

Predicting the grass pollen count from meteorological data with regard to estimating the severity of hayfever symptoms in Melbourne (Australia)

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Abstract

In Melbourne, Australia, grass pollen is the predominant cause of hayfever in late spring and summer. The grass pollen season has been monitored in Melbourne, using a Burkard spore trap, for 13 years (1975–1981, 1985 and 1991–1997). Total counts for grass pollen were highly variable from one season to the next (approximately 1000 to > 8000 grains/m³). The daily grass pollen counts also showed a high variability (0 to approximately 400 grains/m³). In this study, the grass pollen counts of the 13 years (12 grass pollen seasons, extending from October to January) have been compared with meteorological data in order to identify the conditions that can determine the daily amounts of grass pollen in the air. It was found that the seasonal total of grass pollen was directly correlated with the rainfall sum of the preceding 12 months (1 September–31 August): seasonal total of grass pollen (counts/m³) = $18.161 \times \text{rainfall sum of the preceding 12 months (mm)} - 8541.5$ ($r_s = 0.74$, $P < 0.005$, $n = 12$). The daily amounts of grass pollen in the air were positively correlated with the corresponding daily average ambient temperatures ($P < 0.001$). The daily amount of grass pollen which was to be expected with a certain daily average temperature was linked to the seasonal total of grass pollen: in years with high total grass pollen counts, a lower daily average temperature was required for a high daily pollen count than in years with low total grass pollen counts. As the concentration of airborne grass pollen determines the severity of hayfever in sensitive patients, an estimation of daily grass pollen counts can provide an indication of potential pollinosis symptoms. We compared daily grass pollen counts with the reported symptomatic responses of hayfever sufferers in November 1985 and found that hayfever symptoms were significantly correlated to the grass pollen counts ($P < 0.001$ for nasal, $P < 0.005$ for eye symptoms). Thus, a combination of meteorological information (i.e. rainfall and temperature) allows for an estimation of the potential daily pollinosis symptoms during the grass pollen season. Here we propose a symptom estimation chart, allowing a quick prediction of eye and nasal symptoms that are likely to occur as a result of variations in meteorological conditions, thus enabling both physicians and patients to take appropriate avoidance measures or therapy. © 1998 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Meteorological data; Grass pollen counts; Allergens; Hayfever; Symptom estimation

1. Introduction

Grass pollen allergy has a high prevalence in Europe, America and Australia, where up to 70% of patients with type I allergy display IgE reactivity to grass pollen allergens (Freidhoff et al., 1986). In Melbourne, grass

pollen is the major source of allergens in the outdoor environment and the most important cause of hayfever in late spring and summer (Ong et al., 1995). Due to a range of environmental factors, the seasonal total of grass pollen counts is highly variable from one season to the next (Smart and Knox, 1979; Spieksma et al., 1985). In Melbourne, the seasonal total of grass pollen ranged from approximately 1000 (1980/1981) to > 8000 grains/m³ (1993/1994). The daily grass pollen counts

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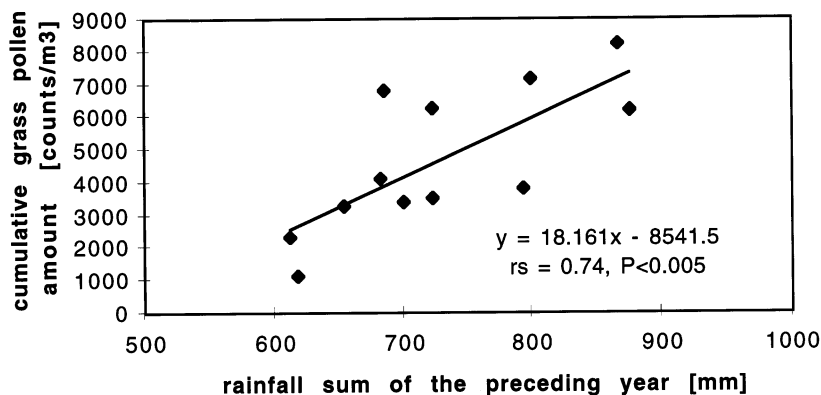


Fig. 1. Correlation between the cumulative daily grass pollen amount (counts/m³) and the rainfall sum (mm) of the preceding year (1 September to 31 August) in Melbourne ($r_s = 0.74$, $P < 0.005$, $n = 12$).

were also highly variable. Under suitable circumstances (in Melbourne: high temperatures with northerly winds during the grass pollen season according to Smart et al., 1979), up to 400 grains/m³ have been detected. In the cool temperate climate of this region, rye-grass (*Lolium perenne*) pollen is more abundant than pollen from other grass species (Hill et al., 1979; Smart and Knox, 1979), since rye-grass is grown extensively as pasture grass in this area and has a very high pollen output (Smart et al., 1979).

Up to 95% of patients allergic to grass pollen possess IgE specific for group 1 allergens and 80% for group 5 allergens, these two groups forming the major allergens of grass pollen (Valenta et al., 1993). These allergens can be released rapidly when grass pollen comes into contact with the oral, nasal or eye mucosa, causing hayfever symptoms in susceptible patients. Thus, the concentration of airborne grass pollen determines the severity of hayfever in sensitive patients. Consequently, daily grass pollen counts can provide an indication of potential pollinosis symptoms. In London, the minimum number of grains to induce hayfever symptoms was shown to be 10–50 grass pollen grains/m³ (Davies and Smith, 1973). In Cardiff, 10% of hayfever patients were estimated to experience symptoms when counts exceeded 10 grass pollen grains/m³ and 100% of hayfever patients experienced symptoms with more than 50 grass pollen grains/m³ in London (Hyde, 1972). Antepara et al. (1995) found that in Bilbao, Spain, 100% of hayfever patients experienced symptoms when more than 37 grass pollen grains/m³ were present. In Finland, grass pollen counts of < 30 grains/m³ were shown to be significantly correlated with nasal symptoms at the start of the grass pollen season (Rantio-Lehtimäki et al., 1991).

In this study we analyzed grass pollen counts for 12 grass pollen seasons and meteorological data to formulate a model for estimating daily grass pollen concentrations. We used grass pollen count data and symptom

scores of susceptible individuals to assess symptomatic response to varying grass pollen levels. The aim of the study was to enable a prediction of potential pollinosis symptoms during the hay fever season, based on meteorological information.

2. Methods

2.1. Grass pollen count

The daily grass pollen count was performed during the seasons of 1975–1981, 1985 and 1991–1997 using a Burkard volumetric trap (Burkard Manufacturing, Rickmansworth, Hertfordshire, UK) according to the manufacturer's instructions. The sampler was located 14 m above ground level, on the roof of a building on the campus of The University of Melbourne, Australia. The air flow was set to 10 l/min. Airborne pollen grains were trapped on a microscope slide previously coated in adhesive (10% Dow Corning A280 in xylene) driven by a clockwork motor. The slides were mounted in Calberla's stain and grass pollen counted by light microscopy.

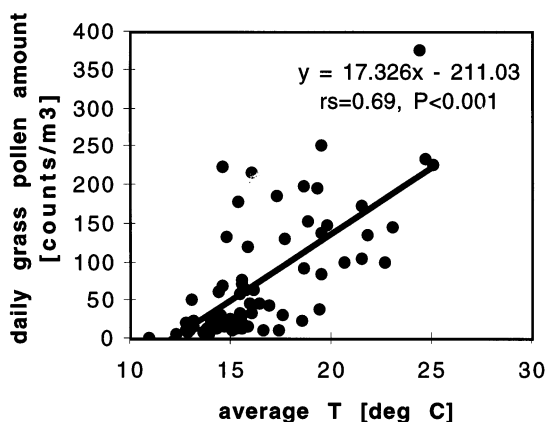


Fig. 2. Correlation between daily grass pollen amounts (counts/m³) and average daily temperature (°C) for the grass pollen season of 1996/1997 in Melbourne ($r_s = 0.69$, $P < 0.001$, $n = 71$).

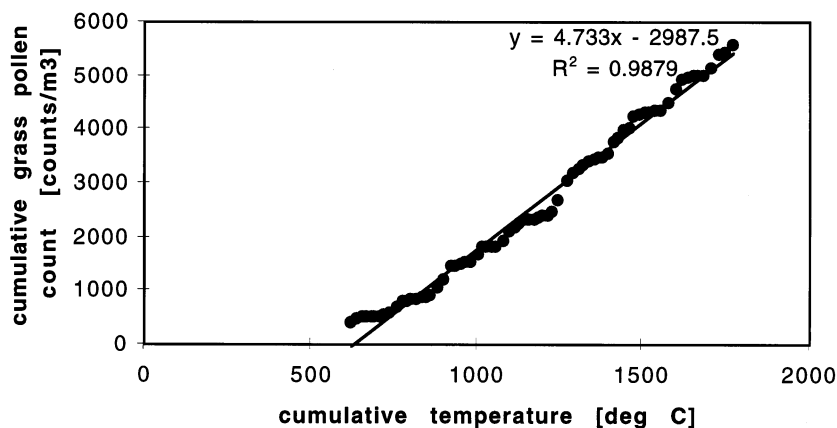


Fig. 3. Plot of the cumulative daily pollen amount (counts/m³) for the season 1996/1997 against cumulative daily average temperature (°C) in Melbourne ($r^2 = 0.98$, $P < 0.001$, $n = 71$).

2.2. Length of the grass pollen season

According to Lejoly-Gabriel (1978), the grass pollen season was defined as starting from the day when the sum of daily pollen concentration reaches 5% of the annual total, provided that this particular day contributes at least 1% itself. Whenever these conditions are not met, the beginning of the season is the first day on which pollen concentration equals or exceeds 1% after the 5% level has been reached. The grass pollen season ends on the last day with more than 1% of the annual total preceded by 2 days with a joint total of at least 3% of the annual total.

2.3. Meteorological data

Meteorological data were obtained from the National Climate Centre, Bureau of Meteorology, Mel-

bourne. These included daily rainfall, minimum, maximum and average temperatures and wind direction.

2.4. Patient data

Hayfever symptoms of 28 volunteers suffering from hayfever were recorded on a daily basis in Melbourne in November 1985 according to the questionnaire outlined below. Participating subjects were selected with moderate to severe hayfever, and were shown to be sensitive to grass pollen. Criteria for inclusion of individuals were as follows:

- aged between 17 and 50,
- clinical history of hayfever for more than 2 years,
- clinical history of moderate or severe hayfever in the grass pollen season of 1984/1985,
- giving a strong positive reaction (weal diameter of > 10 mm) to standard skin prick tests of rye-grass pollen extract,
- available and willing to co-operate with the study, and give an informed consent.

The selected volunteers (15 female, 13 male) were encouraged, if possible, not to take any medication (nasal spray, eyedrops or tablets) for hayfever during the study period. Nasal and eye symptoms were recorded on a questionnaire. In detail, the subjects were asked to provide the following information:

- (i) Nasal symptoms due to hayfever (referring to the worst they have experienced whether it was blockage, discharge or itching). Symptoms were scored between 0 and 3: 0, no symptoms; 1, mild symptoms (symptoms only a slight nuisance); 2, moderate symptoms (symptoms quite obvious but tolerable); 3, severe symptoms (symptoms very obvious and quite intolerable).

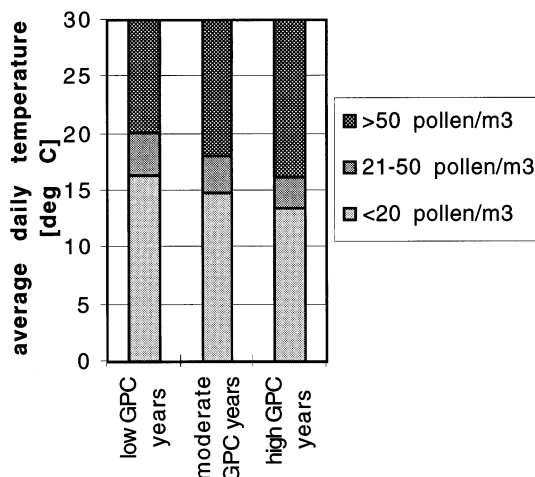


Fig. 4. Amount of grass pollen (counts/m³) associated with average daily temperature (°C) in low, moderate and high grass pollen count (GPC) years.

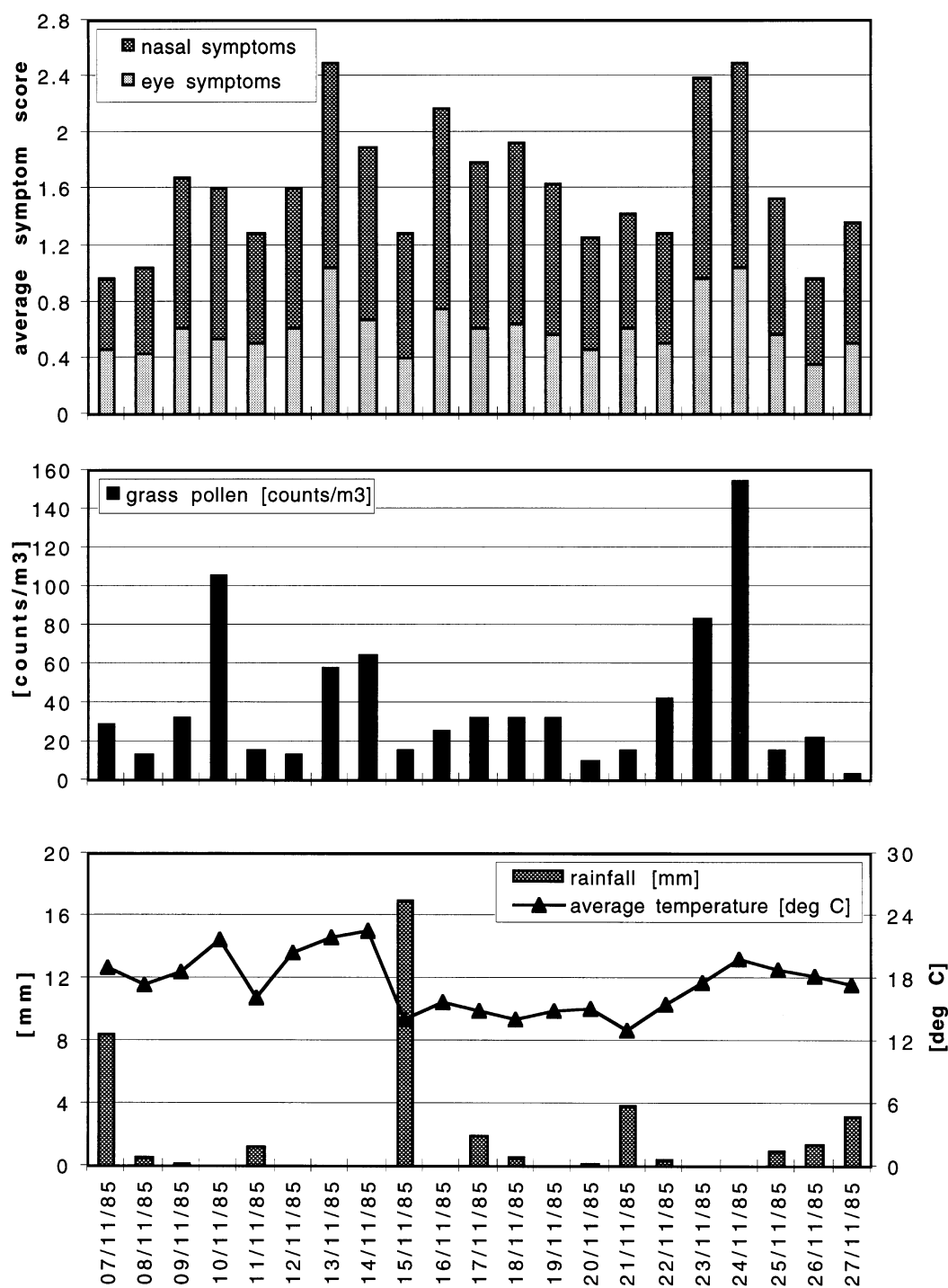


Fig. 5. Grass pollen levels (counts/m³), meteorological parameters and the corresponding average nasal and eye symptom scores in November 1985 in Melbourne.

- (ii) Eye symptoms due to hayfever (referring to the worst they have experienced whether eyes were itching, swelling or running; scored as above).
- (iii) Other comments (such as illness, travel or any other event which may influence hayfever).

2.5. Statistical analysis

The data were compiled and analyzed using Microsoft Excel 5.0 (Microsoft, USA) or Minitab 10 Xtra (Minitab, State College, PA). Correlation analysis for non-parametric data used Spearman's rank correlation

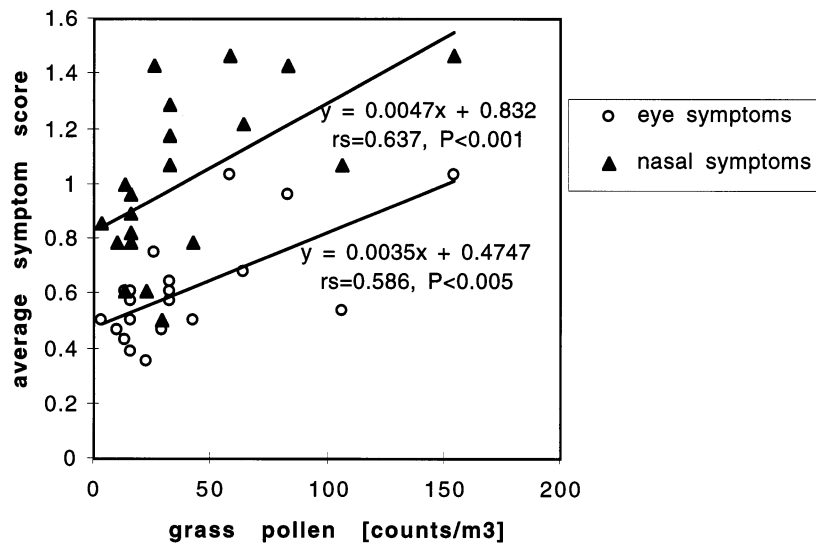


Fig. 6. Correlation of average daily nasal ($r_s = 0.637$, $P < 0.001$, $n = 21$) and eye ($r_s = 0.586$, $P < 0.005$, $n = 21$) symptom scores (0, no symptoms; 1, mild; 2, moderate; 3, severe) with the daily grass pollen counts (counts/m³).

coefficient, r_s . The level of significance was assessed between $P < 0.05$ and $P < 0.001$.

3. Results

3.1. Predicting the intensity of the grass pollen season

The intensity of the grass pollen season, expressed as the cumulative daily grass pollen count (GPC) was shown to be significantly correlated to the rainfall sum of the preceding year (1 September–31 August) (Fig. 1). The regression analysis of data from all 12 grass pollen seasons yielded the equation:

cumulative GPC (counts/m³)

= 18.161

× rainfall sum of the preceding 12 months (mm)

– 8541.5 ($r_s = 0.74$, $P < 0.005$, $n = 12$)

Based on this correlation, we suggest three categories of varying intensity of grass pollen seasons:

- low GPC years: < 3000 cumulative grass pollen counts/m³ (< 635 mm rainfall from 1 September to 31 August of the preceding year),
- moderate GPC years: 3000–6000 cumulative grass pollen counts/m³ (635–800 mm rainfall), and
- high GPC years: > 6000 cumulative grass pollen counts/m³ (> 800 mm rainfall).

Therefore, the rainfall sum of the period 1 September to 31 August can be used to predict the total pollen amount of the following grass pollen season.

There was no significant correlation between the intensity of the grass pollen season with winter rainfall (June to August) ($r^2 = 0.14$, $n = 12$), with July rainfall ($r^2 = 0.001$, $n = 12$), with winter minimum temperature ($r^2 = 0.05$), nor with winter average temperature ($r^2 = 0.001$, $n = 12$). Yet, there was a low, but not significant correlation with the cumulative temperature of the preceding year ($r^2 = 0.39$, $n = 12$).

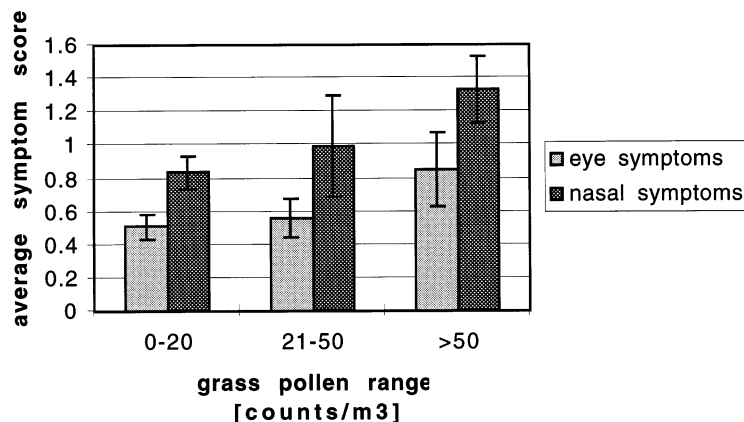


Fig. 7. Average nasal and eye symptom scores (0, no symptoms; 1, mild; 2, moderate; 3, severe) related to three different grass pollen ranges: 0–20 grass pollen grains/m³, 21–50 grass pollen grains/m³ and > 50 grass pollen grains/m³.

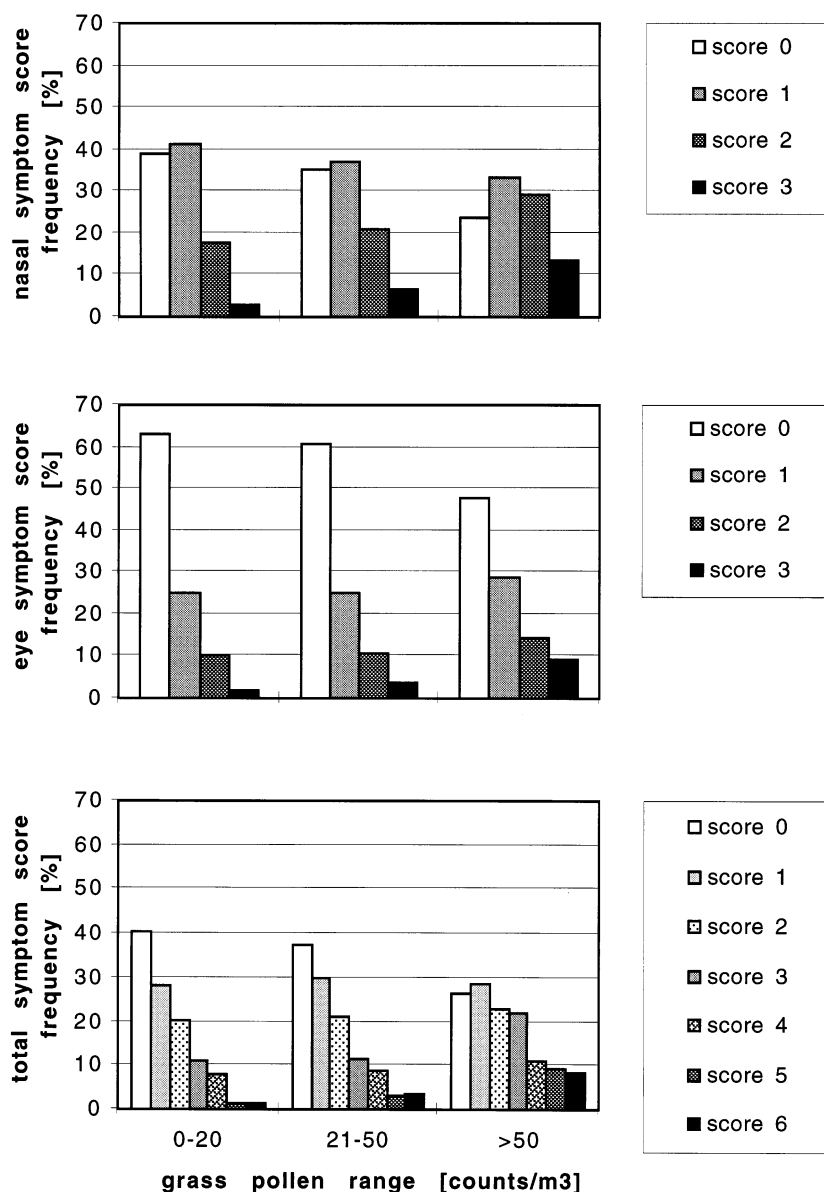


Fig. 8. Frequency (%) of the nasal, eye and total symptom scores (0, no symptoms; 1, mild; 2, moderate; 3, severe) related to the three different grass pollen ranges.

3.2. Predicting daily amounts of grass pollen

We found that the daily average amounts of grass pollen during the grass pollen season (as defined by Lejoly-Gabriel, 1978) were positively correlated with the corresponding daily average ambient temperatures. For example, Fig. 2 shows daily grass pollen counts and average daily temperatures for the grass pollen season 1996/1997 ($r_s = 0.69$, $P < 0.001$, $n = 71$). Cumulative daily pollen counts for the season 1996/1997 were plotted against cumulative daily average temperatures and indicated a linear relationship (Fig. 3). This highlights that the increase in daily grass pollen amount is directly linked to the increase in ambient temperature. Regression analysis of the cumulative temperature and

the cumulative grass pollen counts yielded a coefficient (r^2) of 0.98 ($P < 0.001$, $n = 71$).

Further regression analyses indicated that rainfall and northerly winds, two important parameters that affect the daily amount of grass pollen in the atmosphere of Melbourne, are directly linked with the daily temperature. Rainfall is linked with decreasing average daily temperature and northerly winds are associated with increasing average daily temperature. Thus, the daily temperature reflects both rainfall and wind direction and is therefore an integrative parameter of superior importance. This allowed the sole use of average daily temperature in our model.

The intensity of the grass pollen season determined the daily amount of grass pollen which was to be

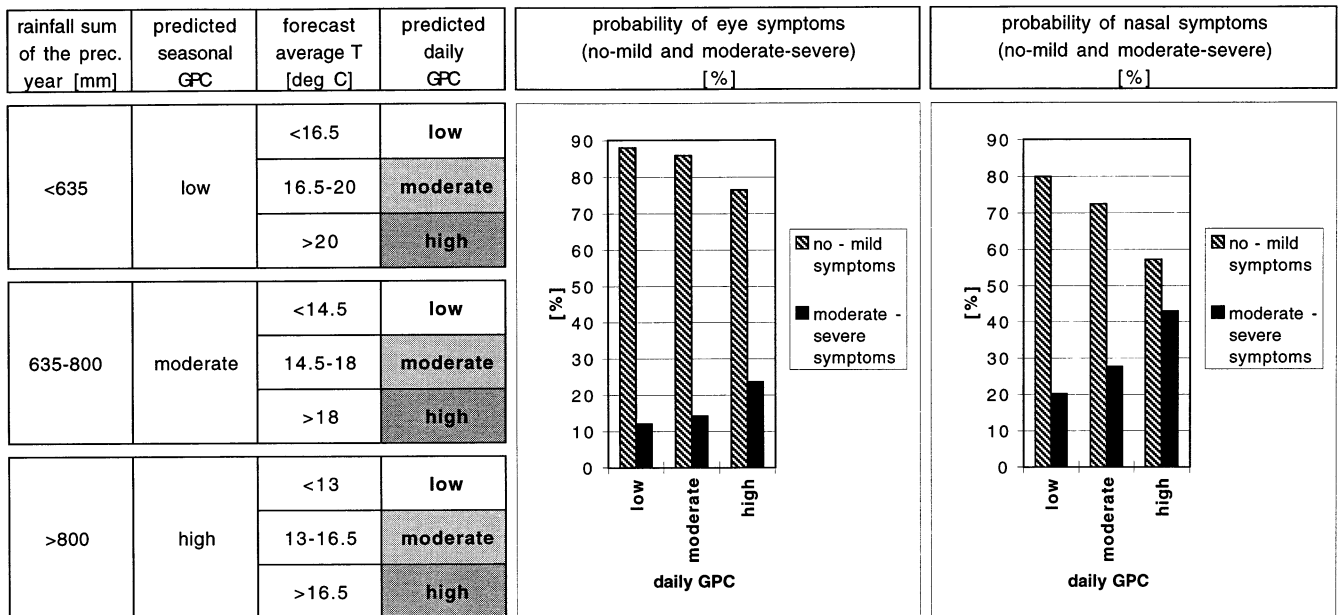


Fig. 9. Symptom estimation chart, proposed for the grass pollen season in Melbourne, Australia, showing the expected severity of eye and nasal symptoms connected to the rainfall sum of the preceding year (mm) and the average daily temperature (°C); GPC, grass pollen count.

expected with a certain daily average temperature (Fig. 4). In years with high total grass pollen counts, a lower daily average temperature was required for a high daily pollen count than in years with low total grass pollen counts.

3.3. Airborne grass pollen and hayfever symptoms

Nasal and eye symptom scores were recorded by each of the 28 hayfever sufferers and indicated, as expected, a high variability. Some of the test individuals reported none or very low symptom scores throughout the study period. The average nasal symptom scores are significantly correlated to the corresponding eye symptom scores ($r_s = 0.902$, $P < 0.001$, $n = 21$).

Grass pollen levels and meteorological parameters during November 1985, and the corresponding average nasal and eye symptom scores are shown in Fig. 5. The average nasal ($r_s = 0.637$, $P < 0.001$, $n = 21$) and eye ($r_s = 0.586$, $P < 0.005$, $n = 21$) symptom scores are significantly correlated to the grass pollen counts (Fig. 6).

The average nasal and eye symptom scores related to three different grass pollen ranges (0–20 grains/m³, 21–50 grains/m³ and > 50 grains/m³) are shown in Fig. 7. The average symptom scores on days with 0–20 grains/m³ are significantly lower ($P < 0.001$) than those on days with > 50 grains/m³. Fig. 8 shows the frequency of nasal (scored 0–3), eye (scored 0–3) and total (sum of nasal and eye scores, thus 0–6) symptoms related to the three different grass pollen ranges as given above. As expected, the low scores decrease and the high scores increase as the grass pollen count in-

creases. On the other hand, there are symptom scores of 0 on days with > 50 grass pollen grains/m³ and even on days with < 20 grass pollen grains/m³ symptom scores > 0 are reported.

3.4. Symptom estimation chart for Melbourne

Based on the results presented in this study, we propose a symptom estimation chart that allows a quick prediction of the severity of eye and nasal symptoms based on statistically defined meteorological data and forecasts (Fig. 9). It is important to note that the proposed model only applies during the grass pollen season as defined by Lejoly-Gabriel (1978), the onset of which can be predicted according to Ong et al. (1997): Number of days from 1 July to date of onset = $147.43 - 0.561 \times \text{July rainfall (mm)}$ ($r^2 = 0.641$, $P < 0.03$).

4. Discussion

Grass pollen counts of the seasons 1975–1981, 1985 and 1991–1997 were compared with meteorological data aiming to produce a model system for the prediction of daily grass pollen concentrations. We found that the seasonal total of grass pollen was significantly correlated to the rainfall sum of the preceding year ($P < 0.005$). Rainfall appears to be a critical factor for the productivity and pollen release of grasses, especially in the regions north of Melbourne. Rainfall during the month of July was inversely correlated with the start of

the grass pollen season in Melbourne (Ong et al., 1997). Here, we report that the daily grass pollen counts during the grass pollen seasons were positively correlated with the corresponding daily average ambient temperatures ($P < 0.001$). A similar relationship was reported recently by Recio et al. (1997) for olive (*Olea europea* L.) pollen in Spain. In Melbourne, the seasonal total of grass pollen determined the amount of grass pollen which was to be expected with a certain average temperature. Our proposed model utilises a weather parameter available prior to the start of the grass pollen season (the rainfall sum of the period 1 September to 31 August) to estimate the intensity of the grass pollen season and meteorological information available on a daily basis (forecast of the ambient temperature).

Since the concentration of airborne grass pollen is the main parameter for the occurrence and severity of hayfever in sensitive patients, an estimation of daily grass pollen counts enables a prediction of potential pollinosis symptoms. We found that hayfever symptoms were significantly correlated with the grass pollen counts ($P < 0.001$ for nasal symptoms, $P < 0.005$ for eye symptoms). Previous studies have reported that 100% of the chosen hayfever patients experienced symptoms upon exposure to either > 50 grass pollen grains/m³ (Hyde, 1972) or even as few as 37 grass pollen grains/m³ (Antepara et al., 1995). In our study, we have included individuals reporting either moderate or severe symptoms during the previous grass pollen season. There is a high level of variability of symptoms between patients on any given day. Individuals occasionally reported no symptoms on days with high grass pollen counts. This may have occurred due to the following reasons: (i) most individuals had indoor occupations and thus, may not have been exposed to the same levels of grass pollen as found outdoors; (ii) a positive reaction to skin test pricks suggests the presence of IgE specific to rye-grass pollen allergens. However, patient IgE levels do not necessarily correlate with symptoms; (iii) the air flora on a given day is composed of pollen from several taxa. However, our pollen counts assess only total grass pollen and patients may be variably sensitive to a range of grass pollen types.

On the other hand, some patients reported symptoms occurring on low grass pollen days. Hayfever symptoms may be caused by sensitivity to allergens from other sources (e.g. dust mites or tree pollen), or to unique and specific allergens within any given pollen. Furthermore, on low grass pollen days, grass pollen allergens have also been recorded in atmospheric particles smaller than pollen grains (Spieksma et al., 1990; Suphioglu et al., 1992; Schäppi et al., 1996). Rye-grass pollen grains have been shown to rupture in rainwater by osmotic shock, each grain releasing about 700 allergen loaded starch granules in the size range of 0.6–2.5 μm . These contain the major allergen Lol p 5 and are capable of triggering IgE-mediated reactions in grass pollen sensitive patients

(Suphioglu et al., 1992). The group 5 allergen in timothy grass (*Phleum pratense*) Phl p 5, has a homologous sequence to Lol p 5 and has also been shown to be present in starch granules (Grote et al., 1994). Therefore, the presence of these micronic allergenic particles in the atmosphere may explain the observation of hayfever symptoms on low grass pollen count days.

The symptom estimation chart presents a quick, approximate guide to predict possible eye and nasal symptoms that can be expected with meteorological conditions in Melbourne. Among hayfever sufferers, the reactivity to grass pollen allergens is variable. In the future, charts can be individually tailored for each patient once the frequency of their symptoms has been monitored for one season. This would provide valuable information for the management of hayfever by allergen avoidance and may also provide useful information for immunotherapy.

5. Conclusions

The concentration of airborne grass pollen determines the severity of hayfever in sensitive patients. Since the daily grass pollen amounts in the air are shown to be linked to the corresponding daily average ambient temperatures and to the rainfall of the preceding 12 months, these meteorological conditions can be useful in the prediction of potential pollinosis symptoms during the grass pollen season in Melbourne. The proposed symptom estimation chart may enable both physicians and patients to take appropriate measures for allergen avoidance.

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