Five of the six previously reported studies in which an association between coeliac disease and DR7 was found were from paediatric centres. Of the two studies recording an association with DR3 alone, one concerned adults only[6]; a second study included a mixed group of children and adults, though 74% were adults[7] (table III).

The association of coeliac disease with DR3 and DR7 may be interpreted on the basis of more than one model. The condition may, for example, be genetically homogenous and dependent on a susceptibility gene at a locus linked to the DR locus and in linkage disequilibrium with both DR3 and DR7. In this regard it is relevant that the DC3 specificity at the DC locus is in linkage disequilibrium with DR3 and DR7, and Tosi *et al* put forward evidence to suggest that the primary association was with DC3.[12] A recent study of patients with coeliac disease who were DR3 and DR7 negative, however, failed to confirm this.[13]

Our finding of heterogeneity of the DR association argues against this simple model and suggests the possibility of more than one susceptibility gene—namely, DR3 and DR7 or genes in linkage disequilibrium, one with DR3 and one with DR7. If the presence of both genes promotes an early onset of disease, and the presence of only DR3 or a gene in linkage disequilibrium with DR3 a later onset, the present findings would be explained.

Further studies of the association of coeliac disease with DR and DC antigens are being carried out, and it seems important that age of onset of disease should be taken into account. Other than the age of onset, HLA differences do not seem to have any influence on other clinical variables. Kumar *et al* found that HLA factors did not appear to make any difference to the mode of presentation.[14]

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# The sick building syndrome: prevalence studies

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## Abstract

**Random samples or the entire workforce in nine offices in which similar clerical work was being performed were studied using a doctor administered questionnaire that inquired into symptoms that have been linked with the "sick building syndrome." Five of the offices were fully air conditioned, one had recirculation of air and mechanical ventilation, and three were naturally ventilated. Workers in three air conditioned and three naturally ventilated buildings were interviewed blind. Seven of the buildings were studied at our request in the absence of any known problem. Comparison of prevalences of symptoms between the naturally ventilated and the other buildings showed a repeated pattern of nasal, eye, and mucous membrane symptoms with lethargy, dry skin, and headaches. There were highly significant excesses of these six symptoms in the air conditioned buildings when compared by $\chi^2$ tests with the naturally ventilated buildings.**

**It is suggested that these six symptoms represent the sick building syndrome and that the size of the problem is probably greater than is currently recognised. Possible causes are discussed.**

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## Introduction

The "sick building syndrome" is generally taken to describe a building in which complaints of ill health are more common than might reasonably be expected. The affected buildings are usually offices that have full air conditioning. The excess of complaints of ill health is not usually reflected in an increase in sickness absence. No definition of the size of the problem has previously been systematically attempted, although Turiel *et al* noted excesses of eye, upper respiratory tract, and chest symptoms in an open comparison of an air conditioned and a naturally ventilated building.[1] In that study 62% of the workers in the air conditioned building and 66% in the naturally ventilated building were interviewed.

Several causes have been postulated for symptoms in office buildings, and, despite much research, no satisfactory explanation of the problem has been found. The postulated causes include formaldehyde (from cavity wall insulation, office

furniture, or carpet adhesive), cigarette smoke, excess of airborne particles, excess of carbon dioxide, bacteria in the air from contamination of the humidifiers, poor circulation of air in the buildings, and lack of negative ions. As up to 90% of the air in an air conditioned building may be recirculated to conserve energy lack of "fresh" air has often been blamed for the symptoms. Following the recent interest in the sick building syndrome,[2] we report the results of a study of nine buildings.

## Buildings and methods

Over the past two years we studied nine buildings in which mainly clerical work was performed. In each investigation a standard, doctor administered questionnaire was used. This inquired into nasal symptoms (blocked/itchy/runny nose), eye symptoms (itching/irritation/watering eyes), drying of mucous membranes (dry throat/stuffy nose), symptoms suggestive of work related asthma (chest tightness/difficulty in breathing/shortness of breath/wheeze), symptoms suggestive of humidifier fever (fever/joint and muscle pains/tiredness/headache), and symptoms of lethargy, nose bleeds, dry skin, rash, itchy skin, and headache. In each case subjects were asked when a particular symptom had started and whether it improved over weekends or holidays. A smoking history was taken and any history of chronic bronchitis, hay fever, or asthma noted.

Each symptom was assessed as work related according to a standard definition: only those symptoms that had developed after the subject started work in the building concerned or, if previously present, had deteriorated after the subject started work in that building, and that improved over weekends or holidays, or both, were considered to be work related. The prevalences of symptoms reported here refer only to work related symptoms as defined above.

In each building studied we attempted to interview either the entire workforce or a random sample of it. We also attempted to interview those who were unwilling to cooperate. The prevalences of symptoms reported here refer only to those found in an entire workforce or in a random sample. Volunteers were excluded from the analysis.

### THE BUILDINGS

In all we studied nine buildings. Table I shows their forms of ventilation. We paired each of three that were naturally ventilated with a fully air conditioned building on the same site: buildings 1 and 2, 3 and 4, and 8 and 9. In each of these six buildings workers were interviewed blind and the details concerning their building entered after the questionnaire had been completed.

Buildings 1 and 2 were the first office buildings studied and drew our attention to a high incidence of complaints, which were included as the last six questions on the questionnaire in all subsequent studies.

## Results

Table I shows the number of employees in the sample from each building and the proportion of the sample that we were able to interview. For ease of understanding, the buildings have been categorised according to their system of ventilation and the presence or absence of humidification and recirculation of air. Table II shows the combined prevalence of each work related symptom and the prevalence of smoking for the buildings in each category.

TABLE I—*Details of buildings and populations studied in each*

| | Buildings | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| No of workers in sample | 246 | 65 | 146 | 143 | 272 | 227 | 78 | 88 | 120 |
| Proportion seen (%) | 81·7 | 75·4 | 88·4 | 78·3 | 82·7 | 87·2 | 93·6 | 88·6 | 81·7 |
| Natural ventilation | − | + | − | + | − | − | − | − | + |
| Mechanical ventilation | + | − | + | − | + | + | + | + | − |
| Humidified | + | − | + | − | + | + | − | + | − |
| Air recirculation | + | − | − | − | − | + | + | + | − |

+ = factor present; − = factor absent.

As the workers in all three naturally ventilated buildings were interviewed blind, they may be regarded as controls. $\chi^2$ analyses were performed comparing the prevalences of symptoms detected in the naturally ventilated buildings with those in buildings using mechanical ventilation with and without humidification and recirculation of air (table II).

TABLE II—*Prevalence of symptoms (%) in relation to method of air supply: comparison with natural ventilation*

| Symptom | Natural ventilation (n = 259) | Mechanical ventilation only (n = 73) | Humidified, no recirculation (n = 354) | Humidified with recirculation (n = 477) |
|---|---|---|---|---|
| Nasal | 5·8 | 13·7* | 22·4*** | 17·2*** |
| Eye | 5·8 | 8·2 | 28·3*** | 17·6*** |
| Mucous membrane | 8·1 | 17·8* | 37·9*** | 32·6*** |
| Tight chest | 2·3 | 1·1 | 9·6*** | 7·8** |
| Shortness of breath | 1·6 | | 4·3 | 2·9 |
| Wheeze | 3·1 | | 5·1 | 4·4 |
| Humidifier fever | 1·1 | | 3·4 | 2·1 |
| Current smoker | 28·2 | 30·1 | 29·1 | 26·5 |
| Headache | 15·7 | 37·0*** | 34·7*** | 39·5*** |
| Nose bleed | 0·5 | | 1·4 | 2·2 |
| Dry skin | 5·7 | 5·5 | 16·2*** | 14·9*** |
| Rash | 1·9 | 2·7 | 3·1 | 2·9 |
| Itchy skin | 2·9 | 2·7 | 7·4* | 7·2* |
| Lethargy | 13·8 | 45·2*** | 49·9*** | 52·5*** |

Significance of difference when compared with natural ventilation: $p^* < 0.05$; $^{**} < 0.01$; $^{***} < 0.001$.

For completeness, table III shows the prevalences of work related symptoms for each of the nine buildings studied, drawing a distinction between those studies that were performed at our request and those performed by request because of a known problem.

## Discussion

Air conditioned offices were originally designed for the comfort, wellbeing, and convenience of the people who were to work in them.[3] The ideal working environment was considered to be a controlled one with no large swings in temperature or large changes in relative humidity and with an air supply sufficient to remove odours. The results of this study would indicate that, at least in the offices we studied, this goal has yet to be achieved. Indeed, examination of the excesses of symptoms shown in tables II and III shows that there is a large discrepancy between reality and the ideal office environment.

TABLE III—*Prevalence of symptoms (%) in each building studied*

| Symptom | Building | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5* | 6 | 7 | 8* | 9 |
| Nasal | 18·4 | 8·2 | 27·6 | 5·4 | 19·6 | 14·1 | 13·7 | 21·8 | 5·1 |
| Eye | 9·5 | 4·1 | 21·9 | 7·1 | 34·7 | 18·7 | 8·2 | 35·6 | 5·1 |
| Mucous membrane | 24·9 | 8·2 | 34·9 | 9·0 | 39·6 | 32·0 | 17·8 | 55·1 | 7·1 |
| Tight chest | 5·0 | 0 | 7·0 | 3·6 | 11·1 | 6·6 | 1·4 | 17·9 | 2·0 |
| Shortness of breath | 1·0 | 2·0 | 3·2 | 1·8 | 4·9 | 2·0 | 0 | 10·4 | 1·0 |
| Wheeze | 4·0 | 2·0 | 8·6 | 4·5 | 3·1 | 4·0 | 0 | 6·4 | 2·0 |
| Humidifier fever | 2·0 | 0 | 9·3 | 1·8 | 0 | 0·5 | 0 | 0 | 0 |
| Current smoker | 30·8 | 26·5 | 24·0 | 25·0 | 32·0 | 22·2 | 30·1 | 25·6 | 32·7 |
| Headache | NA | NA | 31·0 | 15·2 | 36·4 | 32·3 | 37·0 | 57·7 | 16·3 |
| Nosebleed | NA | NA | | | 2·5 | 1·5 | | 3·9 | 1·0 |
| Dry skin | NA | NA | 5·4 | | 23·1 | 12·6 | 5·5 | 20·5 | 12·2 |
| Rash | NA | NA | 3·9 | 0·9 | 2·7 | 1·5 | 2·7 | 6·4 | 3·1 |
| Itchy skin | NA | NA | 3·9 | 1·8 | 9·3 | 6·1 | 2·7 | 10·4 | 4·1 |
| Lethargy | NA | NA | 36·4 | 13·4 | 56·9 | 42·9 | 45·2 | 76·9 | 14·3 |

*Building studied at request of management.
NA = not available.

It is important to note that these field studies were not all initiated by requests from the building management because of complaints from the office staff. Only in buildings 5 and 8 were complaints about the working environment the initiating factor. The studies of buildings 1, 2, 6, 7, and 9 were per-

formed at our request in the absence of any known complaints from the staff, and the studies of buildings 3 and 4 were performed because two workers with symptoms suggestive of humidifier fever, who both worked in building 3, had been seen by the same physician in an outpatients department; this led to our requesting to study the building and a control building alongside it (building 4). Thus, from the sick building syndrome aspect, sites 5 and 8 represented the more severe end of the spectrum compared with sites 1, 3, 6, and 7, in which there was no known excess of complaints. This is borne out in table III, which shows a generally higher prevalence of symptoms in buildings 5 and 8 compared with the others.

Table II shows a repeated pattern of work related symptoms occurring to excess in the air conditioned and mechanically ventilated buildings compared with the naturally ventilated ones. Table III confirms the excesses in each building compared with the naturally ventilated buildings. This excess of symptoms in the air conditioned and mechanically ventilated buildings was also present in the three pairs of buildings in which the workers were interviewed blind: buildings 1 and 2, 3 and 4, and 8 and 9. A complex of symptoms affecting the nose, eyes, and mucous membranes with headache, dry skin, and lethargy emerged. These symptoms were, with one exception (nasal symptoms in building 3), most prevalent in the two buildings (buildings 5 and 8) in which dissatisfaction among the workforce had led to a request for an independent examination of the air conditioning system (table III). In these two buildings one further symptom emerged: itchiness of the skin.

This repetitive pattern was surprising in view of the large differences between the buildings in terms of office accommodation (some were open plan, others had small offices), humidification system, and amount of air recirculated. The prevalences of the symptoms affecting the upper respiratory tract and mucous membranes were high, especially in the humidified buildings, when compared with those in the naturally ventilated buildings. Indeed, in one building (building 8) over half the employees questioned were affected by dryness of the mucous membranes. Part of the high prevalence of symptoms in building 5 may have been explained by dissatisfaction with a new working environment as the workers had all recently been moved to this air conditioned office from a naturally ventilated one. This, however, was not the case in building 8, in which most of the staff had been working for some years. In building 8 a deterioration in the working environment had led to the request for an independent investigation. In buildings 8 and 9 the high prevalence of dryness of the skin was thought to be because the work at these two sites included handling a lot of paper; in many cases the dryness was on the hands only. In most of the other buildings the dryness affected exposed areas of skin, particularly the face, lips, and arms, and was always commoner in women, who often gave a clear history of having to use more skin cream after moving to the air conditioned building.

The prevalence of symptoms of the sick building syndrome in buildings without a known problem has not previously been systematically determined. This is because research into this subject has to date usually been by means of a circulated questionnaire, generally with a low response rate. Typically, less than half return the questionnaire.[4] Consequently, conclusions on the prevalence of symptoms in these buildings cannot be drawn. For this reason the high prevalences of symptoms in buildings 1, 3, 6, and 7 were unexpected findings. In each case the office had been open for at least five years, so that dissatisfaction with a "new" environment could not be blamed as the cause of the symptoms. As the symptoms affect a large proportion of the workforce and do not cause serious illness they often come to be accepted by the workers as a nuisance and as part of coming to work. Furthermore, as they rarely lead to absenteeism these symptoms may easily be overlooked by the medical officer looking after the building.

Headaches and lethargy are very common complaints. It was therefore surprising to find such highly significant differences ($p < 0.001$) between naturally ventilated buildings and those with mechanical ventilation with or without humidification. The headaches described were usually mild (although a few workers appeared to have work related migraine) and tended to develop in the afternoon. The lethargy was in every case undue lethargy for the amount of work done and sleep enjoyed and also tended to develop in the afternoon. In many cases the workers found it an effort to concentrate in the afternoon. Complaints of tiredness are common in a doctor's surgery, and it is rarely a rewarding symptom to investigate. Inquiry about the working environment may show the source of the symptom.

Another symptom that was in excess in the humidified buildings was chest tightness. In most workers with this symptom serial recordings of peak flow rates were made, every two hours for four weeks. These recordings, in all but two cases, did not show any evidence of work related asthma. Turiel *et al* also found an excess of this symptom in their study, although peak flow recordings were not performed.[1] The cause of this symptom in the air conditioned buildings is not clear.

As would be expected, humidifier fever was commoner in humidified than in non-humidified buildings. All cases identified were mild. The low prevalence seen in the naturally ventilated buildings reflected the relatively low specificity of the questionnaire in detecting possible mild cases of this condition.

Regarding the causation of the sick building syndrome several points are of interest: as none of the buildings had urea formaldehyde cavity wall insulation this was not the cause of the syndrome in these buildings; as most of the symptoms of the syndrome occurred in a non-humidified building (building 7), humidifiers were not the specific cause; because a high prevalence of symptoms of the sick building syndrome occurred in two buildings with no recirculation of air (buildings 3 and 5) this energy saving practice cannot be blamed; as all the workers in the naturally ventilated buildings and most in the humidified buildings were interviewed blind, and there were very large differences between the groups, the syndrome must be accepted as a definite entity and cannot be dismissed as hysteria. This last point is made more valid by most of the buildings having been selected before we were aware of any dissatisfaction among the workers.

Finally, although the symptoms of the sick building syndrome do not represent a disease but rather a reaction to the working environment, the scale of the problem is probably considerable, and the high degree of dissatisfaction seen in this study demands attention from architects, engineers, and the medical profession. In particular, more research is needed, preferably of a longitudinal nature, into both air conditioned and naturally ventilated buildings. The facility to alter and measure numerous variables in the working environment—for example, temperature, humidity, radiant heat, air flow rates, fresh air intake, small air ion concentration—and to question the workers repeatedly about their symptomatology should be included in the design of such a study. In this way, if the cause, or causes, of the sick building syndrome were to be identified, this problem might be avoided in future offices by making appropriate modifications to office design and air supply. A study of the type described would necessarily require a high degree of cooperation from both the workers and the management concerned.

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