1 ml, and Absorbed Vertical Length per 1 ml

| Item                              | Calculation formula | Explanation                                      |
|-----------------------------------|---------------------|--------------------------------------------------|
| Weight                            |                     |                                                  |
| Amount of liquid leakage (D)      | D = A + L - B       | - L: Amount of the spraying liquid (10 ml or 20 ml) |
| Absorbed liquid of the cloth diaper immediately after spraying (E) | E = B - A          | - A: Weight of the cloth diaper before spraying  |
| Absorbed liquid of the cloth diaper 5 min. after spraying (F) | F = C - A          | - B: Weight of the cloth diaper immediately after spraying |
| Area                              |                     |                                                  |
| Absorbed area immediately after spraying/ml (Area 1) | Area 1 = B' / E    | - B': Absorbed area immediately after spraying |
| Absorbed area 5 min. after spraying/ml (Area 2) | Area 2 = C' / F    | - C': Absorbed area 5 min. after spraying       |
| Length                            |                     |                                                  |
| Absorbed vertical length 20 min. after spraying/ml (H) | H = G / F          | - G: Absorbed vertical length 20 min. after spraying |
III. Results and Discussions

1. Change of inguinal skin length by movement

Infants’ skin length were measured according to each body part for the case of when legs are spread at 60° and 120° and showed in Table 4. First to compare the length change for ①, ②, ③, 120° showed greater change compared to 60° closer to the perineal region (①<②<③). Also, upon movement, the horizontal length change in the inguinal region increased as the region moved downwards (④<⑤<⑥). Through this, it was known that spreading legs increases from center of perineal region to the horizontal direction. On the other hand, there was almost no vertical length change (⑦, ⑧), and the total length to the front and back of groin was almost constant (⑨, ⑩). Especially, measurement according to subject (number of months) was almost nonexistent. Therefore, the width of groin and perineal area for all age and movement does not have to be large. This study set the diaper width as 5.4 cm from the measurement results which covers up to an infant spreading its legs at 120°.

Table 4. Change in the Inguinal Skin Length, with Legs Spread at 60° and 120° (unit: cm)

| Measurement location | ② | ③ | ④ | ⑤ | ⑥ | ⑦ | ⑧ | ⑨ | ⑩ |
|----------------------|----|----|----|----|----|----|----|----|----|
| Leg angle 60°        |    |    |    |    |    |    |    |    |    |
| 4 months             | 8.5| 4.5| 2  | 0.1| 0.1| 0.1| 8.0| 7.0| 13.5| 15.0|
| 6 months             | 7.0| 4.5| 2.5| 0.1| 0.1| 0.1| 7.0| 6.8| 14.3| 15.5|
| 7 months             | 8.2| 4.0| 2.1| 0.1| 0.1| 0.1| 7.5| 7.2| 14.3| 15.0|
| 9 months             | 7.2| 4.2| 2.3| 0.1| 0.1| 0.1| 8.2| 6.7| 16.0| 15.5|
| 12 months            | 7.5| 5.0| 2.5| 0.1| 0.1| 0.1| 7.0| 9.0| 17.0| 17.0|
| Mean(SD)             | 7.7| 4.4| 2.3| 0.1| 0.1| 0.1| 7.5| 7.3| 15.0| 15.6|
|                      | (±0.6)| (±0.4)| (±0.2)| (±0.0)| (±0.0)| (±0.1)| (±0.6)| (±0.9)| (±1.2)| (±0.8)|
| Leg angle 120°       |    |    |    |    |    |    |    |    |    |
| 4 months             | 9.5| 6.8| 5.0| 0.7| 1.0| 1.4| 8.0| 7.3| 13.8| 15.0|
| 6 months             | 7.7| 6.5| 5.4| 0.7| 0.8| 1.0| 7.0| 6.6| 14.2| 15.6|
| 7 months             | 8.7| 6.3| 5.5| 0.8| 0.9| 1.4| 7.5| 6.9| 14.3| 15.2|
| 9 months             | 8.7| 6.6| 5.8| 0.7| 0.7| 1.0| 8.1| 7.0| 16.0| 15.5|
| 12 months            | 8.5| 7.0| 5.5| 0.8| 1.0| 1.4| 7.7| 8.0| 17.0| 17.0|
| Mean                 | 8.8| 6.7| 5.4| 0.8| 0.9| 1.2| 7.6| 7.2| 15.1| 15.7|
|                      | (±0.7)| (±0.3)| (±0.3)| (±0.1)| (±0.1)| (±0.2)| (±0.4)| (±0.5)| (±1.1)| (±0.8)|
2. Shape and area of water absorption according to variables

Shape of water absorption according to seam placement and amount of water were compared in the case of boy infants for whom water is sprayed 8 cm forward from the center. The results are as in Figure 6.

When water was sprayed from the front, water dripped down due to a slope and shape of water absorption observed was not distinctively different by patterns. However, as more time elapsed and amount of water increased, linear-pattern showed a shape in which more water was absorbed throughout the vertical seam line. Also, for the back of the diapers, I-pattern was observed to have less water spreading compared to other patterns. This phenomenon was more observable when there was more water sprayed (20 ml).

Shape of water absorption according to seam placement and amount of water were compared in the case of girl infants for whom water is sprayed 1 cm forward from the center. When water was sprayed at the center, linear-pattern displayed higher absorption throughout the vertical seam line as time elapsed and the amount of water increased. Also, I–pattern was observed to spread less water to the front and back compared to other patterns. This phenomenon was more observable when there was more water (20 ml).

In the case of linear–pattern, this is because the vertical seam line functions as a wicking, absorbing more water throughout the seam line, and in the case of I-pattern, the horizontal seam line functioned to prevent water from spreading to the front and back. This could be observed more clearly when water was sprayed at the center.

The results of measuring the diaper weight, water leakage, and amount of absorbed water according to diaper pattern, amount of water, and spraying location are in Table 5. Average diaper weight(A) was 30.5(±1.1) g and trivial variance was present depending on seam line placement, but not to a significant degree.

Measuring the water leakage (D) from the weight immediately after spraying water (B), it could be known that leakage increased when there was more water (20 ml) and water was sprayed more to the center. The double layered diapers produced

![Figure 6. Shape and Area of Water Absorption when Water was sprayed 8 cm ahead of the Center](image-url)
for this study are appropriate for infants, but toddlers of over 10 kg require additional layers. Especially for baby boys, urine is excreted at the front, so there is ample area in the diaper to absorb the urine as it drips down the center, but in contrast, baby girls’ urine is focused in the center so there is much leakage through the bottom.

3. Statistics results of water absorption area according to variables

1) Comparison of area and length of absorption according to location of water spraying

The results of comparing amount of absorbed water, amount of leaked water, absorbed area per milliliter, and vertical length per milliliter according to location of spraying is in Table 6.

When 10 ml of water was sprayed, no difference was visible for amount of absorbed water, leaked water, or vertical length per milliliter. On the other hand, when the absorbed areas immediately after spraying and after 5 minutes progressed were compared, spraying 8 cm forward showed larger absorbed area than spraying only 1 cm forward (center) ($p < 0.01$). When 20 ml was sprayed, amount of absorbed water and leaked water displayed significant difference according to the location of spraying. More water was absorbed when water was sprayed 8 cm forward from the center of the diaper ($p < 0.05$), and when water was sprayed 1 cm forward (center), more water leaked through the bottom ($p < 0.01$).

2) Comparison of absorbed area and length per milliliter depending on seam placement (ANOVA)

To compare water absorption according to seam placement, each absorbed area was measured when 10 ml of water was sprayed and when 20 ml was sprayed. As a result, no difference was observed when 10 ml was sprayed, as can be seen in Table 7. However, absorbed area per milliliter (immediately after spraying water & 5 minutes after spraying) showed difference according to seam placement when 20 ml of water was sprayed.

| Seams | Captured image (10 ml) | Captured image (20 ml) |
|-------|------------------------|------------------------|
|       | Immediately after spraying (cm²) | 5 minutes after spraying (cm²) | Immediately after spraying (cm²) | 5 minutes after spraying (cm²) |
| Linear-pattern | Vertical: 56.36 | Vertical: 97.58 | Vertical: 67.10 | Vertical: 112.55 |
| Dark-pattern | Vertical: 51.32 | Vertical: 88.48 | Vertical: 73.32 | Vertical: 116.03 |
| P-pattern | Vertical: 47.52 | Vertical: 78.51 | Vertical: 67.10 | Vertical: 92.39 |

Figure 7. Shape and Area of Water Absorption when Water was sprayed 1 cm ahead of the Center
### Table 5. Diaper Weight and Water Absorption before and after Spraying Water

|                | A (g) | B (g) | C (g) | D (ml) | E (ml) | F (ml) |
|----------------|-------|-------|-------|--------|--------|--------|
| **(1) 8 cm forward** |       |       |       |        |        |        |
| 10 ml          | Linear-pattern | 31     | 40    | 41     | 1      | 9      | 9      |
|                | Darts-pattern  | 29     | 38    | 38     | 1      | 9      | 9      |
|                | I-pattern      | 31     | 39    | 39     | 2      | 8      | 8      |
| 20 ml          | Linear-pattern | 32     | 47    | 46     | 5      | 15     | 14     |
|                | Darts-pattern  | 29     | 45    | 44     | 4      | 16     | 15     |
|                | I-pattern      | 31     | 48    | 48     | 3      | 17     | 17     |
| **(2) 1 cm forward** |       |       |       |        |        |        |
| 10 ml          | Linear-pattern | 31     | 41    | 40     | 0      | 10     | 9      |
|                | Darts-pattern  | 29     | 37    | 37     | 2      | 8      | 8      |
|                | I-pattern      | 30     | 38    | 38     | 2      | 8      | 8      |
| 20 ml          | Linear-pattern | 32     | 42    | 42     | 10     | 10     | 10     |
|                | Darts-pattern  | 30     | 40    | 40     | 10     | 10     | 10     |
|                | I-pattern      | 31     | 41    | 41     | 10     | 10     | 10     |

A: Weight of the cloth diaper before spraying  
B: Weight of the cloth diaper immediately after spraying  
C: Weight of the cloth diaper 5 min. after spraying  
D: Amount of liquid leakage  
E: Absorbed liquid of the cloth diaper immediately after spraying  
F: Absorbed liquid of the cloth diaper 5 min. after spraying

### Table 6. Differences depending on Location of Water Spraying (t-test)

|                | (1)10 ml |            |            | (2)20 ml |            |            |
|----------------|----------|------------|------------|----------|------------|------------|
|                | Location of spraying | Mean (SD) | t | p-value | Locations of spraying | Mean (SD) | t | p-value |
| **D (ml)**     |          |            |            |          |            |            |
| 8 cm forward   |          |            |            |          |            |            |
| 8 cm forward   | 1.33(0.58) | 0.000 | 1.000 |          | 8 cm forward   | 4.00(1.00) | -10.392 | 0.000** |
| 1 cm forward   | 1.33(1.15) |          |            |          | 1 cm forward   | 10.00(0.00) |            |          |
| **F (ml)**     |          |            |            |          |            |            |
| 8 cm forward   | 9.00(1.00) | 1.000 | 0.374 |          | 8 cm forward   | 15.33(1.53) | 6.047 | 0.026** |
| 1 cm forward   | 8.33(0.58) |          |            |          | 1 cm forward   | 10.00(0.00) |            |          |
| **Area 1 (cm²)** |          |            |            |          |            |            |
| 8 cm forward   | 8.55(0.36) | 9.329 | 0.001** |          | 8 cm forward   | 6.70(0.41) | -0.694 | 0.526  |
| 1 cm forward   | 6.21(0.24) |          |            |          | 1 cm forward   | 6.92(0.36) |            |          |
| **Area 2 (cm²)** |          |            |            |          |            |            |
| 8 cm forward   | 13.37(0.64) | 5.329 | 0.006*** |          | 8 cm forward   | 10.24(0.93) | -0.504 | 0.641  |
| 1 cm forward   | 10.56(0.66) |          |            |          | 1 cm forward   | 10.70(1.28) |            |          |
| **H (cm)**     |          |            |            |          |            |            |
| 8 cm forward   | 2.23(0.06) | 1.768 | 0.152 |          | 8 cm forward   | 1.63(0.25) | -1.739 | 0.157  |
| 1 cm forward   | 2.07(0.15) |          |            |          | 1 cm forward   | 2.00(0.26) |            |          |

** p<0.05, *** p<0.01

D: Amount of liquid leakage  
F: Absorbed liquid of the cloth diaper 5 min. after spraying  
Area 1: Absorbed area immediately after spraying/ml  
Area 2: Absorbed area 5 min. after spraying/ml  
H: Absorbed vertical length 20 min. after spraying/ml
Table 7. ANOVA table of Water Absorption and Absorbed Area when Different Amounts of Water were Sprayed for Patterns with Different Seam Placements

| Type of Water | Sum of Squares | df | Mean Square | F   | p-value |
|---------------|----------------|----|-------------|-----|---------|
| 10 ml D (ml)  | 2.33           | 2  | 1.17        | 3.500| 0.164   |
| 10 ml F (ml)  | 2.33           | 2  | 1.17        | 3.500| 0.164   |
| 10 ml Area 1 (cm²) | 0.22       | 2  | 0.11        | 0.039| 0.962   |
| 10 ml Area 2 (cm²) | 0.76        | 2  | 0.38        | 0.089| 0.917   |
| 10 ml H (cm)  | 0.01           | 2  | 0.01        | 0.176| 0.846   |
| 20 ml D (ml)  | 1.00           | 2  | 0.50        | 0.027| 0.973   |
| 20 ml F (ml)  | 2.33           | 2  | 1.17        | 0.078| 0.927   |
| 20 ml Area 1 (cm²) | 0.54       | 2  | 0.27        | 7.068| 0.073*  |
| 20 ml Area 2 (cm²) | 4.48        | 2  | 2.24        | 8.122| 0.062*  |
| 20 ml H (cm)  | 0.26           | 2  | 0.13        | 1.927| 0.290   |

*p<0.1

Figure 8. Duncan’s Post-hoc Test of Absorbed Area per 1 ml, according to Seam Location

Duncan post-hoc test was performed on Area 1 & Area 2 which showed significant difference, and the results are in Figure 8. The result of absorbed area per milliliter immediately after spraying water (Area 1), absorbed area of I-pattern was significantly less than darts-pattern. (p < 0.1). Also, the absorbed area 5 minutes after spraying (Area 2) of I-pattern was significantly less than other patterns (darts-pattern & linear-pattern) (p < 0.1). In summary, more water meant a clearer difference according to the placement of seam, and I-pattern’s horizontal seam lines helped prevent the spreading of water, decreasing the absorbed area.

Secondly, differences in absorbed area...
depending on seam placement in the case of baby boys and baby girls, who have spraying locations of 8 cm forward from the center and 1 cm forward from the center respectively, have been analyzed. As a result, there was no difference in regards to the placement of the seam when water was sprayed 8 cm forward from the center, as can be seen in Table 8. In contrast, when water was sprayed 1 cm forward from the center, absorbed area per milliliter (5 minutes after spraying) and vertical length after 20 minutes showed differences according to the diaper seam placement ($p < 0.05, p < 0.1$).

The results of absorbed area per milliliter 5 minutes after spraying water (Area 2) showed that the Area 2 of I-pattern was significantly less than other patterns (dart-pattern & linear-pattern) ($p < 0.05$). Also, the vertical length of absorbed area (H) after 20 minutes showed that linear-pattern has significantly greater values than I-pattern ($p < 0.1$). In other words, when water is sprayed at the front, placement of seam ceased to cause discrepancies, but when water was sprayed at the center, absorbed area and vertical length differed as time progressed. Especially, linear-pattern absorbed more through above and below the seam line as time passed. On the other hand, I-pattern’s horizontal seam lines prevented water from spreading up and down even after time progressed.

This implies that I-pattern’s horizontal seam lines are appropriate for baby girls’ diapers and to reinforce diaper patterns for baby boys, moving the horizontal seam lines of the I-pattern to the front is expected to be effective.

### Table 8. ANOVA table for Amount of Absorbed Water and Absorbed Area of Different Patterns with Different Placements of Seam (when water was sprayed 1 cm and 8cm ahead of the center)

|                | Type III Sum of Squares | df | Mean Square | F    | $p$-value |
|----------------|-------------------------|----|-------------|------|-----------|
| **8 cm forward** |                         |    |             |      |           |
| D (ml)         | 0.33                    | 2  | 0.17        | 0.038| 0.963     |
| F (ml)         | 0.33                    | 2  | 0.17        | 0.008| 0.993     |
| Area 1 (cm$^2$)| 0.39                    | 2  | 0.20        | 0.111| 0.899     |
| Area 2 (cm$^2$)| 0.48                    | 2  | 0.24        | 0.043| 0.959     |
| H (cm)         | 0.04                    | 2  | 0.02        | 0.103| 0.905     |
| **1 cm forward** |                         |    |             |      |           |
| D (ml)         | 1.33                    | 2  | 0.67        | 0.018| 0.983     |
| F (ml)         | 0.33                    | 2  | 0.17        | 0.111| 0.898     |
| Area 1 (cm$^2$)| 0.32                    | 2  | 0.16        | 0.592| 0.607     |
| Area 2 (cm$^2$)| 3.73                    | 2  | 1.86        | 13.467| 0.032**   |
| H (cm)         | 0.16                    | 2  | 0.08        | 8.167| 0.061*    |

* $p<0.1$, ** $p<0.05$

IV. Conclusions

Despite the increasing preference for use of cloth diapers, there have been few basic studies for the development of comfortable diapers for infants.
In this study, three-dimensional pattern design is mandatory to reflect infants’ groin shape while simultaneously preventing dermatitis from contact to skin when diapers are wet with urine. In other words, the perineal area must be apart from the skin while the groin area that prevents leakage must be in contact. This 3D shape is impossible to design without seam lines. Therefore, this study analyzed water absorption of cloth diapers according to placement of seam line, location of water spraying, and the amount of spray to collect basic data required for the development of cloth diaper patterns with high comfortability upon wearing, and the results are as follows.

Firstly, measurements were performed for the cases when infants’ legs were spread at 60° and 120°, and the center of perineal area extended horizontally as legs were spread apart, though it showed no significant difference according to the infants’ age(months). Therefore, the central width of cloth diapers in the perineal area does not have to be large, and the required width when spreading at 120° (approximately 5.4cm) was reflected in the design of the pattern. Secondly, the location of water spraying was set as 8cm forward and 1 cm forward from the center of the diaper, with the case of boy infants and girl infants respectively in consideration. The shape of absorbed water sprayed at the two locations showed that linear-pattern absorbed more water throughout the vertical seam line as more time progressed and the amount of water increased. Also, I-pattern was observed to spread less water to the front and back when sprayed at the center. This trend was more clearly observable when water was sprayed at the center than the front. Thirdly, diaper’s weight, water leakage, and the amount of absorbed water was measured according to diaper pattern, amount of water, and the location of water spraying. As a result, leakage increased as the amount of water increased (20 ml) and water was sprayed at the center. Fourthly, the differences in the amount
of absorbed water, water leakage, and absorbed area and vertical length per milliliter according to location of water spraying was analyzed. The results showed that the absorbed area increased when water was sprayed from the front than from the center (in the case when 10 ml was sprayed). Also, more water leaked to the side when sprayed at the center than at the front (in the case when 10 ml was sprayed). Finally, absorbed area and length were compared in regards to the placement of the seam, and absorbed area tended to vary depending on the location of the seam when a large amount of water was sprayed (20 ml). I-pattern showed significantly less absorbed area per milliliter compared to other patterns. Also, only when water was sprayed at the center, did absorbed area and length change according to seam placement. When water was sprayed at the center, I-pattern showed less absorbed area and length per milliliter compared to other patterns. This result became evident as time progressed.

In conclusion, this study shows that seam line functions as a path through which water is absorbed. In the case of the linear-pattern, more water was absorbed through the vertical seam line as the amount of water increased and time passed. On the other hand, in the case of the I-pattern, the horizontal seam line prevented the water from spreading to the front and back, reducing the absorbed area. This result was more clearly visible when water was sprayed at the center. This implies that the location of horizontal seam line should be altered appropriately to match the gender. The effect of the seam line became more obvious when there was more water (20 ml), but when water was sprayed at the center, more leakage could be observed. Therefore, to develop a diaper that a toddler of over 10 kg can wear, not only should the number of layers be increased, but other materials should be considered as well. Also, this is expected to be solved by widening the crotch area of the pattern or by adding wing shapes to both sides of the crotch. Using the results of this research, implementation of horizontal seam is expected to prevent the upward spreading of urine.

Until now, almost no studies have been present regarding the development of cloth diapers for infants, so suggesting and observing a product with ergonomics and infants’ groin shape in consideration is very significant academically. However, this study was conducted on amount of urine of a toddler under 10 kg therefore extending its application to the larger amount of urine may be limited. Additionally, because water absorption largely varies by material, further study on effect of seam line when different material is used will be required. In addition, further tests shall be commenced to confirm feedbacks on infants’ experience and whether the cloth diaper actually has effect. This is expected to resolve consumers’ complaint of diapers leaking and provide a different fit compared to the standard rectangular product, thus highly enhancing the commercial sales rate. Also, the increase in the usage of cloth diapers is also very significant for the environment. However, the future research should be conducted on whether skin troubles occur when using diapers containing sewing lines and should focus on the said problems and difference that occurs when material and waterproof covers are worn at the same time.
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