Elevated Plasma Adiponectin Levels in Patients with Chronic Obstructive Pulmonary Disease

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Running title: Plasma adiponectin levels in COPD

Word count: 2615

Number of tables: 4

Number of figures: 2

Number of references: 38

Keywords: Adiponectin, Chronic obstructive pulmonary disease, C-reactive protein, Interleukin-6, Interleukin-8, Lung function

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ABSTRACT

Background: Adiponectin is an anti-inflammatory adipokine and may play a role in COPD pathogenesis. This study was to investigate the relationship between adiponectin, interleukin (IL)-6, IL-8 and C-reactive protein (CRP) and COPD by evaluating these biomarkers in ever-smokers with or without the disease.

Method: Plasma levels of adiponectin, IL-6, IL-8 and CRP were measured using commercial available kits respectively in COPD patients (n=71), healthy ever-smokers (n = 62) and non-smokers (n = 51).

Results: There were significant increases in plasma adiponectin, IL-6 and CRP in COPD patients [median (IQR): 4.39 μg/ml (2.68-6.98 μg/ml), 4.19 pg/ml (<2.40-6.40 pg/ml), 8.75 mg/l (4.26-40.63 mg/l) respectively] compared to healthy ever-smokers [1.90 μg/ml (0.86-2.86 μg/ml), <2.40 pg/ml (<2.40-2.77 pg/ml), 3.71 mg/l (1.97-10.37 mg/l) respectively; p < 0.001] and non-smokers [1.76 μg/ml (1.34-2.52 μg/ml), <2.40 pg/ml (<2.40-2.78 pg/ml), 3.12 mg/l (2.11-5.71 mg/l) respectively; p < 0.001]. COPD patients had lower plasma IL-8 levels than healthy ever-smokers. Among ever-smokers with or without COPD, plasma adiponectin, IL-6 and CRP levels were inversely correlated with FEV₁ (% predicted) after adjustment for age, BMI, smoking status and pack-years.

Conclusion: Our findings suggest that in COPD patients, adiponectin might be
associated with COPD pathogenesis.
INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a major global disease and has been estimated to be the third leading cause of mortality worldwide by 2020.\(^1\) It is a disease characterized by slowly progressive airflow limitation and includes both emphysema and chronic bronchitis.\(^2\) Cigarette smoking is the most important risk factor, contributing to more than 90% of COPD cases.\(^3\) There is increasing evidence of systemic inflammation in patients with COPD. However, the main cause for the presence of systemic inflammation in COPD patients is still unclear but systemic hypoxia due to the progression of COPD has been suggested to be a possibility. Several disease biomarkers have been found to be helpful in assessing systemic and local inflammation including interleukin (IL)-6, IL-8 and C-reactive protein (CRP).\(^4\)-\(^8\)

Adiponectin is a secretary 30kD protein synthesized by adipocytes in healthy subjects. Three isoforms (trimer, hexamer and high molecular weight complex) were found in the circulation with different biochemical properties.\(^9\) Its role in inflammation is controversial since its plasma concentration decreases in diseases such as metabolic syndrome and type II diabetes\(^10\) but increases in some inflammatory diseases like rheumatoid arthritis and systemic lupus erythematosus.\(^11\),\(^12\) Elevation of plasma adiponectin level was found in patients with
stable and acute exacerbation of COPD.\textsuperscript{13,14} However, in one study, adiponectin was found to suppress TNF-\(\alpha\) and MMP-12 production in alveolar macrophages and absence of adiponectin led to an emphysema-like lesion in adiponectin knock-out mice.\textsuperscript{15}

In this study, we hypothesized that circulating levels of adiponectin and other conventional inflammatory biomarkers might be associated with lung function in ever-smokers with or without COPD. Thus, we studied patients with stable COPD who were ever-smokers, and healthy ever-smokers and non-smokers as controls to investigate circulating levels of adiponectin, IL-6, IL-8 and CRP, and the correlations between these biomarkers and lung functions.
METHODS

Study Subjects

Three groups of men, a total of 184, were randomly chosen from our database of the COPD study conducted by the COPD Study Group of the Hong Kong Thoracic Society between 2005 and 2006.\(^{16}\) (1) healthy life long non-smokers; (2) healthy ever-smokers: either current smokers or ex-smokers (defined as those who had not smoked within the last 12 months) with $\text{FEV}_1/\text{FVC} \geq 70$ and $\text{FEV}_1 \geq 80$ (% predicted), and no chronic respiratory symptoms; and (3) stable COPD patients, who are ever-smokers and defined as $\text{FEV}_1/\text{FVC} < 70$ and/or $\text{FEV}_1 < 80$ (% predicted) according to the diagnostic criteria of Global Initiative for Chronic Obstructive Lung Disease (GOLD).\(^{17}\) Stable COPD patients were defined as those who did not have exacerbation within the last 12 weeks prior to recruitment. The healthy subjects, irrespective of smoking habits, were recruited from those attending churches and community centers for the elderly across Hong Kong. COPD patients were recruited from outpatient respiratory clinics. Lung function tests were performed in all control subjects and patients using standardized methods according to the American Thoracic Society guidelines.\(^{18}\) The predicted values were based on reference values obtained from our local population.\(^{19}\) Information about smoking habits, respiratory symptoms and other diseases such as cardiovascular diseases
were obtained from a detailed questionnaire. Subjects were excluded if they had a
history of asthma or other lung illnesses. Four of the COPD patients had coronary
artery disease. There was no patient from our cohort had stage 1 disease \[\text{FEV}_1/\text{FVC} < 70, \text{FEV}_1 \geq 80 \text{ (% predicted)}\] and were subdivided into three groups according to
disease severity based on GOLD criteria (stage 2: 50% \(\leq\) \text{FEV}_1 < 80\% predicted; 
stage 3: 30% \(\leq\) \text{FEV}_1 < 50\% predicted; stage 4: \text{FEV}_1 < 30\% predicted).\(^\text{16}\) Patients
were also subdivided into two groups based on body mass index (BMI): \(\text{BMI} < 18.5 \text{ kg/m}^2\) and \(\text{BMI} \geq 18.5 \text{ kg/m}^2\) according to WHO criteria.\(^\text{20}\) Every participant
signed the informed consent form and this study was approved by the Ethics
Committee of The University of Hong Kong.

**Blood Sampling and Analysis**

Venous blood samples were taken from all subjects, centrifuged immediately
at 1600x g for 10 min at 4\(^\circ\)C and stored at -70\(^\circ\)C. Plasma adiponectin (R&D
Systems Inc., MN, USA), IL-6, IL-8 ((BD Biosciences Pharmingen, San Diego, CA,
USA) and CRP (Diagnostic Systems Laboratories Inc., Texas, USA) were measured
by commercially available enzyme-linked immunosorbent assay (ELISA) kits
respectively.
Statistical Analysis

Data were expressed as mean ± SD or median (interquartile range; IQR) for normally or non-normally distributed variables, respectively, unless specified. The normality was tested by the method of Kolmogorov-Smirnov. Demographic data were compared between any two groups by either Student t test or $\chi^2$ statistics. Plasma levels of adiponectin, IL-6, IL-8 and CRP were compared by Mann-Whitney U test. All data including those whose readings were below the detection limit were included in these comparisons. In COPD patients and healthy ever-smokers, the relationships between adiponectin, IL-6, IL-8 or CRP and the lung function measures or other demographic variables were first investigated by the Spearman rank-order correlation using data from all subjects. If similar results were obtained by the Pearson product-moment correlation, the Pearson partial correlation between log-transformed adiponectin, IL-6, IL-8 or CRP and the lung function measures with adjustment for cofounders was then estimated using data from those with positive values. Multiple linear regression analyses were performed to study the relationships between COPD severity and plasma adiponectin, IL-6, IL-8 or CRP (in log scale), adjusting for age, BMI, smoking status and pack-years smoked within COPD patients only. Stages 2, 3 and 4 COPD patients were coded with values 1, 2 and 3, respectively, and entered the regression model as a continuous independent factor.
All p-values were not adjusted for multiple testing due to the exploratory nature of this study. SPSS for Windows version 16.0 statistical package (SPSS, Chicago, IL) was used for statistical analyses.
RESULTS

Demographic characteristics of the study subjects are summarized in Table 1. All the recruited COPD patients were current or ex-smokers. COPD patients were significantly older and had a significantly lower BMI than healthy non-smokers or ever-smokers. COPD patients also had higher pack-year smoked than healthy ever-smokers. There were 5 missing values for pack-years smoked due to incomplete information in the questionnaire. As expected, there were significant reductions of FEV\(_1\) (% predicted), FVC (% predicted) and FEV\(_1\)/FVC ratio in COPD patients compared with healthy ever-smokers, irrespective of smoking status.

Plasma adiponectin, IL-6 and CRP levels were significantly elevated in COPD patients compared with healthy ever-smokers or non-smokers. Plasma IL-8 levels were significantly increased in COPD patients and healthy ever-smokers compared with healthy non-smokers. Healthy ever-smokers also had higher levels of plasma IL-8 compared with healthy non-smokers while COPD patients had lower plasma IL-8 levels than healthy ever-smokers (Table 2).

In ever-smokers with or without COPD, Spearman’s correlation analysis did not show pair-wise correlations among plasma adiponectin, IL-8 and CRP (r < 0.18 and \(p > 0.05\)). However, plasma IL-6 showed pair-wise correlations with adiponectin and CRP (r = 0.374 and 0.284 respectively, \(p < 0.01\)). Plasma adiponectin and IL-6
was found to have positive correlations with age ($r = 0.424$ and $0.303$ respectively, $p \leq 0.001$) and pack-year smoked ($r = 0.254$ and $0.338$ respectively, $p < 0.01$) and inverse correlation with BMI ($r = -0.623$ and $-0.396$, $p < 0.001$). After controlling for age, BMI, smoking status and pack-year smoked, plasma IL-6 remained positively correlated with plasma CRP ($r = 0.356$, $p < 0.001$). Ex-smokers regardless of lung function status also had higher plasma adiponectin levels than current smokers (median: 3.26, IQR: 1.96-5.65 $\mu$g/ml versus median: 2.24, IQR: 1.03-4.43 $\mu$g/ml, $p = 0.016$, Mann-Whitney U test).

Pulmonary function parameters, FEV$_1$ (% predicted), FVC (% predicted) and FEV$_1$/FVC ratio, correlated negatively with plasma adiponectin, IL-6 and CRP but positively with plasma IL-8 (data not shown). After controlling for age, BMI, smoking status and pack-year smoked, these lung function parameters remained inversely correlated with plasma adiponectin, IL-6 and CRP levels, and positively correlated with plasma IL-8 levels (Table 3).

There were no significant differences in age, BMI and pack years smoked among COPD patients according to disease severity (data not shown). We found an increase in plasma adiponectin and CRP levels with disease severity (Figure 1A and 1D). Stage 4 COPD patients had the highest median of plasma adiponectin levels compared to stage 2 and stage 3 COPD patients. No difference was found in plasma
IL-6 among different stages (Figure 1B). Plasma IL-8 levels show a non-significant
decrease with disease severity (Figure 1C).

The COPD patients with BMI < 18.5 kg/m$^2$ had significantly elevated
plasma adiponectin levels in comparison to those with BMI \(\geq 18.5 \text{ kg/m}^2\) (Figure
2A). They also showed higher median of plasma IL-6 and IL-8, and lower CRP
levels than COPD patients with BMI \(\geq 18.5 \text{ kg/m}^2\) but not reaching statistical
significance (Figure 2B-D).

After adjusting for age, BMI, smoking status and pack-year smoked,
multiple linear regression analyses showed that plasma adiponectin levels still
increased with the COPD staging (Table 4) but plasma IL-6, IL-8 or CRP levels
were not related to COPD staging.
DISCUSSION

In this study, we found that COPD patients who were ever-smokers had significantly higher plasma levels of adiponectin, IL-6 and CRP than healthy ever-smokers and non-smokers. Plasma levels of adiponectin, IL-6 and CRP were negatively correlated with FEV₁ (% predicted) in COPD patients and healthy ever-smokers.

Our findings that COPD patients had a significantly higher plasma adiponectin levels and that the more severe COPD patients had even higher levels suggest that adiponectin might be inappropriately secreted in this disease. The exact role of adiponectin could not be elucidated in this study since it is a cross-sectional study. In contrast to our findings, Tomoda et al.¹³ and Kirdar et al.¹⁴ observed no relationship between lung function and plasma adiponectin. This may probably be due to the limited sample size in their studies. Although the function of adiponectin remains controversial, adiponectin was recently found positively correlated with IL-6 in dialysis patients²¹, in line with our findings. Additionally, we found that plasma adiponectin levels were inversely correlated with BMI in the group of healthy ever-smokers and those with COPD as reported in previous studies.¹³ COPD patients with BMI < 18.5 kg/m² had a significant elevation of circulating adiponectin compared to those with BMI ≥ 18.5 kg/m² as previously reported.¹³ This
could be the consequence of severely decreased body fat as reported in patients with
anorexia nervosa and cachexia.\textsuperscript{22,23}

We demonstrated elevated plasma IL-8 levels in ever-smokers with or
without COPD compared with those of healthy non-smokers; but COPD patients
had lower plasma IL-8 levels than healthy ever-smokers. Our results are in contrast
to that of previous researchers who found marginally higher plasma IL-8 levels in
COPD patients compared with those of healthy smokers\textsuperscript{24}, and elevated IL-8 levels
in induced sputum of COPD patients.\textsuperscript{25,26} This discrepancy might be explained by
the fact that local and systemic inflammations are differentially regulated.\textsuperscript{27} In
studies done by Yoshikawa \textit{et al}\textsuperscript{28}, chemotactic activity and migration of neutrophils
from blood of severe COPD patients were lower than that of less severe patients or
healthy smokers. Fietta and colleagues\textsuperscript{29} also found that the number of functional
neutrophils and monocytes was reduced in chronic bronchitis. Our finding of
reduced plasma IL-8 levels in more severe COPD patients suggests that a reduction
of chemoattractant might be present in severe COPD cases. Another possible
explanation is that the release of IL-8 is suppressed by an endogenous inhibitor
which could be adiponectin as adiponectin has been found to inhibit IL-8
production.\textsuperscript{30} Moreover, IL-8 might also be suppressed by CRP as reported by an \textit{in
\textit{vitro} study.}\textsuperscript{31}
Ever-smokers with COPD had the highest plasma IL-6 and CRP levels compared with those of healthy non-smokers and ever-smokers, in line with previous publications.\(^7,32,33\) \(\text{FEV}_1\) (\% predicted) was found to be inversely correlated to plasma IL-6 and CRP levels as in previous report,\(^8,32\) suggesting that systemic inflammation might play a role in the development of airway obstruction. Plasma IL-6 also showed a positive correlation with CRP, which is consistent with previous findings,\(^32\) since IL-6 is a positive regulator of CRP by triggering acute-phase response in liver.\(^34\)

The strength of our study is that we have investigated the potential role of adiponectin alongside that of other inflammatory biomarkers (IL-6, IL-8 and CRP) in relation to the lung function in the same subjects with a larger sample compared with previous studies.\(^13,14\) In addition, we have used all-male study population to avoid the sex differences in the plasma levels of different forms of adiponectin\(^9\) and the disease state of emphysema due to a heterogeneous population.\(^35\) However, the sample size is still relatively small for subgroup analysis after stratification by disease severity but this is the first study to demonstrate the relationship between plasma adiponectin and COPD severity. Our study also has several limitations. Firstly, this is a cross-sectional study that limits the interpretation of a causal link between the markers adiponectin, IL-6, IL-8 and CRP, and lung function changes.
As reported by Summer and coworkers, mice deficient in adiponectin was more susceptible to develop emphysema, which implied that adiponectin might be involved in tissue repair rather than disease development. However, there are no association studies for adiponectin gene polymorphisms and COPD in determining which polymorphism causes the functional effect. Prospective studies in smokers with or without COPD are required to fully address the role of adiponectin in the development and progression of COPD. Secondly, we carried out the measurements in plasma, which reflects only systemic changes and may not adequately reflect the local concentrations in the lungs. Further studies involving biological samples such as BAL, induced sputum and exhaled breath condensate, might shed more light locally. Thirdly, we measured total adiponectin levels in plasma instead of its different isoforms in the present samples. High molecular weight (HMW) isoform was found to have greater clinical significance than the other two isoforms in obesity-related diseases. A similar pattern of total adiponectin and HMW isoform was recently observed with the HMW isoform being the most abundant adiponectin. In this study, we could not rule out whether a specific isoform such as HMW isoform involves in COPD progression or not, however, the measurement of total adiponectin or a specific isoform in plasma has been demonstrated to produce similar results.
CONCLUSION

We found an inverse relationship between FEV<sub>1</sub> (% predicted) and plasma adiponectin, IL-6 or CRP levels in ever smokers. In COPD patients, we found elevated plasma adiponectin, IL-6 and CRP levels and the more severe the disease, the higher the adiponectin levels. These findings suggest that these biomarkers might be associated with COPD. As this study provides evidence of association rather than of causation, prospective studies are required to assess biological significance of these associations.
Acknowledgements

This work was supported partly by the Hong Kong Lung Foundation. The authors wish to thank all nurses and laboratory staffs who took part in this study; all of the subjects for their participation. KHC designed, coordinated and carried most of the work, ELISA and the statistical analysis, drafted the manuscript. SCY performed ELISA. TJY gave advice on performing the statistical analysis. AHKC helped the recruitment of the study subjects. MSMI and MMWC-Y helped to improve the final manuscript. JCWM conceived of the study, aided technical trouble shooting, helped to perform the statistical analysis, and drafted and edited the manuscript. All authors read and approved the final manuscript.
References


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33. Pinto-Plata VM, Mullerova H, Toso JF, et al. C-reactive protein in patients with


Table 1. Characteristics of study subjects

<table>
<thead>
<tr>
<th></th>
<th>Healthy non-smokers</th>
<th>Healthy ever-smokers</th>
<th>COPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>51</td>
<td>62</td>
<td>71</td>
</tr>
<tr>
<td>Age</td>
<td>45 ± 13</td>
<td>56 ± 15†</td>
<td>70 ± 9‡</td>
</tr>
<tr>
<td>Smoking status</td>
<td>NA</td>
<td>31/31</td>
<td>19/52ξ</td>
</tr>
<tr>
<td>(current/ex-smoker)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pack-years smoked</td>
<td>NA</td>
<td>23 ± 15</td>
<td>48 ± 34‡</td>
</tr>
<tr>
<td>BMI</td>
<td>24.6 ± 3.5</td>
<td>23.7 ± 3.2</td>
<td>20.7 ± 3.7‡</td>
</tr>
<tr>
<td>FEV₁ % predicted</td>
<td>105 ± 14</td>
<td>102 ± 15</td>
<td>37 ± 13†‡</td>
</tr>
<tr>
<td>FVC % predicted</td>
<td>104±14</td>
<td>102 ± 13</td>
<td>72 ± 21†‡</td>
</tr>
<tr>
<td>FEV₁/ FVC</td>
<td>81 ± 5</td>
<td>78 ± 6‡</td>
<td>39 ± 9†‡</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD.

† p < 0.01 between healthy non-smokers and ever-smokers, ‡ p < 0.001 between healthy non-smokers and COPD patients and § p < 0.05 between healthy ever-smokers and COPD patients by either t-test or Mann-Whitney U test.

ξ p = 0.01 by Chi-square test with continuity correction.
Table 2. Plasma levels of inflammatory mediators

<table>
<thead>
<tr>
<th></th>
<th>Healthy non-smokers</th>
<th>Healthy ever-smokers</th>
<th>COPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adiponectin (μg/ml)</td>
<td>1.76 (1.34-2.52)</td>
<td>1.90 (0.86-2.86)</td>
<td>4.39 (2.68-6.98)</td>
</tr>
<tr>
<td>IL-6 (pg/ml) (all)</td>
<td>&lt;2.40 (&lt;2.40-2.78)</td>
<td>&lt;2.40 (&lt;2.40-2.77)</td>
<td>4.19 (2.67-6.40)</td>
</tr>
<tr>
<td>≥ 2.4* only</td>
<td>n = 18</td>
<td>n = 20</td>
<td>n = 56</td>
</tr>
<tr>
<td>IL-8 (pg/ml) (all)</td>
<td>&lt; 3.10 (&lt;3.10-4.14)</td>
<td>13.84 (6.86-29.73)</td>
<td>7.26 (3.63-14.25)</td>
</tr>
<tr>
<td>≥ 3.1† only</td>
<td>n = 16</td>
<td>n = 55</td>
<td>n = 55</td>
</tr>
<tr>
<td>CRP (mg/l)</td>
<td>3.12 (2.11-5.71)</td>
<td>3.71 (1.97-10.37)</td>
<td>8.75 (4.26-40.63)</td>
</tr>
</tbody>
</table>

Data are expressed as median (IQR).

* The detection limit for IL-6 was 2.4 pg/ml. There were 33 healthy non-smokers, 42 healthy ever-smokers and 15 COPD patients whose IL-6 was < 2.4 pg/ml.

† The detection limit for IL-8 was 3.1 pg/ml. There were 35 healthy non-smokers, 7 healthy ever-smokers and 16 COPD patients whose IL-8 was < 3.1 pg/ml.

# $p < 0.01$ between healthy non-smokers and ever-smokers, † $p < 0.001$ between healthy non-smokers and COPD patients and ‡ $p < 0.05$ between healthy ever-smokers and COPD patients by either t-test or Mann-Whitney U test.
Table 3. Relationship between plasma adiponectin, IL-6, IL-8 or CRP and lung function parameters in ever-smokers with or without COPD (Pearson partial correlation)\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Adiponectin</th>
<th>IL-6\textsuperscript{b}</th>
<th>IL-8\textsuperscript{c}</th>
<th>CRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV\textsubscript{1} (% predicted)</td>
<td>-0.370\textsuperscript{***}</td>
<td>-0.381\textsuperscript{***}</td>
<td>0.208\textsuperscript{*}</td>
<td>-0.303\textsuperscript{**}</td>
</tr>
<tr>
<td>FVC (% predicted)</td>
<td>-0.262\textsuperscript{**}</td>
<td>-0.189</td>
<td>0.196\textsuperscript{*}</td>
<td>-0.187</td>
</tr>
<tr>
<td>FEV\textsubscript{1}/FVC ratio</td>
<td>-0.302\textsuperscript{**}</td>
<td>-0.368\textsuperscript{***}</td>
<td>0.193\textsuperscript{*}</td>
<td>-0.284\textsuperscript{**}</td>
</tr>
</tbody>
</table>

\textsuperscript{*}p < 0.05, \textsuperscript{**}p < 0.01 and \textsuperscript{***}p < 0.001. \textsuperscript{a}adjusted for age, BMI, smoking status and pack-years smoked.

\textsuperscript{b}All patients with data on smoking status were included, except 21 with negative IL-6 values.

\textsuperscript{c}All patients with data on smoking status were included, except 7 with negative IL-8 values.
Table 4. Associations between plasma levels of adiponectin, IL-6, IL-8 or CRP and disease severity in patients with COPD adjusted for age, BMI, smoking status and pack-years smoked by multiple linear regression analysis

<table>
<thead>
<tr>
<th></th>
<th>Adiponectin</th>
<th>IL-6&lt;sup&gt;a&lt;/sup&gt;</th>
<th>IL-8&lt;sup&gt;b&lt;/sup&gt;</th>
<th>CRP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\beta$</td>
<td>SE*</td>
<td>$p$</td>
<td>$\beta$</td>
</tr>
<tr>
<td>Age</td>
<td>0.004</td>
<td>0.009</td>
<td>0.623</td>
<td>-0.002</td>
</tr>
<tr>
<td>BMI</td>
<td>-0.114</td>
<td>0.02</td>
<td>&lt;0.001</td>
<td>-0.047</td>
</tr>
<tr>
<td>Smoking status</td>
<td>0.203</td>
<td>0.175</td>
<td>0.251</td>
<td>-0.121</td>
</tr>
<tr>
<td>Pack-year smoked</td>
<td>-0.002</td>
<td>0.002</td>
<td>0.436</td>
<td>0.003</td>
</tr>
<tr>
<td>Disease severity</td>
<td>0.220</td>
<td>0.103</td>
<td>0.037</td>
<td>-0.183</td>
</tr>
</tbody>
</table>

<sup>#</sup> Unstandardized coefficients; *Standard error

<sup>a,b</sup> All COPD patients with data on smoking status were included, except 6 with negative IL-6 values and 4 with negative IL-8 values.
Figure 1

A

Adiponectin (μg/ml)

Stage 2  Stage 3  Stage 4

B

IL-6 (pg/ml)

Stage 2  Stage 3  Stage 4

C

IL-8 (pg/ml)

Stage 2  Stage 3  Stage 4

D

CRP (mg/l)

Stage 2  Stage 3  Stage 4
Figure 2

A

BMI \geq 18.5  
BMI < 18.5

Adiponectin (\mu g/ml)

B

BMI \geq 18.5  
BMI < 18.5

IL-6 (pg/ml)

C

BMI \geq 18.5  
BMI < 18.5

IL-8 (pg/ml)

D

BMI \geq 18.5  
BMI < 18.5

CRP (mg/l)
**Figure legends**

**Figure 1.** Plasma adiponectin, IL-8, IL-6 and CRP levels according to disease severity.

(A) Plasma adiponectin in stage 2, 3, and 4 COPD patients with n = 14, 35, and 22 respectively. *p < 0.05* by Mann-Whitney U test. (B) Plasma IL-6 in stage 2, 3, and 4 COPD patients with n = 11, 33, and 21 respectively. Three negative values from stage 2, two negative values from stage 3 and one negative value from stage 4 were not included in the plot. (C) Plasma IL-8 in stage 2, 3 and 4 COPD patients with n = 14, 32, and 21 respectively. Three negative values from stage 3 and one negative value from stage 4 were not included in the plot. (D) Plasma CRP in stage 2, 3 and 4 COPD patients with n = 14, 35 and 22 respectively. The y-axis of plasma CRP was restricted to 150 mg/l; one subject from stage 2 (251 mg/l), four subjects from stage 3 (196, 373, 411, and 551 mg/l) and three subjects from stage 4 (165, 199, and 414 mg/l) were not shown in the plot. The horizontal line represents median values.

**Figure 2.** Plasma levels of adiponectin, IL-8, IL-6 and CRP according to BMI. (A) Plasma adiponectin in COPD patients with BMI ≥ 18.5 kg/m² (n = 49) and BMI < 18.5 kg/m² (n = 22). ***p < 0.001* between BMI ≥ 18.5 kg/m² and BMI < 18.5 kg/m² by Mann-Whitney U test. (B) Plasma IL-6 in COPD patients with BMI ≥ 18.5 kg/m² (n = 45) and BMI < 18.5 kg/m² (n = 20). Four negative values from BMI ≥ 18.5 kg/m² and two negative values from BMI < 18.5 kg/m² were not included in the plot. (C)
Plasma IL-8 in COPD patients with BMI ≥ 18.5 kg/m$^2$ (n = 45) and BMI < 18.5 kg/m$^2$ (n = 22). Four negative values from BMI ≥ 18.5 kg/m$^2$ were not included in the plot.

(D) Plasma CRP in COPD patients with BMI ≥ 18.5 kg/m$^2$ (n = 49) and BMI < 18.5 kg/m$^2$ (n = 22). The y-axis of plasma CRP was restricted to 150 mg/l; four subjects from BMI ≥ 18.5 kg/m$^2$ (196, 199, 441 and 551 mg/l) and four subjects from BMI < 18.5 kg/m$^2$ (165, 251, 373 and 411 mg/l) were not shown in the plot. The horizontal line represents median values.