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The association of biomass fuel combustion on pulmonary function tests in the adult population of Mid-Anatolia

Summary

Objectives: To assess the association of biomass as domestic energy source on respiratory function in rural areas of Mid-Anatolia in Turkey where biomass use is frequent.
Methods: In a cross-sectional study, pulmonary functions measurements of 112 cow-dung users and 153 modern energy source users, all non-smokers, were assessed and compared. Several sociodemographic factors were assessed by questionnaire, and ventilatory function measurements included forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), FEV_1/FVC ratio and the flow between the first 25 and 75 of forced expiratory flow (FEF_{25-75}), and were compared, deploying univariate and multivariate methods, between the two groups.
Results: The individuals in the biomass exposed and unexposed group were similar regarding demographic characteristics: 67.0 % were female (exposed) vs 60.1 % (unexposed) with an age range of 17 to 64 (exposed) and 18 to 70 years (unexposed), and with 36 % of biomass users having had pulmonary tract infections (20 % in non-users). For all pulmonary function test parameters FEV_1, FVC, FEV_1/FVC, and FEF_{25-75} a highly significant ($p < 0.0001$) reduction was observed in biomass users. A 12.4 % (95 % confidence interval: 7.0 % to 17.7 %) reduction in forced vital capacity was observed in multivariate linear regression.
Conclusions: It is well known that biomass combustion is a relevant public health problem. The substantial differences in pulmonary functions associated with biomass use as an energy source observed in this cross-sectional study in non-smokers support that also in rural Turkey measures may be in need to reduce this public health problem.

Keywords: Biomass – Cow-dung – Pulmonary function tests.

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The majority of households in developing countries use biomass as a major energy source for cooking and heating, especially cow-dung, wood and agricultural waste (Koning et al. 1985; Perez-Padilla et al. 1999). In developing countries such as Turkey, these materials are typically burnt in simple stoves with very incomplete combustion. Continuous indoor burning of biomass and exposure to large amounts of biomass smoke starting in childhood with inefficient conditions for removing smoke and air pollutants may cause pulmonary diseases such as repetitive upper and lower respiratory infections, and chronic obstructive pulmonary disease (Bruce et al. 2000; Behera et al. 1998; Boleu et al. 1989).
In rural regions of Sivas city cow-dung is generally used as the major energy source. As, to our knowledge, no field study had investigated the effect of biomass burning (especially cow-dung) on pulmonary functions among this region's population, we conducted a cross-sectional study among 265 persons with different energy use patterns comparing pulmonary function parameters.

Methods

Recruitment of participants
This investigation was conducted in 265 non-smoking individuals who were selected from Sivas city centre and from the villages in the Mid-Anatolia region of Turkey. Based on their energy source, 112 participants living in the villages Koyuncu and Kavlak were selected into the biomass exposed group, and 153 living in the city centre of the Emek Health House Region were selected as control group. The total population of the villagers living in Koyuncu and Kavlak villages was 822 (413 aged 20 years or older). Of the 160 known non-smokers living in the villages Koyuncu and Kavlak, 112 (70.0 %) accepted to participate in the study.

All participants lived in non-ventilated houses, were exposed to biomass throughout the winter by using stoves and open fire for cooking in the rest of seasons. In this biomass users group, women and men usually spend their time indoor, especially throughout the winter. Indoor pollution levels, however, were not objectively measured due to the insufficient technical support and the fact that the study was conducted during the summer months (June–August). The participants of the comparison group not using biomass were selected by simple random sampling from the people using modern energy sources living in Emek Health House Region. 153 of 160 selected subjects could be reached. Only non-smokers that have been identified by questionnaire were included in this study in the Mid-Anatolia region of Turkey. Also in this group, all respiratory measurements were made in the summer months (June–August).
Participants answered a general questionnaire asking about fuels used as an energy source and about information relating to their socio-economic and health status. The participants were also asked about having experienced recurrent pulmonary tract infections. In all the houses of the biomass using villages only cow-dung were used as the energy source (since childhood) and housing conditions and socio-economic parameters were not good.

Assessment of pulmonary function
Pulmonary function test parameters were collected by using the Minato AS 600 spirometer. The values were measured as body temperature and pressure saturated (BTPS). After every five measurement the spirometer was calibrated with 2-L calibrator syringe accurate to ± 1%. All measurements were made in the standing position with a nose clip applied. Examinations were conducted by the same trained technical staff. In every measurement subjects performed three maximal efforts after detailed instruction and the highest one was recorded. The ventilatory function test measurements included forced expiratory volume in one second (FEV_1 in litre), forced vital capacity (FVC in litre), FEV_1/FVC ratio (a ratio multiplied by 100), and the flow between the 25 and 75 of forced expiratory flow (FEF_{25-75} in litre/second). The short blows were discarded throughout the all measurements. All pulmonary function assessments were made by expert physiologist by the using suitable techniques in the present study.

Statistical analysis
When comparing in an univariate fashion age, weight, height, and number of persons and rooms in the household of biomass users with non-users we calculated the Kruskal-Wallis test statistic thus avoiding assuming distribution characteristics. We used chi-square test statistic for comparing categorical characteristics as gender, respiratory tract infections (yes vs no) in the two biomass user groups. We also calculated the Kruskal-Wallis test statistic for the comparison of the pulmonary function test results when comparisons were performed stratified for gender and age groups (Cassens 1992). In a third step multivariate linear regression analyses were performed for describing the relationship of biomass exposure on the forced vital capacity, the most important pulmonary function test, while controlling for the other relevant factors associated with pulmonary function. For these analyses continuous variables (age, height, weight) and the number of rooms and persons in the household of the participants were centred (as described in the footnote of the corresponding tables). Categorical variables were entered into the model as indicator variables. The possibility of inappropriate model specification was assessed by graphical inspection of plots of the standardised residuals vs age, weight, height, and the predicted values. A linear regression was performed for the relationship of the standardised residuals vs predicted values. All analyses were performed using STATA version 8 (www.stata.com).

Results

The individuals in the biomass exposed and unexposed group were similar regarding demographic characteristics: 67.0% were female (exposed) vs 60.1% (unexposed) (table 1), with an age range of 17 to 64 (exposed) and 18 to 70 years (unexposed). There was an indication of an imbalance of the two groups regarding the number of persons living in the home ($p = 0.053$) and the number of rooms in the home ($p = 0.043$). Quite a substantial difference was present for having had pulmonary tract infections (35.9% in exposed vs 19.6% in unexposed). For all pulmonary function test parameters FEV_1, FVC, FEV_1/FVC, and FEF_{25-75} highly significant differences ($p < 0.0001$) were observed between biomass exposed and unexposed individuals, with mean values lower in those with biomass exposure (Tab. 1).
Linear regression analysis was used for describing the relationship of biomass use and the pulmonary function measurements, while controlling for the other relevant factors associated with pulmonary function. The estimated mean value for a female person with of age 35, weight 65, height 165, 5 persons living in a home, 4 rooms in the house, and no history of infections was 12.4% lower (95% confidence interval: 7.0% to 17.7%) when she was biomass exposed compared to a women without biomass exposure (0.382 lower compared to 3.093) (Tab. 2 to 5).
Visual inspection of plots of the standardised residuals vs age, height and weight and a linear regression of the

Table 1 Demographic and social characteristics, and values for pulmonary function measurements by biomass exposure status

	Biomass (+) (n = 112)	Biomass (–) (n = 153)	p-value*
Age (year) (mean ± SD)	36.4 ± 14.0	35.3 ± 11.8	p = 0.89
Weight (kg) (mean ± SD)	66.5 ± 11.7	67.2 ± 12.7	p = 0.78
Height (cm) (mean ± SD)	164.0 ± 9.2	165.3 ± 9.9	p = 0.28
Gender			
Male (%)	33.0	39.9	p = 0.26
Female (%)	67.0	60.1	
Persons living in a home (mean ± SD)	4.7 ± 1.3	4.4 ± 1.0	p = 0.053
Rooms number in a home (mean ± SD)	3.1 ± 0.8	3.3 ± 0.9	p = 0.043
Percent with a history of recurrent pulmonary tract infections	35.9	19.6	p < 0.0001
[1]FEF_{25-75} (in litre/second)	3.56 ± 1.44	4.38 ± 1.56	0.0001
[1]FEV_1 (in litre)	2.65 ± 0.96	3.16 ± 0.97	0.0001
[1]FVC (in litre)	2.83 ± 0.99	3.35 ± 1.06	0.0001
[1]FEV_1 /FVC (a ratio multiplied by 100)	89.51 ± 7.09	94.59 ± 5.51	0.0001

* p-values based on Kruskal-Wallis test for age, weight, height, persons in a home, number of rooms in a home, pulmonary function tests, and Pearson's chi-square test statistics for gender and history of recurrent pulmonary tract infections
[1] Forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), FEV_1/FVC ratio, and the flow between the 25 and 75 of forced expiratory flow (FEF_{25-75})

Table 2 Estimated parameters and 95 % confidence interval of multivariate linear regression analysis of forced vital capacity (in litre)

Model components	Difference in FVC in L	95 % confidence interval		p-value
Constant	3.093	2.941	3.245	< 0.0001
Biomass (yes vs no)	– 0.382	– 0.549	– 0.215	< 0.0001
Sex (male vs female)	0.580	0.352	0.808	< 0.0001
Age (per 1 year increase)	– 0.032	– 0.038	– 0.026	< 0.0001
Weight (per 1 kg increase)	0.009	0.002	0.016	0.002
Height (per 1 cm increase)	0.046	0.034	0.058	< 0.0001
Persons living in a home (per person more)	– 0.006	– 0.069	0.057	0.86
Rooms number in a home (per room more)	– 0.008	– 0.078	0.095	0.85
History of recurrent respiratory tract infections (yes vs no)	– 0.026	– 0.144	0.196	0.76

Predictors were centered when entering into the model: For these regressions the estimated constant is representing the value for a female person with no biomass exposure, age 35, weight 65, height 165, 5 persons living in a home, 4 rooms in the house, and no history of recurrent respiratory tract infections

Table 3 Estimated parameters and 95 % confidence interval of multivariate linear regression analysis of forced expiratory volume in one second

Model components	Difference in FEV_1 in L	95 % confidence interval		p-value
Constant	2.932	2.785	3.080	< 0.0001
Biomass (yes vs no)	– 0.396	– 0.558	– 0.235	< 0.0001
Sex (male vs female)	0.488	0.268	0.710	< 0.0001
Age (per 1 year increase)	– 0.034	– 0.040	– 0.028	< 0.0001
Weight (per 1 kg increase)	0.008	0.001	0.015	0.029
Height (per 1 cm increase)	0.041	0.029	0.052	< 0.0001
Persons living in a home (per person more)	– 0.008	– 0.069	0.053	0.79
Rooms number in a home (per room more)	– 0.001	– 0.084	0.082	0.98
History of recurrent respiratory tract infections (yes vs no)	0.045	– 0.120	0.209	0.59

Predictors were centered when entering into the model: For these regressions the estimated constant is representing the value for a female person with no biomass exposure, age 35, weight 65, height 165, 5 persons living in a home, 4 rooms in the house, and no history of recurrent respiratory tract infections

Table 4 Estimated parameters and 95% confidence interval of multivariate linear regression analysis of FEV_1/FVC ratio

Model components	Difference in FEV_1/FVC in L	95 % confidence interval		p-value
Constant	95.348	93.884	96.813	< 0.0001
Biomass (yes vs no)	– 5.269	– 6.878	– 3.659	< 0.0001
Sex (male vs female)	– 1.894	– 4.095	0.306	0.09
Age (per 1 year increase)	– 0.167	– 0.226	– 0.108	< 0.0001
Weight (per 1 kg increase)	0.023	– 0.046	0.092	0.51
Height (per 1 cm increase)	– 0.078	– 0.193	0.036	0.18
Persons living in a home (per person more)	0.027	– 0.582	0.635	0.93
Rooms number in a home (per room more)	0.061	– 0.769	0.892	0.88
History of recurrent respiratory tract infections (yes vs no)	0.385	– 1.252	2.022	0.64

Predictors were centered when entering into the model: For these regressions the estimated constant is representing the value for a female person with no biomass exposure, age 35, weight 65, height 165, 5 persons living in a home, 4 rooms in the house, and no history of recurrent respiratory tract infections

Table 5 Estimated parameters and 95 % confidence interval of multivariate linear regression analysis of the flow between the 25 and 75 of forced expiratory flow ($FEF_{25–75}$)

Model components	Difference in $FEF_{25–75}$ in L/second	95 % confidence interval		p-value
Constant	3.970	3.677	4.264	< 0.0001
Biomass (yes vs no)	– 0.631	– 0.953	– 0.309	< 0.0001
Sex (male vs female)	0.950	0.510	1.390	< 0.0001
Age (per 1 year increase)	– 0.054	– 0.066	– 0.043	< 0.0001
Weight (per 1 kg increase)	0.0004	– 0.013	0.014	0.95
Height (per 1 cm increase)	0.029	0.006	0.052	0.01
Persons living in a home (per person more)	– 0.036	– 0.157	0.086	0.56
Rooms number in a home (per room more)	– 0.028	– 0.194	0.138	0.74
History of recurrent respiratory tract infections (yes vs no)	– 0.038	– 0.365	0.290	0.82

Predictors were centered when entering into the model: For these regressions the estimated constant is representing the value for a female person with no biomass exposure, age 35, weight 65, height 165, 5 persons living in a home, 4 rooms in the house, and no history of recurrent respiratory tract infections

relationship of the standardised residuals vs predicted values did not reveal inappropriate model specification.

Discussion

In this cross-sectional study among non-smokers we observed that the mean values of pulmonary function test measurements were significantly decreased both in males and females who used biomass compared to non-users. Multivariate regression confirmed univariate results and estimated a 12.4 % (95 % confidence interval: 7.0 % to 17.7 %) reduction in forced vital capacity associated with biomass use. This finding is thought to be related with decreased air flow both in big and small airways. Because of the high proportion of reported respiratory tract infections and the lower values of some pulmonary function test parameters (like FEV_1, FVC, FEV_1/FVC, $FEF_{25–75}$) that are associated with a higher risk for obstructive lung diseases, we speculate that the risk of chronic obstructive lung disease may be increased among the biomass users in our study.

Limitations and of this study

When interpreting the results of this study the cross-sectional design and the possibility of confounding need to be acknowledged to limit causal inference. It is plausible to speculate that the biomass using population in rural Turkey differed in several respects from the more urban not biomass using population, and that some of these differences might affect results of pulmonary respiratory functions. This study was careful in that smoking, a main factor affecting respiratory function, was removed from the list of possible confounders because only non-smoking participants were included in the study. Additionally, socio-economic proxy-factors (number of rooms and number of persons in the home) and the history of recurrent pulmonary tract infections were assessed by a standardised questionnaire, and included in multivariable regression, in addition to the demographic variables age, sex, height, and weight that are known to affect respiratory function measurements. Therefore, the average differences in respiratory function measurements observed in multivariate regression between the biomass

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and non-biomass users are not due to the possible differences between the two groups in the variables included in the analysis. However, we did not assess directly air quality in the houses of the participants and the two groups might have differed in the amount of passive smoking exposure in the house. Therefore, we cannot rule out the possibility that residual confounding might be, in part, responsible for the observed differences. Additionally, due to the cross-sectional design we cannot substantiate the time sequence of biomass exposure and its physiological sequelae on respiratory function, and the fact that we assessed exposure in a dichotomous (yes/no) category we were not able to investigate or substantiate dose-response relationships. However, in the light of the known consequences of biomass use, we think that it is unlikely that the observed differences are only due to residual confounding or unprecise exposure assessment.

This study in the context of other studies

In various studies made by Demirtas (1997) and Ozbay et al. (2001) strong statistical correlations were found between the prevalence of chronic obstructive lung disease and biomass smoke exposure in Turkey. In these studies mean values of FEV_1, FVC, FEV_1/FVC and peak expiratory flow were found to be decreased among biomass affected people. In a study in Mexican women of Perez-Padilla et al. (1996), to live in smoky rooms in which wood and cow-dung fires were present was a risk factor for repeated respiratory infections. In the study of Pandey (1984) a similar relationship between decrease of lung function measured by spirometry and indoor biomass exposure could be shown. In ongoing studies by Helsing et al. (1982) and Jones et al. (1983) pulmonary function was shown to be decreased among women using biomass fuel as an energy source while cooking. Similarly, Jindal (1993) and Dossing et al. (1994) have observed an increased prevalence of chronic obstructive lung disease among biomass using people. In rural regions where biomass fuels are used measured levels of certain pulmonary toxic agents such as aldehyde, CO and benzopyren exceeded official limits of indoor air concentrations (Darlington et al. 2000).

Consequences of biomass use

Especially in the rural regions of developing countries biomass burning is widely used as an energy source and causes important health problems (Koning et al. 1985). The harmful effects of cow-dung and other organic fuels are due to waste products of combustion such as hydrocarbons (e.g., aldehyde, phenol, toluen) (Koning et al. 1985). The inflammatory reactions caused by recurrent exposure to irritant and mucus-coagulating emissions make the trachea, bronchi and bronchioles susceptible to infection, which may lead to infective bronchitis, bronchiolitis or pneumonia (Koning et al. 1985). As a result of this, populations living in regions with predominant biomass use have higher incidence of respiratory diseases (Baris 1995). Pulmonary function tests facilitate the investigation of the effects of biomass use on the respiratory system and the diagnosis of the associated respiratory diseases.

Reduced pulmonary function measurements and recurrent respiratory infections are known to represent a complex marker of overall health status. The observed reductions in pulmonary function measurements in biomass users were real. Although, due to the study limitations, we cannot attribute these differences causally and with certainty to biomass use, we expect that these differences translate into important differences in overall health between biomass user and non-users in the rural regions of Sivas city.

The rural region of Sivas city can be considered to be representative for the situation in many developing countries where this form of energy supply is used. The populations in these countries will experience the same overall health differences associated with burning biomass, and a concerted and international efforts are required to reduce these differences, mainly aiming at reducing levels of certain pulmonary toxic agents, and at finding alternative energy supply.

Zusammenfassung

Zusammenhang zwischen Verwendung von Biomasse und Lungenfunktionstests bei Erwachsenen in Zentralanatolien

Fragestellung: Besteht in einer ländlichen Gegend in der Türkei ein Zusammenhang zwischen Lungenfunktion und der Verwendung von Biomasse als häusliche Energiequelle?

Methode: In einer Querschnitts-Studie von Nichtrauchern wurden bei 112 Personen, die für das Kochen und Heizen getrockneten Kuhdung verbrannten, und 153 Personen, die moderne Energiequellen verwendeten, die Lungenfunktion gemessen und mit univariablen und multivariablen Auswertungs-Methoden verglichen. Soziodemographische Faktoren wurden per Fragebogen erhoben und die folgenden Lungenfunktionsparameter wurden standardisiert gemessen: Das forcierte Ausatmungsvolumen Erstsekundenvolumen (FEV_1), die forcierte Vitalkapazität (FVC), das Verhältnis von FEV_1/FVC und die Flussraten zwischen 25 % und 75 % der forcierten Vitalkapazität (FEF_{25-75}).

Ergebnisse: Die Teilnehmer in den beiden Gruppen mit Biomasse-Verwendung (Exponierte) und ohne Biomasse-Verwendung (Nicht-Exponierte) waren ähnlich in Bezug auf demographische Charakteristika: Bei den Exponierten waren 67,0 % weiblich und 60,1 % bei den Nicht-Exponierten, und die Altersverteilung umspannte 17 bis 64 (Exponierte) bzw. 18 bis 70 Jahre (Nicht-Exponierte). Von den Exponierten hatten 36 % über wiederkehrende Infektionen der unteren Atemwege berichtet im Vergleich zu 20 % der Nicht-Exponierten. Alle Lungenfunktionsparameter (FEV_1, FVC, FEV_1/FVC und FEF_{25-75}) waren bei den Biomasse-Verwendern im Vergleich zu den Kontrollpersonen reduziert ($p < 0,0001$). In der multivariablen linearen Regression resultierte eine Reduktion in der forcierten Vitalkapazität um 12,4 % (95 %-Konfidenzintervall: 7,0 % bis 17,7 %).

Schlussfolgerungen: Es ist gut bekannt, dass die Verwendung von Biomasse für die Heizung zu relevanten Gesundheitsauswirkungen führt. Die in dieser Querschnitts-Studie mit Biomasse-Heizung assoziierten substantiellen Unterschiede der Lungenfunktionsparameter bei Nichtrauchern in einer ländlichen Gegend der Türkei liefern eine weitere Begründung dafür, dass Massnahmen nötig sind, um dieses Public-Health-Problem zu reduzieren.

Résumé

Association entre la combustion de biocarburant et des tests de fonctions pulmonaires chez des adultes d'Anatolie centrale

Objectifs: Déterminer l'association entre le biocarburant utilisé comme source domestique d'énergie et la fonction respiratoire dans des zones rurales d'Anatolie centrale en Turquie où l'usage du biocarburant est fréquent.

Méthodes: Enquête transversale, fonctions pulmonaires mesurées auprès de 112 utilisateurs de bouse de vache et 153 utilisateurs de source d'énergie moderne, tous non fumeurs. Des facteurs sociodémographiques obtenus par questionnaire. Mesures de fonctions pulmonaires: volume expiratoire maximal en une seconde (VEMS), capacité vitale forcée (CVF), rapport VEMS/CVF et débit expiratoire moyen (25 % et 75 %) DEM_{25-75}. Ces mesures ont été comparées avec des méthodes univariées et multivariées.

Résultats: Les groupes exposés et non exposés au biocarburant avaient des caractéristiques démographiques semblables: les femmes représentaient 67 % des exposés et 60.1 % des non exposés, la fourchette d'âge était de 17 à 64 ans chez les exposés et de 18 à 70 ans chez les non exposés, la fréquence des infections pulmonaires était de 36% chez les exposés et 20 % chez les non exposés. Tous les paramètres des fonctions pulmonaires VEMS, CVF, VEMS/CFV et DEM_{25-75} étaient diminués de façon statistiquement significative ($p < 0.001$) chez les utilisateurs de biocarburant. Une réduction de 12.4 % (intervalle de confiance à 95 %: 7 à 17.7 %) est observée par régression linéaire multivariée.

Conclusions: Il est bien connu que la combustion du biocarburant est un problème important de santé publique. Des différences importantes de fonctions pulmonaires associées à l'usage de biocarburant comme source d'énergie ont été observées dans cette étude transversale de non fumeurs. Il s'agit donc d'un problème de santé publique également dans les zones rurales de Turquie.

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