Impacts of regular physical activity on hospitalisation in chronic obstructive pulmonary disease: a nationwide population-based study

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ABSTRACT
Introduction Studies that comprehensively evaluate the association between physical activity (PA) levels, particularly by quantifying PA intensity, and healthcare use requiring emergency department (ED) visit or hospitalisation in patients with chronic obstructive pulmonary disease (COPD) are limited. Method The risk of all-cause and respiratory ED visit or hospitalisation according to the presence or absence of COPD and the level of PA was evaluated in a retrospective nationwide cohort comprising 3308 subjects with COPD (COPD cohort) and 293 358 subjects without COPD (non-COPD cohort) from 2009 to 2017. Results The COPD group exhibited a higher relative risk of all-cause and respiratory ED visit or hospitalisation across all levels of PA compared with the highly active control group (≥1500 metabolic equivalents (METs)-min/week). Specifically, the highest risk was observed in the sedentary group (adjusted HR (aHR) (95% CI) = 1.70 (1.59 to 1.81) for all-cause ED visit or hospitalisation, 5.45 (4.86 to 6.12) for respiratory ED visit or hospitalisation). A 500 MET-min/week increase in PA was associated with reductions in all-cause and respiratory ED visit or hospitalisation in the COPD cohort (aHR (95% CI) = 0.92 (0.88 to 0.96) for all-cause, 0.87 (0.82 to 0.93) for respiratory cause). Conclusions Compared with the presumed healthiest cohort, the control group with PA ≥1500 METs-min/week, the COPD group with reduced PA has a higher risk of ED visit or hospitalisation.

INTRODUCTION
Chronic obstructive pulmonary disease (COPD), with a prevalence of 10% in adults, is one of the main causes of morbidity and the leading cause of death worldwide.1 The disease burden associated with COPD is substantial, and a considerable proportion of this burden is associated with urgent medical care (ie, emergency department (ED) visit) and conditions requiring hospital admission. Frequent ED visit and hospitalisation reduce the quality of life3 and increase morbidity and mortality in patients with COPD,3 which are associated with increased medical costs.4 5 Accordingly, medical and non-medical treatments that reduce these medical uses are significantly important.

Patients with COPD are typically characterised by lower physical activity (PA) compared with their age-matched peers,6 which is associated with poor health outcomes.7 8 9 Several epidemiological analyses using population-based adult cohorts have reported that lower PA levels are associated with decreased lung function and accelerated deterioration
of lung function.\textsuperscript{7} \textsuperscript{10–12} Furthermore, in patients with COPD, PA levels are the strongest predictor of all-cause mortality\textsuperscript{13} and an independent predictor of the risk of hospitalisation for acute exacerbation and premature death.\textsuperscript{7} \textsuperscript{8} \textsuperscript{14}

Quantifying PA is important in revealing the relationship between PA levels and COPD outcomes objectively. Until now, various methods have been used to measure PA levels. For example, some researchers evaluated PA levels in COPD by measuring daily steps.\textsuperscript{15} \textsuperscript{16} Other researchers used an accelerometer-based activity monitor to measure PA and showed that PA is reduced after hospitalisation for exacerbation of COPD and persistently reduced PA is a risk factor for readmission.\textsuperscript{17} Besides these measures, other investigators used metabolic equivalents (METs), which are widely used to estimate the energy expenditure for many common PA, and showed that breathlessness could help identify COPD patients at risk of reduced PA measured by METs.\textsuperscript{16} \textsuperscript{18} However, little information is available on the association between PA level assessed by METs and the risk of hospitalisation in COPD. Thus, providing information regarding this issue would be very helpful in pushing broad-scale interventions to support PA in Korea.

Thus, this study aimed to quantify PA levels and evaluate their effects on all-cause and respiratory ED visit or hospitalisation in subjects with and without COPD in Korea using a nationwide representative database.

**METHODS**

**Study population**

We used the Health Screening Examination data from the National Health Insurance Service-National Sample Cohort (NHIS-NSC), which is a population-based retrospective cohort that includes a 2.2% representative sample of Korean citizens. The NHIS-NSC database collects health data regarding\textsuperscript{1} major and minor diagnoses using the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) codes,\textsuperscript{2} drug prescriptions, and\textsuperscript{3} health examination findings. Detailed information on the NHIS-NSC database has been published previously.\textsuperscript{19}

As shown in figure 1, between 1 January 2009 and 31 December 2017, there were 490,495 adult subjects aged ≥40 years. We excluded 12013 subjects who had missing values for any of the items of the health screening examination and 78,467 subjects who had cancer (C00–C97). Of the remaining 400,013 subjects, 66,532 had one or more ICD-10 codes for COPD and 333,481 subjects had no ICD-10 codes for COPD. Of 66,532 subjects with one or more ICD-10 codes for COPD, 12,468 subjects had one or more ICD-10 codes for COPD within 1 year of health examination and finally, 3308 subjects had at least one ICD-10 code for COPD and COPD-related medications within 1 year of health examination (COPD cohort). Of 333,481 subjects with no ICD-10 codes for COPD, we excluded 40,123 subjects with one or more ICD-10 codes for COPD between 2002 and 2008, or 2018 and 2019. Finally, 293,358 subjects had no COPD (non-COPD cohort). All subjects were followed up until death or 31 December 2019.

The study protocol was approved by the Institutional Review Board (IRB) of Chungbuk National University Hospital (IRB application no. CBNUH 2022-08-026). The requirement for informed consent from the subjects was waived owing to the nature of the anonymised NHIS data.

**Definition**

COPD was defined as the presence of any J43 or J44 code (except J43.0) (ICD-10) and the prescription of COPD medication at least twice within a year. These medications included long-acting muscarinic antagonists, long-acting beta-2 agonists (LABAs), inhaled corticosteroids plus...
LABAs, short-acting muscarinic antagonists (SAMAs), short-acting beta-2 agonists (SABAs), SAMAs plus SABAs, methylxanthines, and systemic beta-agonists.20

Exposures
The primary exposure was the PA. PA intensity was measured using self-reported questionnaires. The survey included the following three questions on the frequency and duration of PA during the prior 7 days:1 light-intensity activity ≥30 min (eg, walking at a slow pace),2 moderate-intensity activity ≥30 min (eg, brisk walking, slow cycling, or tennis doubles), and5 vigorous-intensity activity ≥20 min (eg, jogging or running, bicycling>15 km/h, brisk climbing up a hill, or exercising in an aerobics class). To calculate PA level, we assigned ratings of 2.9, 4.0, and 7.0 METs for light-intensity, moderate-intensity, and vigorous-intensity PAs, respectively.21–23

Outcomes
The main outcomes of this study were all-cause and respiratory ED visit or hospitalisation. The NHIS-NSC database provides major and minor diagnoses using (ICD-10) codes during outpatient visit, ED visit, and hospitalisation. Respiratory ED visit and hospitalisation were defined as ED visit and hospitalisation under ICD-10 codes for respiratory diseases (J00–J99).25

Covariates
Body mass index (BMI) was calculated as the weight (kg) divided by the square of height (m). Based on the Asian classification, subjects were classified into underweight (<18.5 kg/m²), normal (18.5–22.9 kg/m²), overweight (23.0–24.9 kg/m²), and obese (≥25.0 kg/m²) groups.24 Low-income level was determined to be the lowest quintile and medical aid. Smoking status was classified as never, ex-smoker, or current smoker. The subjects were classified as never, mild to moderate (<30 g of alcohol/day), and heavy drinkers (≥30 g of alcohol/day) based on the amount of alcohol consumed. Comorbidities were defined using the following ICD-10 diagnosis codes: hypertension (I10–I15), diabetes mellitus (E10–E14), asthma (J45–J46), ischaemic heart disease (I20–I21), heart failure (I50), cerebrovascular disease (G45–G46, I60–I69, or H34.0), and chronic kidney disease (N18).23–31 The Charlson Comorbidity Index (CCI) was calculated according to a previous report.32

Statistical analyses
Categorical data are presented as numbers (percentages), and continuous data are presented as mean (SD) or median (IQR), as appropriate. Categorical data were compared using the χ² test, and continuous data were compared using Student’s t-test or Mann–Whitney U test, as appropriate. The respective incidence of ED visit or hospitalisation was calculated by dividing the number of ED visit or hospitalisation by the sum of the follow-up duration, presented as the rate per 1000 person-years (PY).

To determine the hazard ratio (HR) for outcomes according to the presence of COPD and PA level, a multivariable Cox proportional hazards regression model was used after adjusting for age, sex, smoking history, BMI, income level, alcohol consumption, and CCI score. In this categorised PA model, PA was included as a categorical variable (ie, sedentary, 1–499 METs·min/week, 500–999 METs·min/week, 1000–1499 METs·min/week, vs ≥1500 METs·min/week).21–23 We also used an additional multivariable Cox proportional hazards regression model, in which PA was included as a continuous variable to calculate HRs for outcomes associated with changes in PA by 500 MET·min/week (continuous PA model).

We also used a non-parametric PA model with a penalised spline to visualise the relationship between changes in PA level and all-cause and respiratory ED visit or hospitalisation. PA (continuous variable), age, sex, smoking history, BMI, income level, alcohol consumption, and CCI score were included in this model.

All tests were two-sided, and p values<0.05 were considered statistically significant. All statistical analyses were performed using the SAS software (V.9.4; SAS Institute, Cary, NC, USA).

RESULTS
Baseline characteristics
The baseline characteristics of the 296666 study subjects are summarised in table 1. COPD was associated with a higher proportion of older age, sex, underweight, ex-smokers, lower income, and comorbidities (hypertension, diabetes, asthma, ischaemic heart disease, heart failure, cerebrovascular disease, and chronic kidney disease) (p<0.01 for all variables).

PA levels
The median PA level was 414 METs·min/week (IQR, 87–728) for all study subjects (online supplemental table 1). The PA level was significantly lower in the COPD cohort (280 (IQR, 0–609) METs·min/week) than in the non-COPD cohort (414 (IQR, 87–728) METs·min/week) (p<0.001), showing a greater proportion of sedentary activity in the COPD cohort than in the non-COPD cohort (35.4% vs 24.1%, p<0.001).

All-cause ED visit or hospitalisation
Across the PA level, the all-cause ED visit or hospitalisation rate (/1000 PY) was significantly higher in the COPD cohort than in the control cohort (p<0.01 for all PA groups) (online supplemental table 2). A categorised PA model was used to assess the relative risk of overall ED visit or hospitalisation, according to the presence of COPD and PA level (table 2). Compared with the non-COPD group with PA≥1500 METs·min/week, the COPD group had a higher risk of all-cause ED visit and hospitalisation.
hospitalisation across all PA levels, with the highest risk in the sedentary group (adjusted HR (95% confidence interval, CI) = 1.70 (1.59 to 1.81)).

Figure 2 depicts the association between PA and the risk of all-cause ED visit or hospitalisation in the COPD and control cohorts when analysed using a non-parametric Cox model with a penalised spline. Regardless of the presence or absence of COPD, there was an inverse association between PA and all-cause ED visit or hospitalisation.

Similarly, the continuous PA model showed that a 500 METs-min/week increase in PA was associated with reduced all-cause ED visit or hospitalisation by 10% (aHR (95% CI) = 0.92 (0.88 to 0.96)) in the COPD cohort and 3% (aHR (95% CI) = 0.98 (0.97 to 0.98)) in the non-COPD cohort.

Table 1  Baseline characteristics of the study subjects

<table>
<thead>
<tr>
<th>Age group, years</th>
<th>Total (n = 296666)</th>
<th>COPD cohort (n = 3308)</th>
<th>Non-COPD cohort (n = 293358)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>40–49</td>
<td>166681 (56.2)</td>
<td>461 (13.9)</td>
<td>166220 (56.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>50–59</td>
<td>78709 (26.5)</td>
<td>674 (20.4)</td>
<td>78035 (26.6)</td>
<td></td>
</tr>
<tr>
<td>60–69</td>
<td>34800 (11.7)</td>
<td>951 (28.8)</td>
<td>33849 (11.5)</td>
<td></td>
</tr>
<tr>
<td>≥70</td>
<td>16476 (5.6)</td>
<td>1222 (36.9)</td>
<td>15254 (5.2)</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td>0.140</td>
</tr>
<tr>
<td>Male</td>
<td>147543 (49.7)</td>
<td>1603 (48.5)</td>
<td>145940 (49.8)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>149123 (50.3)</td>
<td>1705 (51.5)</td>
<td>147418 (50.3)</td>
<td></td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&lt;18.5</td>
<td>8170 (2.8)</td>
<td>234 (7.1)</td>
<td>7936 (2.7)</td>
<td></td>
</tr>
<tr>
<td>18–22.9</td>
<td>111090 (37.5)</td>
<td>1193 (36.1)</td>
<td>109897 (37.5)</td>
<td></td>
</tr>
<tr>
<td>23–24.9</td>
<td>73649 (24.3)</td>
<td>720 (21.8)</td>
<td>72929 (24.9)</td>
<td></td>
</tr>
<tr>
<td>≥25</td>
<td>103757 (35.0)</td>
<td>1161 (35.1)</td>
<td>102596 (35.0)</td>
<td></td>
</tr>
<tr>
<td>Waist circumference</td>
<td>81 (74–87)</td>
<td>82 (76–89)</td>
<td>81 (74–87)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Personal behaviour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking history</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Never</td>
<td>179798 (60.6)</td>
<td>2056 (62.2)</td>
<td>177742 (60.6)</td>
<td></td>
</tr>
<tr>
<td>Ex-smoker</td>
<td>44102 (14.9)</td>
<td>597 (18.1)</td>
<td>43505 (14.8)</td>
<td></td>
</tr>
<tr>
<td>Current smoker</td>
<td>72766 (24.5)</td>
<td>655 (19.8)</td>
<td>72111 (24.6)</td>
<td></td>
</tr>
<tr>
<td>Heavy drinker</td>
<td>25091 (8.5)</td>
<td>153 (4.6)</td>
<td>24938 (8.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Physical activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>129344 (43.6)</td>
<td>1079 (32.6)</td>
<td>128265 (43.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Vigorous</td>
<td>111154 (37.5)</td>
<td>838 (25.3)</td>
<td>110316 (37.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Low income</td>
<td>26871 (9.1)</td>
<td>495 (15.0)</td>
<td>26376 (9.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>56797 (19.2)</td>
<td>1630 (49.3)</td>
<td>55167 (18.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diabetes</td>
<td>27065 (9.1)</td>
<td>814 (24.6)</td>
<td>26251 (9.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Asthma</td>
<td>19735 (6.7)</td>
<td>2031 (61.4)</td>
<td>17704 (6.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ischaemic heart disease</td>
<td>9735 (3.3)</td>
<td>479 (14.5)</td>
<td>9256 (3.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Heart failure</td>
<td>1611 (0.5)</td>
<td>218 (6.6)</td>
<td>1393 (0.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>7702 (2.6)</td>
<td>316 (9.6)</td>
<td>7386 (2.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chronic kidney disease</td>
<td>16029 (5.4)</td>
<td>593 (17.9)</td>
<td>15436 (5.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Charlson Comorbidity Index score</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&lt;2</td>
<td>249410 (84.1)</td>
<td>1308 (39.5)</td>
<td>248102 (84.6)</td>
<td></td>
</tr>
<tr>
<td>≥2</td>
<td>47256 (15.9)</td>
<td>2000 (60.5)</td>
<td>45256 (15.4)</td>
<td></td>
</tr>
</tbody>
</table>

Data are presented as numbers (%). COPD, chronic obstructive pulmonary disease;
Respiratory ED visit or hospitalisation

Similar to the association between PA and all-cause ED visit or hospitalisation rate, the respiratory ED visit or hospitalisation rate (/1000 PY) was significantly greater in the COPD group than in the control group across all PA levels (p<0.01 for all PA groups) (online supplemental table 2). A categorised PA model was used to assess the relative risk of overall ED visit or hospitalisation, according to the presence of COPD and PA level (table 2). Compared with the non-COPD group with PA≥1500 METs-min/week, across all PA levels, the COPD group had a higher risk of all-cause ED visit and hospitalisation, showing the highest risk in the sedentary group (adjusted HR (95% CI) = 5.45 (4.86 to 6.12)).

Figure 3 depicts the association between PA and the risk of respiratory-related ED hospitalisation in the COPD and non-COPD cohorts using a non-parametric Cox model with a penalised spline. Regardless of the presence or absence of COPD, there was an inverse association between PA and respiratory-related hospitalisation.

Similarly, the continuous PA model showed that a 500 METs-min/week increase in PA was associated with reduced respiratory ED visit or hospitalisation by 14% (adjusted HR (95% CI) = 0.87 (0.82 to 0.93)) in the COPD cohort and 7% (adjusted HR (95% CI) = 0.94 (0.92 to 0.95)) in the control cohort.

Table 2  Adjusted HR for all-cause and respiratory-related ED visit or hospitalisation according to the presence of COPD and the level of physical activity relative to the physical activity of ≥1500 METs-min/week in the control group

<table>
<thead>
<tr>
<th>All-cause ED visit or hospitalisation adjusted HR* (95% CI)</th>
<th>Respiratory-related ED visit or hospitalisation adjusted HR* (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-COPD cohort</td>
<td>COPD cohort</td>
</tr>
<tr>
<td>≥1500 METs-min/week Reference</td>
<td>1.36 (1.15 to 1.61)</td>
</tr>
<tr>
<td>1000–1499 METs-min/week</td>
<td>0.96 (0.94 to 0.99)</td>
</tr>
<tr>
<td>500–999 METs-min/week</td>
<td>0.97 (0.95 to 0.99)</td>
</tr>
<tr>
<td>1–499 METs-min/week</td>
<td>0.98 (0.96 to 1.00)</td>
</tr>
<tr>
<td>Sedentary</td>
<td>1.07 (1.05 to 1.09)</td>
</tr>
</tbody>
</table>

Data are presented as a ratio (95% CI).

*Multivariate Cox proportional hazards regression models were used after adjusting for age, sex, BMI, smoking history, income level, alcohol consumption, and Charlson Comorbidity Index score.

BMI, Body Mass Index; CI, confidence interval; COPD, chronic obstructive pulmonary disease; ED, emergency department; METs, metabolic equivalents.
DISCUSSION

This study evaluated the effects of PA on the risk of all-cause and respiratory ED visit or hospitalisation in patients with COPD compared with those without COPD. Compared with the presumed healthiest cohort, the control group with PA >1500 METs-min/week, a reduction in PA resulted in a higher risk of an all-cause ED visit or hospitalisation in subjects with COPD, which was more substantial for respiratory ED visit or hospitalisation. Enhancing PA by 500 METs-min/week reduced all-cause and respiratory ED visit or hospitalisation by 10% and 14%, respectively, in subjects with COPD.

Several studies have shown similar results to those of our study on the benefits of regular PA in patients with COPD. In a cohort study of patients with moderate to severe COPD, hospitalisation rates were lower in patients with COPD who reported PA equivalent to walking for at least 1 hour per day than in patients with COPD who reported PA equivalent to walking for 20 min or less per day.\(^3\) Additionally, a recent 20-year follow-up study of 2386 subjects with COPD demonstrated a 30%–40% reduction in the risk of hospitalisation and respiratory mortality due to COPD when the level of PA equivalent to walking or cycling was 2 hour or more per week.\(^7\) Although regular PA is considered important because of its potentially significant beneficial effects and associated implications for lowering health costs, none of the studies quantified PA level when assessing the association between PA and COPD outcomes. Thus, our study has the strength of showing that by quantifying PA, higher levels of regular PA may be associated with improvement in the outcomes of COPD in Korea.

While METs are a valuable measure for large-scale population studies, they can provide more dimensional insight when used in conjunction with other measures such as accelerometers. For example, the combination of MET and accelerometer data more accurately represented energy expenditure in COPD patients than either measure alone.\(^3\) Another study also showed that METs combined with accelerometer data can provide a comprehensive view of PA levels, especially in clinical settings where the accuracy of monitoring and tailored interventions are important.\(^3\) This may improve the accuracy of PA assessment and better inform patient management intervention strategies when these indicators are combined in the context of COPD management.

Although the mechanisms underlying the potentially beneficial effects of regular PA in COPD, such as reduced ED visit or hospitalisation rates, are unknown, improved exercise tolerance and anti-inflammatory effects by enhanced PA level might be biologically plausible explanations; PA improves peripheral muscle function, which is associated with improved exercise tolerance.\(^3\) Increased exercise tolerance is associated with a reduced risk of hospitalisation for patients with COPD\(^3\) and reduces COPD exacerbation and mortality in patients with COPD.\(^4\) Besides studies showed that regular PA has anti-inflammatory and antioxidant effects in patients with COPD and healthy subjects.\(^4\) These exercise-induced anti-inflammatory and antioxidant effects are believed to protect patients with COPD from infections and reduce exacerbations, thereby reducing ED visit and hospitalisation.

Figure 3  A non-parametric Cox model with a penalised spline was used to assess the association between changes in physical activity and the risk of respiratory-related ED or hospitalisation stratified by the presence of COPD. aHR, adjusted HR; CI, confidence interval; COPD, chronic obstructive pulmonary disease; ED, emergency department; METs, metabolic equivalents.
Our study has several clinical implications. First, our findings may help clinicians stratify patients with COPD based on their PA level. Because self-reported PA is associated with ED visit and hospitalisation, this information may help identify patients at high risk for adverse events who may benefit from closer monitoring and targeted interventions. Second, our study also indicates that not only physicians, but also patients themselves, family members, and communities should pay more attention to PA in COPD patients. Assessing PA levels and concomitant PA modification may provide benefits in improving clinical outcomes in patients with COPD. Third, given the scarcity of PA intervention studies in Korea, our study results would be useful in promoting broad-scale intervention studies to support PA in Korea.

Although our study has the advantage of exploring the association between PA levels and COPD outcomes using a large population-based longitudinal study, this study has some limitations. First, we evaluated PA level using questionnaires, and the potential recall bias was a major limitation. Second, the questionnaires focused on aerobic PA, and we were not able to consider the effects of non-aerobic exercises. Third, despite statistical adjustments to address potential confounding factors, including personal habits, such as smoking and alcohol consumption, some additional confounding factors may not have been addressed. For example, subjects with higher PA levels may have better pulmonary function and a favourable lifestyle (eg, a healthy diet). Unfortunately, NHIS-NSC data do not include information on these factors. Fourth, contrary to the well-known findings that the prevalence of COPD is more common in males than in females in Korea, more females were included in the COPD group. This phenomenon was caused by excluding COPD subjects with any malignancy histories, of whom about 70% were males. However, excluding subjects with malignancy was necessary since the presence of malignancy can affect our primary outcomes. Finally, our major findings, a potential 10%-14% reduction in ED visit and hospitalisation by enhancing PA among COPD patients have not been empirically verified, needing well-designed prospective studies to confirm our findings.

In conclusion, this retrospective observational study revealed that compared with the presumed healthiest cohort, the control group with PA >1500 METs-min/week, the COPD group has a higher risk of ED visit or hospitalisation, with the highest risk in the sedentary group. Increasing PA would be important for improving long-term outcomes in patients with COPD in Korea. Confirmative future prospective studies are needed on whether assessing and modifying PA levels could reduce ED visit or hospitalisation in COPD.

REFERENCES
### Supplemental Table 1. Level of physical activity in the COPD and control cohorts

<table>
<thead>
<tr>
<th>Physical activity, METs-min/week</th>
<th>Total (n = 400,013)</th>
<th>COPD cohort (n = 1,912)</th>
<th>Non-COPD cohort (n = 398,101)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median (IQR)</td>
<td>414 (87–728)</td>
<td>280 (0–609)</td>
<td>414 (87–728)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>≥ 1,500</td>
<td>15,293 (5.2)</td>
<td>162 (4.9)</td>
<td>15,131 (5.2)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>1,000–1,500</td>
<td>31,532 (10.6)</td>
<td>270 (8.2)</td>
<td>31,262 (10.7)</td>
<td></td>
</tr>
<tr>
<td>500–999</td>
<td>82,790 (27.9)</td>
<td>799 (24.2)</td>
<td>81,991 (28.0)</td>
<td></td>
</tr>
<tr>
<td>1–499</td>
<td>95,157 (32.1)</td>
<td>905 (27.4)</td>
<td>94,252 (32.1)</td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71,894 (24.2)</td>
<td>1,172 (35.4)</td>
<td>70,722 (24.1)</td>
<td></td>
</tr>
</tbody>
</table>

2 Data are presented as medians (IQRs) or numbers (%).

3 METs, metabolic equivalents; IQR, interquartile range.
**Supplemental Table 2.** Incidence rates of overall and respiratory ED visit or hospitalization according to the presence of COPD and the level of physical activity

<table>
<thead>
<tr>
<th>Level of Physical Activity</th>
<th>All-cause ED visit or hospitalization</th>
<th>Respiratory-related ED visit or hospitalization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incidence rate (95% CI) (/1,000 person-years)</td>
<td>Incidence rate (95% CI) (/1,000 person-years)</td>
</tr>
<tr>
<td></td>
<td>Non-COPD cohort</td>
<td>COPD cohort</td>
</tr>
<tr>
<td>1–499 METs-min/week</td>
<td>42,146 (41,787–42,508)</td>
<td>95,402 (88,700–102,477)</td>
</tr>
<tr>
<td>500–999 METs-min/week</td>
<td>42,291 (41,905–42,680)</td>
<td>89,396 (82,720–96,467)</td>
</tr>
<tr>
<td>1,000–1,499 METs-min/week</td>
<td>42,136 (41,517–42,763)</td>
<td>74,357 (64,640–85,123)</td>
</tr>
<tr>
<td>≥1,500 METs-min/week</td>
<td>45,638 (44,704–46,585)</td>
<td>88,077 (74,044–103,995)</td>
</tr>
</tbody>
</table>

Data are presented as number (95% CI).
CI, confidence interval; METs, metabolic equivalents.