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THE WEATHER IN SOME BEDS IN THE NETHERLANDS AND ITS POSSIBLE CONSEQUENCES FOR DEVELOPMENT OF ALLERGENIC MITES AND FUNGI

J. E. M. H. van Bronswijk & H. F. Linskens

Laboratory of Minibiology
Department of Dermatology
State University, Utrecht,
The Netherlands

Section of Experimental Ecology
Department of Botany
Catholic University, Nijmegen,
The Netherlands

1. INTRODUCTION

"During sleep, the functioning of the body's heat regulatory mechanism is rather restricted and unable to compensate for large climatic changes. The bed mainly eliminates all draft and a considerable part of the temperature variations which in fact will assure proper rest"(Landsberg, (1941). In addition the bed harbors a community with pyroglyphid mites and xerophilic fungi as the dominant organisms (van de Lustgraaf, 1978; van Bronswijk, 1981).

Long series of climatic measurements in bed, extending over many years, are absent. Therefore we prefer to speak about weather instead of climate when the meteorological situation is concerned in the different layers of the bed.

Measurement of bedtemperature in ralation to room air temperature has been reported on different occasions in the last half century. All investigators agree that in occupied comfortable beds, the temperature of the air adjacent to the sleeper is usually about 30^{o}C, with a mean skin temperature of the sleeper of about 34-35^{o}C. To the periphery of the bed the temperature lowers gradually to the room air temperature (Brezina & Schmidt, 1937; Landsberg, 1938, 1941; Taylor, 1971; Koekkoek & van Bronswijk, 1972; Hughes & Maunsell, 1973; Dusbâbek, 1975; Müller-Limmroth, 1977; van de Lustgraaf et al., 1978).

The heat resistance of the bedmaterials is usually such that the body comes in danger of overheating, unless sweating starts. Per hour per m^2 skin surface water losses of 4-74 gram have been measured (Müller-Limmroth, 1977).

The relative humidity in bed seems to vary. Increase and decrease after occupancy of the bed has been reported, with values of 70-75% RH or higher only seen occasionally (Heilesen, 1946; Koekkoek & van Bronswijk, 1972; Hughes & Maunsell, 1973; Dusbâbek, 1975; Müller-Limmroth, 1977; van de Lustgraaf et al., 1978). This is amazing since the abundantly present common species of pyroglyphid mites and xerophilic fungi need these high values for rapid development. These organisms increase the allergenic content of the inhaled dust, thus being a hasard for the allergic asthmatic sleeper (van de Lustgraaf et al., 1978; van Bronswijk, 1981).

When the sides and the center of occupied mattresses were compared as to their contents of mites and fungi, the sides usually contained higher numbers (Mulla et al., 1975; Lang & Mulla, 1978; van de Lustgraaf, unpublished). Other layers of the bed were studied less extensively.

This study aims at discovering the different gradients and changes in temperature and humidity in different locations in the bed, in order to get insight in the development possibilities for mites and fungi in the bed.

2. MEASUREMENTS

Two beds were used in this study. The bed occupied by a female subject in her thirties consisted of a steel bedstead, an under mattres from jute, a polyether mattress covered with a polyester ticking, a cotton swanskin, a cotton undersheet, a cotton upper sheet, and in addition 1 acrylic blanket (June, July 1978), 2 acrylic blankets (June, July 1980), or 2 acrylic blankets and 1 woolen blanket (November, December 1977). On top of the bed was a cotton bedspread. The pillow was fabricated from Java kapok and covered with 2 cotton pillow cases. The bedroom was not heated and located on the topfloor of a 2-storey detached village house. The mattress was known to be inhabited by pyroglyphid mites (Dermatophagoides, Euroglyphus) and xerophilic fungi (Aspergillus, Wallemia). The sleeper had no complaints about the weather within the bed.

Temperature and relative humidity were measured in the room air and at different locations in the bed. Two experimental setups were used. In November, December 1977 and June,July 1978,the subject always slept from 23.00H until 7.00H local time (variations in start and end of sleeping period less than 15 min.). For the measurements in the room air a thermohygrograph (Wilh. Lambrecht KG, Göttingen, Germany, type 252 Ua)making 1 revolution in 24 hours was used, and placed 35 cm to the right of the rear end of the bed at bed height (about 50 cm above floor level). Direct sunlight could not reach the thermohygrograph. In bed temperature was measured with a distance thermograph (Wilh. Lambrecht KG, Göttingen, Germany, type 256 Ua), making one revolution in 24 hours. A Rotronic Hygroskop DT (Rotronic AG, Zürich, Switzerland) measured the relative humidity within the bed. It was fitted with a sensor PG of the same company. Measurements were recorded continously on a potentiometric recorder (Servogor^r, Goerz Electro Ges. mbH, Wien, Austria, operated at a speed of 1 cm/hour.Five sites of measurement for air temperature and humidity were selected in the bed:

A) 25-30 cm from the head end of the mattress of the mattress between the lower part of the pillow case and the pillow, 40 cm from the right as well as the left side of the bed.
B) in between the upper blanket and the bedspread, 75 cm from the head end of the bed, 25 cm from the left side of the bed.
C) in between the lower bedsheet and the swanskin, 75 cm from the head end of the bed, 25 cm from the

right side of the bed.
D) in between the under mattress and the mattress, 75 cm from the head end of the bed, 40 cm from the right as well as the left side of the bed.
E) in between the lower bedsheet and the swanskin, 25 cm from the rear end (= 165 cm from the head end) of the bed, 40 cm from the left as well as the right side of the bed.

Since the instruments described above, allowed for only 1 series of measurements in the bed, the 5 sites were investigated successively, for each during 5 times 24 hours in the following order: A, B, C, D, E (November, December 1977), or D, E, A, C, B (June, July 1978). In July equilibrium between bed-weather and room-weather were studied with a series of measurements on sites B and C, consisting of 1 night bed in use, 2 nights bed vacated, and 2 nights bed in use again. Room air temperature and relative humidity were measured continuously during the experimental periods.

The time needed by the different sensors to come in equilibrium with the surrounding air differs; The Rotronic ones being much faster than the Lambrecht ones. Therefore it was decided not to use the original graphs for calculations and drawing conclusions. The "fast peaks" of the Rotronic hygrograph were ignored, from all registration papers values for every whole hour were read, and these values were used to make new graphs. From values for temperature and relative humidity halfway the sleeping period (3.00H) and 12 hours before the start of the sleeping period (11.00H), the absolute humidity during occupancy and befor were calculated with the aid of the appropriate conversion tables (Deutschen Wetterdienst, 1963).

In 1980 an instrument became available to measure and registrate concurrently at 6 different sites temperature and relative humidity (a Rotronic Hygroskop SLTT/12P fitted with 6 sensors and a potentiometric recorder type ARE 40; Rotronic AG, Zürich, Switzerland). In June, July 1980 measuring sites were installed in the above mentioned bed en bedroom. One sensor was placed in the bedroom air, 75 cm over the floor surface, same site as before. Five sensors were installed in the bed:
A') as A, but measured in between swanskin and lower bedsheet.
B') as B, but measured 165 cm from the head end of the bed, and 40 cm from the right as well as the left side of the bed.
D') as D, but measured 25 cm from the head end of the bed, and 40 cm from the right as well as the left side of the bed.
D'') as D, but measured 25 cm from the rear end of the bed, and 40 cm from the right as well as the left side of the bed.
E') as E.

The experiment was divided in the following phases: bed occupied for 2 nights, bed left unoccupied for 8 nights, bed occupied for 9 nights, bed left unoccupied for 6 nights, and bed occupied for 4 nights. Sleeping times were not fixed but depended on the needs of the experimental sleeper.

Since significant differences in temperature and relative humidity are known from within beds occupied by female as opposed to male persons (Müller-Limmroth, 1977) 5 nights were studied with the Rotronic Hygroskop SLTT/12P in the bed of a male 59-years old subject (October 1980). The bed was located in a central heated home, and consisted of a wooden bedstead, a foamrubber mattress, a woolen swanskin, a cotton undersheet, a cotton upper sheet, and a quilt. The sensors were placed in between swanskin and mattress at the left and right side of the upper and lower part of the body, under the shoulders and under the feet (2 nights); within the cavities of the latex mattress in the same pattern (3 nights).

3. TEMPERATURE PATTERNS

The temperature within occupied beds goes through daily cycles depending more on occupancy than on the temperature variations in the room air. The general level of the room temperature, however, has a profound influence on bed temperatures.

Table 1
Comparison of average temperature 12 hours before the sleeping period (11.00H) and halfway the sleeping period (3.00H) in winter and summer in the 5 series of measurement (female sleeper).

site of measurement	temperature °C November 1977 11.00H	3.00H	June 1978 11.00H	3.00H
A. pillow	17.0	26.2	19.0	23.1
B. bedspread	12.2	15.8	15.8	19.5
C. next to sleeper	12.2	26.5	18.1	26.5
D. under mattress	7.9	10.2	18.9	19.4
E. near feet	7.4	18.0	16.0	28.2

The nearer to the sleeper a measuring site is, the more constant the average temperature (site C). But even under the mattress and under the bedspread does the temperature rise under influence of the sleeper. Fluctuations in temperature during occupancy are highest in the vicinity of the sleeper. Within 1 night, the temperature at site C varied from 25 to 32°C. When the experimental sleeper was in het twenties, measurements at site A gave slightly higher values: 29°C when at 11.00H temperature was 20°C, and 26-28°C when the 11.00H temperature was 16°C (Koekkoek & van Bronswijk, 1972).

From the measurements in 1980 is became clear that after an initial slow or fast rise in temperature of the measuring sites near the sleeper, the temperature started to fluctuate with a peak every 1½ or 2 hours.

After the bed had been vacated equilibrium conditions with the room air were achieved after 6 to 8 hours. Under the mattress at the rear end of the bed (site D''), at the largest distance from the sleeper, temperature does not rise until about 1 or 2 hours after occupancy of the bed.

The highest temperature measured in the bed occupied by the female person was 38°C at site E'. The highest temperature measured in the bed of the male subject was 37° C (under the belly of the sleeper). Temperatures near the feet of the male sleeper did not differ markedly from the situation near the female sleeper. The averages under the mattress were higher, however, (30°C halfway the sleeping period, 19°C 12 hours before the sleeping period). Apparently the mattress, in this case, has a higher conductability for heat.

From the point of view of the mites and fungi living in the bed, the sleeper improves their temperature conditions. But even without a sleeper temperature in the bed is nowhere and never lethal.

4. MOISTURE CONDITIONS

Sleepers do sweat and a rise in absolute humidity of the air at the different measuring sites in the bed is apparent, especially in winter.

Table 2
Rise in absolute humidity of the air (mean and standard deviation) from 12 hours before the sleeping period (11.00H) to halfway the sleeping period (3.00H) in winter and summer in the 5 series of measurement (female sleeper).

site of measurement	absolute humidity g/m^3 November 1977	June 1978
A. pillow	7.2±0.9	3.8±1.5
B. bedspread	3.7±6.5	2.4±2.0
C. next to sleeper	6.8±2.8	4.7±1.8
D. under mattress	0.6±0.4	0.4±0.9
E. near feet	5.0±3.6	5.8±2.9

The nearer to the sleeper a measuring site is, the higher the absolute humidity (Values at A have been elevated by the breathing of the sleeper). In general more sweat is produced or retained in winter as compared to summer.

Van de Lustgraaf et al. (1978) found a rise in absolute humidity under the body of a male sleeper in his thirties of 10.4 g/m^3; on the mattress near the side of the bed the rise was 3.6 g/m^3. Near the feet of our male experimental sleeper the absolute humidity rose 7.6 g/m^3, under his mattress 10.5 g/m^3. Rise at site A when the female experimental sleeper was in het twenties consisted of 9.7 or 9.8 g/m^3 at room temperature of 14°C, and 7.5 g/m^3 at 20°C room air temperature.

Müller-Limmroth (1977) showed a significant difference in weather conditions in beds occupied by male and female sleepers. In beds of female sleepers temperatures were higher, in those of male sleepers more sweat was produced. Our results indicate also that the male sleeper sweated more than the female sleeper. Probably sweating also decreases with age.

5. RELATIVE HUMIDITY

For the water economy of the mites and fungi living in beds not the absolute humidity is of importance but the relative humidity. Values over 70%RH are needed for at least part of the day to ensure rapid development of very common species such as Dermatophagoides farinae, D. pteronyssinus, Euroglyphus maynei, Aspergillus repens, A. penicilloides, and Wallemia sebi (van de Lustgraaf et al., 1978; van Bronswijk, 1981).

Near the male experimental sleeper range of relative humidities measured on top of the mattress was 49-87%, in the cavities of the latex mattress 58-86%.

Nearest to the female sleeper (sites C, E, table 3) the ranges are the same in summer as well as winter. On other sites the summer ranges are more extensive, especially on the dry end of the scale.

For growth of mites and fungi in winter the upper side of the top blanket and the under side

Table 3
Ranges of relative humidity at the different measuring sites in the occupied bed. The first 50 min. of occupation are not included.(female sleeper).

site of measurement	relative humidity % Nov.-Dec.	June-July
A. pillow	60-67	43-61
A'. id.		55-70
B. bedspread	60-85	47-78
B'. id.		55-96
C. next to sleeper	38-72	33-76
D. under mattress	69-80	55-72
D'. id.		61-83
D''. id.		61-81
E. near feet	36-67	30-62
E'. id.		39-72

of the mattress seem to be best. Especially between the popyether mattress and the jute under mattress humidity conditions are ideal. Apparently the natural jute fibers store more moister than the polyether foam. The relative humidity under the mattress keeps on rising until 2-4 hours (in winter) or 0-1 hours (in summer) after sleeping has been terminated. Natural fibers in general may absorb considerable amounts of water for the atmosphere, while synthetic fibers are almost unable to do so (van Bronswijk, 1981).

The relative humidity on top of the upper blanket fluctuates widely during the night. Growth of mites and fungi may be hampered for some time every night when the relative humisity drops below 70%RH.

Site A (pillow) although not suitable for mite and fungal growth in winter in this study, was found to be very suitable under slightly different conditions (Koekkoek & van Bronswijk, 1972).

In summer a greater number of sites in the bed is suitable for mite and fungal growth, at least part of the night. Under the matress again the best conditions are found. Measurements with the Rotronic Hygroskop SLTT/12P showed that below the bedspread (site A', female sleeper), near the feet (site E', female sleeper), and sometimes near the sides of the body of the sleeper (male sleeper), the relative humidity fluctuates strongly and regularly, with peaks every 1½ or 2 hours. The peaks in temperature at the same sites are usually seen at the same time or a little earlier than the peaks in relative humidity. It was suggested that the heat regulatory mechanism of man does not function during the REM phases of sleep that occur every 90 to 120 min. (Müller-Limmroth, 1977). This could mean a slight undercooling during the REM phase that is promply corrected afterwards (the temperature peak).Suppose the body overshoots a little when correcting, then sweating is needed to cool the body to the preset temperature.

The sleeping period at the 3 sites mentioned above always start with a peak of 20-40 min. duration in the relative humidity measured. It is known that at the beginning of the sleep the body temperature is set at a lower value (Müller-Limmroth, 1977). Probably the body is cooled to that value by sweating, causing a peak in relative humidity in spite of a rise in temperature in the bed at the same time.

The high number of peaks in relative humidity extending 70-75%RH, make it possible for the house-dust organisms to sorb water from the air in most of the sites in the bed, thus being able to survive the dry periods in between. Populations of mites and fungi will probably never thrive on the mattress very near the sleeper. It was reported before that mite number in the mattress are lower in the center as compared to the sides of the mattress (Mulla et al. 1975; Lang & Mulla, 1978). In the bed of the female sleeper under investigation the same was true for pyroglyphid mites as well as xerophilic fungi (van de Lustgraaf, unpublished).

Although the temperature in the bed is in equilibrium with the temperature of the room air, before the bed is again occupied (see above), it takes in summer 205½ hours before the relative humidity of the kapok pillow is in equilibrium with the surrounding room air. For the jute under mattress this time laps is 109-146 hours, for mattress, blankets and sheets 38½-92½ hours. During the phase of non-equilibrium relative humidity in the jute under mattress is slightly higher than the room air temperature. All other sides have a lower relative humidity than the room air. This explains the damp sensation of beds that have not been used for some time. It also explains why mites may grow well in winter in beds not used and kept in unheated rooms (van Bronswijk & Jorde, 1975). The indoor air humidity in winter is lethal for pyroglyphid mites in the temperate climate of The Netherlands, provided proper heating is used (van Bronswijk, 1981). These organisms may find refuge also in occupied beds, as mentioned before.

6. CONCLUSIONS

The nearer to the sleeper a measuring site was, the more constant the average temperature, the higher the rise in absolute humidity, and the larger the ranges in relative humidity.

In winter more sweat is produced or retained in the bed than in winter.

Male sleepers tend to sweat more than female sleepers. Conditions in male beds could be better for growth of microorganisms and mites than conditions in female beds.

Younger persons probably have better mite and fungal weather in their beds than older persons.

The best places for the house-dust organisms seem to be those sites that are at some distance from the sleeper, especially at the underside of the mattress.

The particular organisation of the sleep of man (REM phases) probably gives additional humidity advantages to the bedfauna and flora.

If bedmaterials could be constructed that combine thermal insulation with high moisture conductability, the weather in beds could be much more detrimental to the populations of mites and fungi.

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