Damp housing and asthma: a case-control study

I J Williamson, C J Martin, G McGill, R D H Monie, A G Fennerty

Abstract

Background **– Several epidemiological studies have reported a higher prevalence of respiratory symptoms in subjects living in damp housing, but links with specific respiratory diseases such as asthma have not been satisfactorily established.**

Methods **– One hundred and two subjects with physician diagnosed asthma and 196 age and sex matched controls were interviewed; 222 (75%) then agreed to have their dwelling surveyed for dampness. The prevalence of both self-reported and observed dampness in the homes of the asthmatic subjects and controls were compared. Both asthma and the severity of the dampness were quantified so that the possibility of a dose-response relationship could be investigated.**

Results **– Asthmatic subjects reported dampness in their current (odds ratio (OR) 1.92, 95% confidence interval (CI) 1.18 to 3.12) and previous (OR 2.11, 95% CI 1.29 to 3.47) dwellings more frequently than control subjects. The surveyor confirmed dampness in 58 of 90 (64%) dwellings of asthmatic subjects compared with 54 of 132 (41%) dwellings of control subjects (OR 2.62, 95% CI 1.50 to 4.55). This association persisted after controlling for socioeconomic and other confounding variables (adjusted OR 3.03, 95% CI 1.65 to 5.57). The severity of asthma was found to correlate statistically with measures of total dampness ($r=0.30$, $p=0.006$) and mould growth ($r=0.23$, $p=0.035$) in the dwelling. Patients living in homes with confirmed areas of dampness had greater evidence of airflow obstruction than those living in dry homes (mean difference in forced expiratory volume in one second (FEV_1) 10.6%, 95% CI 1.0 to 20.3).**

Conclusions **– Asthma is associated with living in damp housing and there appears to be a dose-response relationship. Action to improve damp housing conditions may therefore favourably influence asthma morbidity.**

(*Thorax* 1997;**52**:229–234)

Keywords: asthma, damp housing.

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Received 2 February 1996
Returned to authors 23 May 1996
Revised version received 21 October 1996
Accepted for publication 7 November 1996

Damp housing is a common problem in Britain today. National surveys have estimated that between 25% and 33% of dwellings are affected to some degree by either dampness, condensation, or mould growth.[1–3] The problem tends to be greatest in inner city housing where evidence of disrepair due to dampness has been found in as many as 47% of dwellings.[4] The possibility that damp housing may adversely affect health and, in particular, predispose to respiratory symptoms has been the focus of several recent cross-sectional epidemiological studies.[5–13] All reported a higher prevalence of respiratory symptoms, especially wheeze, in subjects living in damp housing, but links with specific respiratory diseases such as asthma could not be satisfactorily established. A few studies of case-control design do, however, suggest that asthmatic subjects are more likely to live in homes with evidence of dampness with the highest odds ratios for children sleeping in damp bedrooms.[14–16]

Several biologically plausible mechanisms could account for such an association. Asthmatic subjects are frequently allergic to house dust mite (HDM) and moulds, both of which are found in greater numbers in damp dwellings.[17–20] As higher levels of exposure to HDM allergen are known to increase asthma severity,[12] it is theoretically possible for damp housing to influence the severity of asthma adversely. No such relationship has yet been demonstrated.

Establishing a link between asthma and damp housing is by no means straightforward. The design of such a study has to eliminate many areas of potential bias. If information on health and measures of dampness in the dwelling is obtained from the same questionnaire, reporting or recall bias may occur with the potential for subjects in damp dwellings to over-report or exaggerate the severity of the symptoms.[21–23] This has been a particular criticism of many of the previous studies and it is universally agreed that objective measurements of dampness are therefore preferable. Respiratory health and dampness of housing may also be indirectly related through socioeconomic status, and particular attention has to be given to confounding factors.

This case-control study was designed, firstly, to establish whether subjects with physician diagnosed asthma were more likely than age and sex matched controls to live in damp housing and, secondly, to determine whether living in such conditions adversely influences the severity of asthma.

Methods

SUBJECTS

Consecutive patients with physician diagnosed asthma aged 5–44 years attending the Southern General Hospital Asthma Clinic between November 1992 and February 1993 were eligible for entry into the study. Three patients refused to participate and 102 were recruited. For each asthmatic patient entered, two control subjects matched for sex and age to within five years were randomly selected from the Greater Glasgow Health Board Community Health Index. If a selected control subject was no longer resident at the contact address or refused to participate, a further matched control was selected as a replacement. Two hundred and one of the 450 subjects randomly selected from the index were no longer resident at the contact address and could not be traced; 196 (79%) control subjects successfully contacted agreed to participate in the study. All asthmatic and control subjects lived within the catchment area of the hospital defined by area postal codes G51–53.

Approval for the study was obtained from the local ethics committee.

QUESTIONNAIRE

All subjects completed a structured interview with a trained researcher. The questionnaire was a modified version of that used by Martin *et al* in two previous studies investigating the relationship between respiratory symptoms and damp housing.[5 22] Questions relating to housing conditions included the presence of current dampness or condensation in the home and exposure to dampness and mould in previous dwellings. Questions regarding respiratory symptoms included the presence, frequency and severity of wheeze, chest tightness, cough, and shortness of breath on exercise. Current asthma medications and the number of exacerbations of asthma requiring oral steroids in the previous year were noted.

LUNG FUNCTION

Patients performed spirometric tests (Vitalograph) at the asthma clinic at the time of entry to the study. The best forced expiratory volume in one second (FEV_1) and the ratio of FEV_1 to the forced vital capacity (FVC) were recorded from three attempts. FEV_1 was expressed as a percentage of the predicted values.

ASTHMA SEVERITY SCORE

An asthma severity score was calculated for each patient based on questionnaire responses regarding severity of asthma symptoms, medication requirements, and FEV_1 recorded at the last clinic visit (table 1). The sum of these seven severity items comprised the asthma severity raw score, with a possible range of 0 to 24. Asthmatic subjects were divided into approximately three equal sized groups labelled mild (raw severity score 0–8), moderate (9–13), and severe (14–24).

DAMPNESS SURVEY

After completion of the questionnaire, subjects were asked if their home could be independently assessed for dampness and mould by a qualified surveyor who would be unaware of their health status. Each dwelling was surveyed in a standard fashion as detailed below.

1. Spot temperature and relative humidity measurements were recorded outdoors and within each room in the dwelling using a Whatman R 200 digital hygrometer.

Table 1 Asthma severity score

Severity variable	*Score*	*n*
Frequency of asthma symptoms		
Never	0	0
Less than once per week	1	29
2–3 times per week	2	28
4–5 times per week	3	9
Most days or nights	4	36
Shortness of breath on exercise		
Never	0	8
Playing games or sports	1	4
Walking uphill or stairs	2	39
Walking on level	3	15
Walking around house or dressing	4	36
Inhaled β_2 agonist use		
Never	0	2
Less than daily	1	35
Daily	2	65
Dose of inhaled steroid		
None	0	9
Up to 400 μg daily (or Intal)	1	25
401 to 800 μg daily	2	15
801 to 1500 μg daily	3	35
>1500 μg daily	4	18
Nebuliser use		
No	0	84
Yes	2	18
Use of oral steroids in last 12 months		
None	0	44
1 or 2 short courses	1	29
More than 2 courses	2	25
Maintenance	4	4
Lung function: FEV_1 (%predicted)		
>80%	0	57
70–79%	1	11
60–69%	2	14
50–59%	3	6
<50%	4	9
Not measured	—	5

2. An electronic resistance type moisture meter (Protimeter Surveymaster) was used to obtain measurements of dampness just above skirting board height from three points on each wall (usually the middle and either end) in every room in the dwelling. At each point where a measurement was obtained dampness was graded semi-quantitatively, depending on the percentage scale deflection on the meter, as 0 (dry, <10%), 1 (11–25%), 2 (26–50%), 3 (51–75%), and 4 (>76%) The sum of all these dampness measurements (total dampness score) and the worst grade of dampness recorded were used as measures of the severity of dampness for each dwelling.

3. The presence and severity of visible mould growth on each wall in each room of the dwelling was graded subjectively on a four-point scale where 0 = absent, 1 = trace, 2 = obvious but localised, and 3 = obvious and widespread. The sum of these grades (total mould score) was used as a measure of mould severity within the dwelling. Dwellings with a total mould score of 3 or more were classified as having significant mould.

STATISTICAL ANALYSIS

Asthmatic and control subjects were compared in groups rather than individual matched pairs. Comparisons between categorical groups were made using the χ^2 test with odds ratios and their 95% confidence intervals or χ^2 trend stated where appropriate. Continuous variables were compared using the Student's t test or Wilcoxon sum rank test. The dampness and mould severity scores were positively skewed and logarithmic transformations were used for

Table 2 Comparison of sociodemographic characteristics between asthmatic and control subjects

	Asthmatic (n=102)	*Control (n=196)*	*p value*
Mean (SD) age (years)	26.4 (12)	25.8 (12)	NS
Male sex	36 (35)	78 (40)	NS
Mean (SD) persons/room	0.65 (0.23)	0.65 (0.23)	NS
Employment status*			
Employed	36 (35)	108 (55)	0.001
Unemployed	5 (5)	23 (12)	
Sickness benefit	35 (34)	16 (8)	
Housewife	18 (18)	41 (21)	
Other	8 (8)	8 (4)	
No adult in paid employment	47 (46)	70 (36)	NS
Housing tenure			
Rented	67 (66)	108 (55)	NS
Mean (SD) duration of tenancy (years)	7.4 (6.5)	7.4 (7.0)	NS
Net weekly household income			
Less than £200	76 (75)	118 (60)	0.02
Heating			
Central	67 (66)	121 (62)	NS
Gas fire	63 (62)	90 (46)	0.01
Paraffin	8 (8)	12 (6)	NS
Gas cooking	66 (65)	112 (57)	NS
Clothes dried indoors	71 (70)	137 (70)	NS
Respondent smoking status			
Non-smoker	48 (47)	82 (42)	0.001
Ex-smoker	25 (24)	18 (9)	
Smoker	29 (29)	96 (49)	
Smoker in household	60 (59)	137 (70)	0.05
Household pet	57 (56)	90 (46)	NS

Figures represent number (percentage) unless otherwise stated. p values are calculated from χ^2 test or Student's *t* test.
* Employment status of adult respondent or parent of child.

statistical analysis. Linear associations between continuous variables were assessed using the Pearson correlation coefficient. When controlling for confounding, if the outcome variable was binary, multiple unconditional logistic regression models were constructed using the maximum likelihood method with adjusted odds ratios and their 95% confidence intervals calculated from the logistic regression coefficients, otherwise multiple linear regression models were constructed using the stepwise method. Analysis was performed using the SPSS for Windows, Release 6.0.[24] A significance level of 5% was used.

Results

DEMOGRAPHIC CHARACTERISTICS

Two hundred and ninety eight subjects (102 with asthma and 196 controls) were successfully recruited. A summary of their demographic characteristics is listed in table 2. Although control subjects were matched for age and sex, several differences were identified between the two groups, particularly relating to smoking habit, employment status, and household income.

The data concerning the asthma severity measures are shown in table 1. The overall severity score ranged from 2 to 24 with a mean (SD) of 11.3 (5.1). All patients experienced symptoms of wheeze, chest tightness, cough, or shortness of breath on exercise. Only two did not require to use an inhaled bronchodilator, at least on an occasional basis, and 92 (90%) were taking prophylactic therapy in the form of inhaled corticosteroids or sodium cromoglycate. The FEV_1 was more than 80% of predicted normal values in 57 (60%) of patients; 85% of patients were atopic with one or more positive skin prick tests to common allergens.

HOUSING CONDITIONS SURVEY

Dampness surveys were conducted for 75% of the sample. A comparison between those surveyed (n = 222) and those not surveyed (n = 76) showed no difference in sociodemographic characteristics including subject sex, age, household size, housing tenure, duration of tenancy, weekly household income, cigarette smoking, pet ownership, or self-reported dampness. The only significant difference concerned employment where fewer respondents in the surveyed households were employed (p = 0.01).

One hundred and ten (49%) of the dwellings surveyed were categorised as dry. Excess moisture was detected in 112 homes (51%) with 43 (19%) containing at least one area of grade 3 or 4 (severe) dampness. Mould growth was observed in a total of 57 dwellings (26%) and in 33 homes (15%) was classified as significant (total mould score $\geqslant 3$). There was a strong relationship between the presence of dampness and mould within a dwelling. Forty nine (86%) dwellings with evidence of visible mould growth also had areas of detectable dampness and there was a significant correlation between the total mould and total dampness scores of a dwelling ($r = 0.51$, $p = 0.0005$).

There was a tendency for both asthmatic and control subjects to underestimate dampness in the home. Dampness was detected in the dwellings of 21 (52%) asthmatic and 27 (32%) control subjects who claimed their homes were dry. Agreement between self-reported dampness and the findings of the surveyor occurred in 83 homes (63%) of control subjects and 56 (63%) of asthmatic subjects.

Table 3 Prevalence of dampness in dwellings of asthmatic and control subjects

Dampness measures	*Controls*	*Asthmatic subjects**			*χ^2 trend*	*p value*
		Mild	*Moderate*	*Severe*		
Self reported	(n=196)	(n=33)	(n=32)	(n=32)		
Any dampness/condensation	76 (39)	16 (48)	18 (56)	20 (62)	8.72	0.003
Serious dampness/condensation	22 (11)	6 (18)	12 (37)	15 (47)	30.5	0.00005
Previous house damp	56 (28)	12 (36)	16 (50)	17 (53)	11.3	0.0008
Moved because damp house	20 (10)	5 (15)	8 (25)	8 (25)	8.33	0.004
Observed	(n=132)	(n=29)	(n=29)	(n=27)		
Any dampness	54 (41)	13 (45)	20 (69)	21 (78)	16.2	0.00006
Severe dampness[1]	19 (14)	4 (14)	8 (28)	10 (37)	8.20	0.004
Any mould	30 (23)	5 (17)	8 (28)	12 (44)	4.24	0.04
Significant mould[2]	15 (11)	3 (10)	6 (21)	9 (33)	8.10	0.005

* Severity score not available in five cases due to incomplete data.
[1]Dwellings in which at least one dampness measurement was of grade 3 or 4 severity.
[2]Dwellings with total mould score ≥ 3.
Figures represent numbers (percentages).

Table 4 Crude and adjusted odds ratios for asthmatic subjects living in dwellings with evidence of dampness

Dampness measures	*Crude OR (95% CI)*	*Adjusted OR* (95% CI)*
Self reported	(n=298)	(n=283)
Any dampness/condensation	1.92 (1.18 to 3.12)	1.93 (1.14 to 3.28)
Serious dampness/condensation	4.13 (2.26 to 7.55)	5.45 (2.81 to 10.6)
Previous home damp	2.11 (1.29 to 3.47)	2.55 (1.49 to 4.37)
Moved because previous home damp	2.28 (1.17 to 4.44)	2.08 (1.02 to 4.24)
Observed	(n=222)	(n=211)
Any dampness	2.62 (1.55 to 4.72)	3.03 (1.65 to 5.57)
Severe dampness[1]	2.14 (1.06 to 4.03)	2.36 (1.34 to 4.01)
Any mould	1.46 (0.82 to 2.78)	1.35 (0.79 to 2.28)
Significant mould[2]	2.23 (1.21 to 5.32)	1.70 (0.78 to 3.71)

[1]Dwellings in which at least one dampness measurement was of grade 3 or 4 severity.
[2]Dwellings with total mould score ≥3.
* Adjusted for subject age, sex, weekly household income <£200, unemployment, respondent smoker, other smoker in household and pet ownership. Fifteen subjects did not disclose household income and were not included in the logistic regression models. Odds ratios and 95% confidence intervals calculated from logistic regression coefficients.

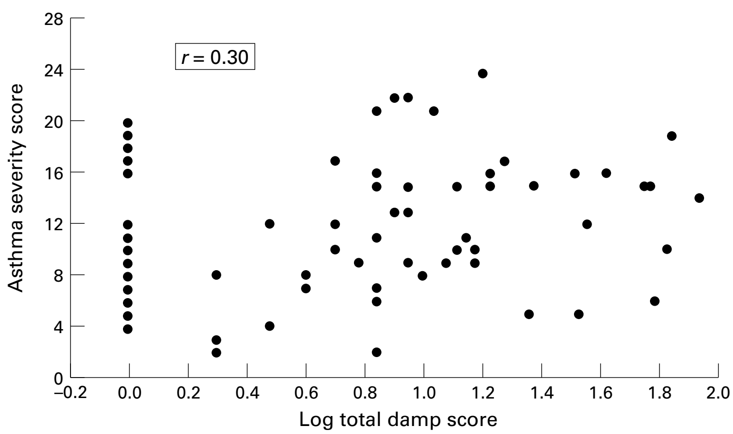

Figure 1 Scatter plot showing the relationship between severity of asthma and severity of dampness in the dwellings.

The frequencies of both self-reported and observed dampness and mould in the dwellings of asthmatic and control subjects are listed in table 3. There were significant trends for the prevalence of both measures of dampness or mould to rise with increasing severity of asthma.

The mean indoor temperature in the homes of asthmatic subjects was slightly lower than that in the homes of control subjects (16.7°C versus 17.7°C, $p=0.023$). Although homes without central heating were slightly colder than those with central heating (mean indoor temperature 16.7°C versus 17.7°C, $p=0.006$), there was no significant difference in the use of this mode of heating in homes of asthmatic and control subjects ($p=0.4$). No significant difference was observed in the mean indoor relative humidity measurements from the homes of asthmatic and control subjects (57% versus 56%, respectively, $p=0.5$).

CONTROLLING FOR CONFOUNDING VARIABLES

Possible confounding variables identified using univariate statistics included employment status, household income, respondent smoking, and the presence of another smoker in the household. To control for the possible confounding effect of these variables, as well as age, sex and pet ownership, logistic regression models were constructed with asthma as the dependent variable and the measures of dampness or mould and the confounding variables entered as covariates. The crude and adjusted odds ratios for self-reported and surveyor observed damp are listed in table 4. The adjusted odds ratios for the various measures of damp in the dwelling differed little from the crude ratios, suggesting that the above variables had only a small confounding effect. However, the adjusted odds ratios for the presence of mould in the dwelling were lower than the crude ratios with 95% confidence intervals that included unity.

Table 5 Multiple regression analysis

Asthma severity measure	*B (95% CI)*	*p value*
Asthma severity score	2.30 (0.53 to 4.07)	0.01
FEV_1 (% predicted)	−11.9 (−19.4 to −4.39)	0.03
FEV_1/FEV ratio	−5.79 (−10.2 to −1.35)	0.01

B=regression coefficient; FEV_1=forced expiratory volume in one second; FVC=forced vital capacity.
Associations between measures of asthma severity and total dampness scores, controlling for unemployment, household income (above/below £200), respondent smoker, other smoker in house, and pet ownership.

DAMP HOUSING AND ASTHMA SEVERITY

The relationship between asthma severity and increasing severity of dampness or mould in the dwelling was assessed in the asthmatic subjects. The total dampness scores ranged from 0 to 85 with a median of 6. Total mould scores were likewise positively skewed and logarithmic transformations were used to normalise the distributions. The relationship between asthma severity and the severity of dampness in the dwelling is shown in fig 1. A statistically significant positive correlation was seen between asthma severity and total dampness scores ($r=0.30$, $p=0.006$). A similar significant correlation was also observed between the asthma severity and total mould scores ($r=0.23$, $p=0.035$). The greater the severity of dampness or mould in the home, the more likely the patient was to have more severe asthma.

DAMP HOUSING AND LUNG FUNCTION

There were significant negative correlations between the total dampness score for the dwelling and the percentage predicted FEV_1 ($r=-0.30$, $p=0.006$) and FEV_1/FVC ratio ($r=-0.25$, $p=0.023$). These correlations remained statistically significant after controlling for the confounding factors mentioned previously (table 5). Patients living in homes in which the surveyor had confirmed evidence of dampness had a lower FEV_1 (mean difference 10.6%, 95% CI 1.0 to 20.3) and FEV_1/FVC ratios (mean difference 5.4%, 95% CI −0.1 to 10.9) than those living in dry dwellings. Overall, the severity of dampness within the dwelling accounted for approximately 7% of the variance in FEV_1.

Discussion

The results of this study show that asthmatic patients attending a hospital asthma clinic were two to three times more likely to live in a dwelling with evidence of dampness than an age and sex matched random sample of the general population living in the same area of the city of Glasgow. There were significant trends for the prevalence of both self-reported and observed measures of dampness to rise with increasing severity of asthma. Furthermore, there were significant correlations between asthma severity and, in particular, severity of airflow obstruction and the severity of dampness and mould in the dwelling, suggestive of a dose-response relationship.

Most previous studies investigating the effects of damp housing on health have relied on the same questionnaire to elicit information on both the subject's health and indicators of dampness in the dwelling, raising the possibility of respondent bias.[21 23] Although our asthmatic subjects reported more dampness, condensation, and mould in both their current and previous dwellings than did control subjects, they were unaware of the purpose of the study at the time of completion of the questionnaire. Furthermore, we adopted an independent, standardised, semiquantitative approach to the assessment of dampness in each dwelling to avoid having to rely solely on measures of self-reported dampness. It is of interest that both asthmatic and control subjects under-reported the presence of dampness in the home to the same degree, suggesting that asthmatic subjects do not over-report dampness in the home and significant respondent bias was unlikely to have occurred. As dampness and mould in the dwelling was measured objectively and the diagnosis of asthma had been previously established by a respiratory physician, investigator bias was also effectively eliminated.

Asthmatic subjects were more likely to be unemployed or receiving invalidity benefit and therefore live in a household with a lower net income. This could result in their gravitating towards poorer quality housing which could be more prone to dampness and more difficult to heat. However, most of our asthmatic and control subjects lived in local authority housing and it is unlikely that asthmatic subjects were preferentially allocated poorer housing. Furthermore, the association between asthma and damp housing remained statistically significant after controlling for these confounding variables.

We are not currently aware of any previous study that has identified a dose-response relationship between damp housing and asthma severity. This study identified significant trends for higher prevalences of dampness and mould in the dwellings of subjects with increasing severity of asthma, and statistically significant correlations between asthma severity and quantity of dampness and mould in the home. These findings strengthen the case for a dose-response relationship.

Our reported odds ratios for asthmatic subjects living in damp homes are in keeping with those described in previous studies where associations were reported between respiratory symptoms such as wheeze and cough and dampness or mould in the home,[7 8 13] but they are higher than those previously quoted for associations between asthma and dampness in the home. The trend for a rise in the prevalence of dampness in the home with increasing severity of asthma (table 3) suggests that the higher odds ratios reported in this study are likely to be due to our selection of a high proportion of patients with moderate to severe asthma.

There are several plausible biological mechanisms to explain a higher prevalence of asthma in subjects living in damp dwellings. The house dust mite *Dermatophagoides pteronyssinus* is known to thrive in damp conditions and both mite numbers and allergen levels have been shown to increase with both higher indoor humidity[4 18] and indicators of dampness in the home.[4 25] Measurements of exposure to HDM were not undertaken in this study but it has been shown that increased exposure to HDM allergen may result in increased sensitisation[26] and act as an exacerbating factor for asthma.[27] Storage mites have also been found in significant numbers in house dust from damp dwellings.[28 29] Allergy to these mites has been implicated as a cause of occupational asthma in farmers[30] but it is not clear whether this allergy is present in subjects who live in damp dwellings but have no relevant occupational exposure.

The presence of mould growth in dwellings in this study was much more common in those which also had areas of severe dampness. The self-reporting of mould in a dwelling, as used in previous studies, may therefore act only as a marker for the presence of severe dampness and hence higher exposure to HDM allergens. Alternatively, exposure to moulds and airborne fungal spores can exacerbate respiratory symptoms in susceptible individuals.[31] It is estimated that 10–15% of asthmatic subjects have allergy to moulds, assessed by skin prick testing, most commonly to *Aspergillus fumigatus, Alternaria alternata, Penicillium*, and *Cladosporium*.[32–34] However, they frequently also have allergy to other antigens such as the house dust mite and the contribution of the mould allergy to their disease is often difficult to assess.

It is generally agreed that both the prevalence and severity of asthma are increasing[35–37] and more attention is being focused on possible environmental factors which may account for this. We have shown that there is an association between asthma and damp housing but our asthmatic subjects were selected from a hospital outpatient clinic and are likely to represent the more severe end of the disease severity spectrum. Whether dampness in the home predisposes to the development of asthma or aggravates the severity of the disease clearly requires further investigation, but the results of this study suggest that action to reduce dampness in the home could favourably influence asthma morbidity.

This study was supported by a grant from the Chest, Heart and Stroke Association, Scotland.

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