Comfort Perception of Breathable and Nonbreathable Diapers

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Abstract

Breathable diapers were rated significantly drier, cooler and more comfortable than nonbreathable diapers over a range of controlled environmental conditions. Healthy, continent adults evaluated two types of diapers, one of which contained a microporous, breathable outer cover and the other a standard occlusive cover, in a series of blinded, comparison studies under various external conditions and activity levels. The subjects were capable of perceiving comfort or discomfort in the diaper area to a remarkable degree. Subjective perceptions of warmth and wetness underneath the diaper correlated with objective measurements of temperature and relative humidity (RH). Comfort ratings for the breathable diaper increased significantly over that of the nonbreathable garment as ambient temperature, RH and physical activity increased. Data analysis showed that the sensation of wetness in the diaper area was strongly associated with discomfort.

Keywords

Breathable, comfort, disposable, nonwoven, skin, temperature, humidity, diaper, perception

Introduction

Human comfort is determined to a large extent by the type of clothing worn [1,2,6]. Since discomfort is strongly associated with the amount of moisture on the skin, garments that restrict the passage of water vapor are perceived to be uncomfortable, especially in a warm environment or as activity levels and perspiration increase [2]. Skin underneath occlusive clothing can become wet from normal transepidermal water loss (TEWL), sweating and, in the case of diapers, from the presence of urine or feces. Diapers cover only a relatively small region of the human anatomy, and, since infants cannot express themselves verbally, it was not generally known to what extent the occlusive nature of these undergarments cause discomfort.

"Breathable" diapers containing microporous film covers have been shown to diminish excessive skin hydration and reduce the prevalence of diaper dermatitis (3,4). Consequently, these undergarments should be more comfortable to the wearer than conventional "nonbreathable" diapers. In order to evaluate the comfort perception of breathable versus nonbreathable diapers, tests were conducted with healthy continent adults. Volunteers, wearing adult-sized diapers participated in a variety of activities under varying environmental conditions. RH and temperature inside the garments were monitored throughout the testing period and were compared with subjective ratings of warmth, wetness and comfort.

Materials and Methods

Diapers: The two types of diapers used in the study were manufactured on a standard adult diaper production line using standard infant diaper component materials; consequently, they were identical to infant diapers except for size. One set of diapers was made with a conventional nonbreathable, film laminate outer cover. The other set contained a microporous, breathable outer cover. The two types of diapers were indistinguishable in appearance.

Vapor permeability of the cover material was determined by a modification of the ASTM E96 water vapor transmission rate (WVTR) test (Breathable Diaper = 3000 g/m2/24hrs), Nonbreathable Diaper = 55 g/m2/24hrs). Breathability levels of whole diapers were determined by tracer gas analysis (TGA) [5], which measures the amount of air exchange between the inside of the diaper and the external environment while the garment is worn. Air exchange values for breathable diapers were about 750 cc/min. Nonbreathable diapers had air exchange values of about 50 cc/min, which most likely represents air movement through the leg and waist cuffs.

Subjects: Thirty adult females, 35 to 47 years of age, were selected from a pool of sensory evaluation panelists who had

been screened for tactile discrimination acuity. In addition, each volunteer was further evaluated for her ability to participate in the exercise regimen required by the protocol. Subjects were instructed to rate the two diapers for how they felt on the skin under varying external conditions and activity levels. They were encouraged to disregard sensations on other parts of the body and to focus their attention on the diaper area.

Table 1
SUMMARY OF PROTOCOL

Rating Period	Length of time	Activity	Environmental Conditions
1	15 min	Standing	
2	15 min	Sitting	70°F and 50% RH
3	15 min	Stepping	
4	15 min	Walking	

The above protocol was repeated for hours 2 and 3 for the following conditions: 75°F with 55% RH and 80°F with 60%RH.

Table 2
RATING SCALE FOR SUBJECTIVE ASSESSMENT

Wetness	Temperature	Comfort
1 = Dry	1 = Cool	1 = Very Comfortable
2 = Slightly Damp	2 = Neutral	2 =
3 = Damp	3 = Slightly Warm	3 =
4 = Very Damp	4 = Warm	4 = Moderately Comfortable
5 = Wet	5 = Very Warm	5 =
6 = Very Wet	6 = Hot	6 =
		7 = Moderately Uncomfortable
		8 =
		9 =
		10 = Very Uncomfortable

Test Procedure: In this study, no natural or synthetic urine was added to the diapers; wetness underneath the garments resulted from normal TEWL and perspiration. The diapers were evaluated during three-hour sessions which were conducted in an atmosphere-controlled environmental room. Temperature and RH inside the diapers were measured objectively with RH/Temperature probes and each subject rated her own perceptions of heat, skin wetness and overall comfort at selected times during the test using a rating scale. Subjects wore one of the diapers for the first session and the other in a second session several days later. The diapers were assigned in a randomized block design so that half the subjects wore the breathable code during the first session. Prior to the actual test, subjects participated in a mock session to familiarize themselves with the protocol and with the sensation of wearing a diaper. A loose-fitting, 50/50 polyester/cotton scrub suit was worn over the diaper. Each hour of the 3-hour test sessions was divided into four activity phases of 15 minutes each: standing, sitting, stepping, and walking. During the first hour, temperature within the room was set at 70°F (21.1°C) and relative humidity at 50%. Temperature and RH were increased in the second hour and again in the third. The evaluation procedure is summarized in Table 1.

The escalations in physical activity together with the increasing stress in the chamber were designed to simulate extremes in conditions that may be experienced by individuals who wear diapers or incontinence garments, with each phase having a specific purpose. In the initial standing phase, subjects stood relatively motionless to allow each participant to attain a basal metabolic state. The sitting phase was designed to ensure that sufficient pressure was placed on the diaper. The purpose of the stepping phase, during which subjects stepped up and down on a 4" bench at the rate of 40 steps per minute, was to gradually induce a low level of sweating. The last phase was designed to increase metabolic activity and sweating to a high level as subjects moved around the room at a brisk pace. The same activities were repeated during the second and third hours.

Subjective Assessment of Comfort: Each subject recorded her perception of skin warmth and wetness during each phase of the study along with the level of comfort or discomfort that they perceived, using a 10 point scale (Table 2).

Objective measurement: Twelve of the 30 subjects were randomly chosen for objective measurement of temperature and RH inside the diaper. Measurements were recorded during the mid point of each phase with a Cole-Parmer Model 37000-50 temperature/humidity probe inserted down the back of the diaper to about the level of the coccyx. Care was taken to prevent opening the diaper to the outside atmosphere during measurement. The time required to measure each subject was about 30 seconds.

Statistical Analyses: Objective and subjective scores were analyzed to determine if the subjects could accurately sense heat and wetness and, if so, how these factors related to comfort. Data were analyzed by Logistic Regression and multivariate - covariance analysis to determine how probe values (humidity, temperature) correlated with subjective perception attributes (moisture, temperature, comfort).

Gravimetric analysis of diaper wetness: The test garments were weighed before and after testing to determine if the breathable cover affected the amount of liquid retained by allowing moisture vapor to escape.

Results

Subjects rated the breathable diaper drier, cooler, and more comfortable than the nonbreathable product over all rating periods. Furthermore, the subjects' perceptions of heat and wetness closely matched objective measurements of temperature and humidity. Both objective and subjective differences

Table 3
SUBJECTIVE EVALUATION DURING THIRD HOUR

	Wetness		Temperature		Comfort	
	B	NB	B	NB	B	NB
Phase # 1 Standing	2.5*	3.0	3.7	3.9	4.6	4.9
Phase # 2 Sitting	2.6*	3.3	3.5*	3.9	4.7	4.9
Phase # 3 Stepping	3.3*	3.9	4.3*	4.8	5.3*	6.0
Phase # 4 Walking	3.6	4.0	4.3*	4.8	5.4*	6.8

NB = nonbreathable diaper
B = breathable diaper
* significantly lower than nonbreathable diaper at $p<0.05$

Table 4
OBJECTIVE MEASUREMENTS DURING THE THIRD HOUR

	Temperature (°F)		Humidity (%RH)	
	B	NB	B	NB
Phase #1 Standing	82.2*	83.6	79.2*	92.1
Phase #2 Sitting	81.5	83.5	75*	91.36
Phase #3 Steppping	83.0*	85.3	88.3*	96
Phase #4 Walking	83.4*	85	87.5*	96

NB = nonbreathable diaper
B = breathable diaper
* significantly lower than nonbreathable diaper at $p<0.05$

between the two products were greatest during the third hour when ambient temperature and humidity were highest. Also, as expected, maximum differences occurred when subjects were the most active. *Table 3* shows the mean subjective ratings during the third hour.

The mean objective recordings are shown in *Table 4*. The breathable product maintained significantly lower humidity levels (drier) and slightly lower temperature levels (cooler) over all rating periods ($p<0.05$).

Post-use weight differences indicated that the breathable garment retained significantly less moisture than the nonbreathable garment *(Table 5)*.

Figure 1 shows the high level of agreement between humidity underneath the diaper as measured with the RH probe and subjects' perception of wetness (correlation coefficient $R^2= .94$).

The relationship between true skin temperature and subjective perception of warmth or coolness is shown in *Figure 2*. While this correlation, $R^2 = .88$, was not as high as that between humidity and wetness sensation, it is clear that participants could readily perceive slight increases in temperature.

As shown in *Figure 3*, there was a strong positive relationship between increasing humidity and the subjects' perception of discomfort (Correlation Coefficient $R^2 = .92$). This relationship suggests that humidity is the driving force behind comfortable or uncomfortable perceptions.

Temperature underneath the diaper also had a strong influence on comfort perception however not as great as humidity. The correlation coefficient of true temperature and subjects' perception of comfort was 0.88.

Table 5
MOISTURE RETENTION OF DIAPERS AFTER USE

Product	Increase Diaper Weight (g)
Beathable	3.62
Non-Breathable	8.70

Discussion

The diaper-covered skin of infants can be up to10 times more hydrated than other regions of the body as a result of being kept partially occluded most of the time and frequently exposed to urine [4]. Excessive hydration is the major cause of diaper dermatitis, a painful condition that is stressful to both the wearer and the care provider. In addition to causing an unhealthy skin condition, occlusive diapers block the diffusion of fresh air to the skin, which is a key factor in clothing comfort [1,2,6]. Although adults do not generally choose to wear occlusive undergarments, infants and young children have in the past been subjected to tight-fitting rubber pants

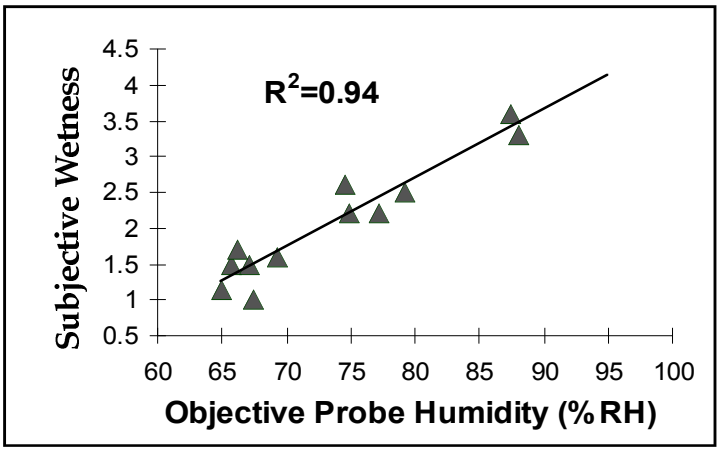


Figure 1
OBJECTIVE VS. SUBJECTIVE WETNESS CORRELATION

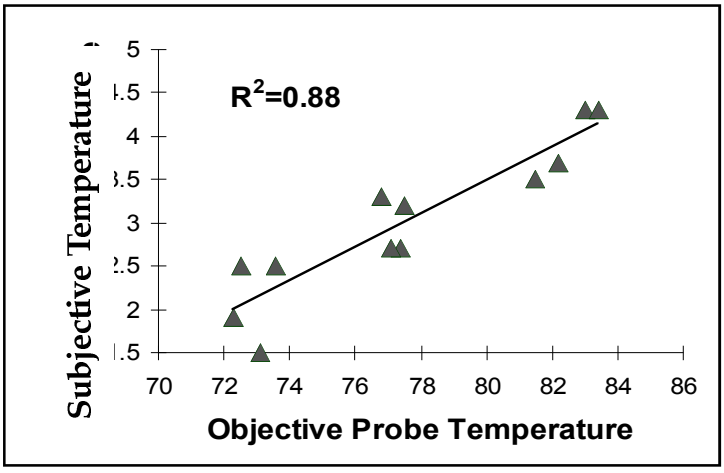
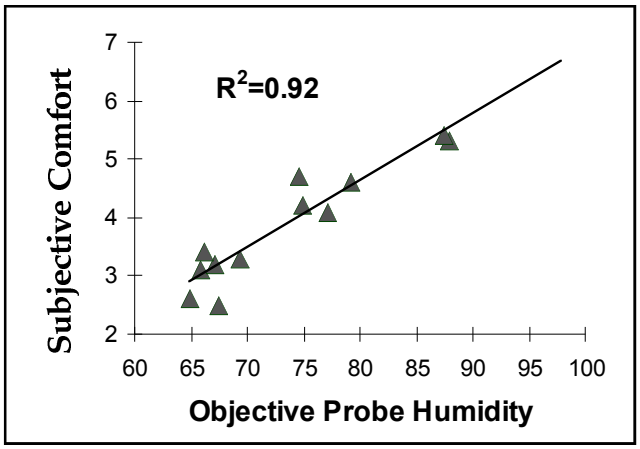


Figure 2
OBJECTIVE VS. SUBJECTIVE TEMPERATURE CORRELATION

Figure 3
HUMIDITY VS. SUBJECTIVE COMFORT CORRELATION



placed over cloth diapers and more recently to disposable diapers with plastic outer covers. The hapless infant, unable to verbally describe discomfort, can only express discontent with displays of temperament.

The studies presented here with adult subjects showed that the build-up of heat and humidity inside the diaper is readily discernable and clearly perceived as discomfort. The sensation of discomfort became more pronounced with the stress of physical activity and an increasingly sweltering environment. The fact that subjective perceptions of heat and humidity were strongly correlated with actual measurements indicates that the individuals are capable of discriminating even slight gradations in these parameters within the diaper area. As in the case with most types of clothing, diapers that kept the skin drier and cooler were more comfortable to the wearer than contrasting garments. Based on the evidence presented here, breathable diapers, in addition to improving the health of children's' skin, will also keep them cooler, drier and more comfortable.

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