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► To cite this version:

Simon Jan, Marie-Astrid Metten, Anthony Chapron, Solenne Marette, Ange-Marie Robert, et al.. Use of the COPD Assessment Test (CAT) to screen for COPD in dairy farmers: AIRBAG study. *Clinical Respiratory Journal*, 2020, 14 (9), pp.813-821. 10.1111/crj.13201 . hal-02635151

HAL Id: hal-02635151

<https://univ-rennes.hal.science/hal-02635151v1>

Submitted on 28 May 2020

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Use of the COPD Assessment Test (CAT) to screen for COPD in dairy farmers: AIRBAG study

Simon Jan¹, Marie-Astrid Metten^{1,2}, Anthony Chapron^{3,4}, Solenne Marette⁵, Ange-Marie Robert⁶, Stéphanie Guillot⁷, Carole Mailloux⁸, Stéphane Jouneau^{2,9,†}, Jean-François Viel^{1,2,†,*}, on behalf of the AIRBAG research group‡

¹ Department of Epidemiology and Public Health, University Hospital, F-35033 Rennes, France

² Univ Rennes, CHU Rennes, Inserm, EHESP, Irset (Institut de recherche en santé, environnement et travail) - UMR_S 1085, F-35000 Rennes, France

³ Department of General Practice, Rennes 1 University, F-35000 Rennes, France

⁴ INSERM, CIC-1414, Primary Care Research Team, F-35000 Rennes, France

⁵ Department of Occupational Pathology, University Hospital, F-35033 Rennes, France

⁶ Department of Clinical Research, University Hospital, F-35033 Rennes, France

⁷ Department of Pulmonary Function Tests, University Hospital, F-35033 Rennes, France

⁸ Mutualité Sociale Agricole des Portes de Bretagne, F-35170 Bruz, France

⁹ Department of Respiratory Medicine, University Hospital, F-35033 Rennes, France

† Equally contributed

‡ AIRBAG research group: Jean Barakat, Anne-Laure Barel, Henri-Pierre Baron, Rachel Bassen, Florence Behaghel-Baruteau, Cyril Bernier, Séverine Beyer, Romain Boissel, Vanessa Brault, Graziella Brinchault, Dominique Bureau, Odile Castel, Anne-France Cazuguel, Anthony Chapron, Catherine Decelle-Trochet, Benoît Desrues, Marcel Delaunay, Isabelle Delaunay-Lelièvre, Bruno Eveno, Krisztina Fekete, Lisa Fourmont, Thomas Gouyet, Amandine Guervin, Stéphanie Guillot, Tiphaine Guy, Guillaume Héry, Pauline Hardouin, Anne Hespel, Nathalie Jeffray, Stéphane Jouneau, Yves Koskas, Virginie de Lauzun, Antoine Lebossé, Sandrine Lecot, Carole Mailloux, Solenne Marette, David Marquette, Virginie Martin, Ahmed Merzoug, Hugues Morel, Jean Morer, Patrick Morisseau, Aurélie Oksenhendler, Elisabeth Orhant, Dominique Peron, Mauricette Piguel-Royer, Marie Pinault, Jean-Paul Pousset, Jean-Claude Presle, Patrick Raillard, Bernard Regnault, Ange-Marie Robert, Antoine Séguineau, Anne Sevin, Fanny Thépault, Christian Verger, Jean-François Viel.

* Corresponding author: Department of Epidemiology and Public Health, University Hospital, 2 rue Henri Le Guilloux, 35033 Rennes Cedex 9, France.

e-mail: jean-francois.viel@univ-rennes1.fr; telephone number: +33 299 289 827

Running title: Screening for COPD in dairy farmers

AUTHOR CONTRIBUTIONS

conceived and designed the study: Jouneau, Viel

participated in the acquisition of data: Jouneau, Marette, Robert, Guillot, Mailloux

analysed the data: Jan, Metten, Viel

interpreted the results: Jan, Metten, Jouneau, Viel

drafted the article: Jan, Metten, Viel

revised the article critically for important intellectual content: Jouneau

All authors read and approved the version to be submitted.

CONFLICTS OF INTERESTS

The authors report no conflicts of interest.

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2 PROF. STÉPHANE JOUNEAU (Orcid ID : 0000-0002-1949-3461)

3 PROF. JEAN-FRANCOIS VIEL (Orcid ID : 0000-0002-6716-7468)

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6 Article type : Original Article

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8

9 **Abstract**

10 **Objectives:** People at risk of chronic obstructive pulmonary disease (COPD) can benefit from
11 appropriate medical management before severe symptoms appear. This study assesses the value of the
12 COPD Assessment Test (CAT) questionnaire for screening dairy farmers, who tend to be slow or
13 reluctant to seek health care.

14 **Methods:** During the time period 2012-2017, 2089 randomly selected dairy farmers in Brittany
15 (France) were invited to complete self-administered questionnaires (including the CAT) and to
16 undergo an occupational health check-up using an electronic mini-spirometer and conventional
17 spirometry. Those showing symptoms suggestive of COPD and/or a ratio $FEV_1/FEV_6 < 80\%$ were
18 sent to a pulmonologist for further check-up, including spirometry with a reversibility test.
19 Multivariate logistic models based on CAT scores and socio-demographic or work-related factors
20 were developed to predict COPD.

21 **Results:** The 1231 farmers who underwent the occupational health check-up included 1203 who met
22 the inclusion/exclusion criteria. Pulmonologist identified 16 (1.3%) cases of COPD. A multivariate
23 logistic regression model (covariates: CAT sum score, on-farm time, BMI, smoking status, free-stall
24 mulching) provided an area under the receiver-operating characteristic curve (AUC) of 0.87 (95% CI:
25 0.75-0.98). Using a cut-off of 0.007 gave a sensitivity of 93.8%, and a specificity of 62.4%. Another
26 model that included CAT breathlessness and the same covariates performed marginally better (AUC =
27 0.88, 95% CI: 0.77-0.98).

28 **Conclusion:** Our predictive models can both benefit dairy farmers by providing early diagnosis and
29 management of their COPD and avoid unnecessary, costly spirometry during screening process.

30

31 **KEYWORDS**

32 Chronic obstructive pulmonary disease; CAT questionnaire; screening; dairy farmers

34 1. INTRODUCTION

35

36 Chronic obstructive pulmonary disease (COPD) is a major public health concern that could become
37 the fourth leading cause of death world-wide by 2030.¹ The onset of symptoms is insidious so that
38 COPD is frequently under-diagnosed and, when diagnosed, this is often late with severe respiratory
39 disorders.² Overwhelming interest in smoking as the major risk factor has overshadowed the
40 importance of non-smoking causes,³ such as occupational exposure (including farming activities).⁴⁻⁶

41 Although spirometry is the reference test for diagnosing COPD, it is not a cost-effective way to
42 screen the general population.⁷ A promising alternative is low-cost electronic mini-spirometry (EMS)
43 measuring the FEV₁/FEV₆ ratio but its diagnostic performance depends very much on how well
44 practitioners are trained.⁸ Previous studies have suggested using self-administered questionnaires to
45 screen for COPD.⁹⁻¹¹ The COPD Assessment Test (CAT) was initially developed and validated for
46 routinely assessing and monitoring COPD patients.¹²⁻¹³ It was later used to help screen for COPD in
47 both smokers,¹⁴⁻¹⁵ and the general population.¹⁶⁻¹⁷ Subjects who the CAT questionnaire indicated were
48 at risk then underwent diagnostic spirometry and appropriate medical management, if necessary,
49 before any severe symptoms developed. However, the CAT questionnaire has not yet been used to
50 screen farmers for COPD, who are often slow or reluctant to seek health care.

51 We therefore assessed the value of the CAT questionnaire for screening a large population of dairy
52 farmers for COPD and for developing a predictive model that combines CAT scores with other COPD
53 predictors.

54

55 2. MATERIALS AND METHODS

56

57 2.1 Study population

58

59 The AIRBAg cross-sectional study was conducted between March 2012 and February 2017 in the
60 French region of Brittany to determine the prevalence and to identify the risk factors of COPD in
61 dairy farmers.¹⁸ It was carried out on 2089 dairy farmers randomly selected from the 3831 registered
62 in the "Mutualité Sociale Agricole" (MSA, French Health Insurance for farmers) regional database.
63 The inclusion criteria were: dairy farming for more than ten years and agreeing to participate in the
64 study. The exclusion criteria were: pig, poultry or agricultural farming as the main activity, having a
65 legal guardian, having had a respiratory infection in the two months immediately preceding sampling,
66 having been treated with oral corticosteroids or immunosuppressive drugs, having been pregnant or
67 not having had any dairy activity for more than five years (e.g. retired).

68

69 2.2 Data collection

70

71 Each randomly selected dairy farmer was invited to complete a standardized self-administered
72 questionnaire and to undergo a health check-up with his/her local MSA occupational physician.
73 During this check-up, the questionnaire was reviewed and a clinical examination, followed by an
74 EMS and conventional spirometry, was performed. The first part of the questionnaire contained items
75 pertaining to health outcomes including: chronic cough (cough > 2 months), chronic bronchitis (cough
76 and sputum > 3 months/year for over two consecutive years) and wheezing when handling hay or
77 during any other activity. The second part of the questionnaire collected farm and occupational
78 characteristics such as farm size, numbers of cattle and milking cows, crops grown and daily activities
79 (milking, production and distribution of feed concentrate, free stall mulching, etc.). CAT and the
80 modified Medical Research Council (mMRC) scores were also assessed during this check-up. The
81 CAT questionnaire consists of 8 items (cough, phlegm, chest tightness, breathlessness, activity
82 limitation, confidence leaving home, sleep, energy) with scores of 0–5 for the severity of each item.
83 These were then summed to give an overall score ranging from 0 (excellent perceived health) to 40
84 (worst case).

85

86 2.3 Respiratory tests performed by occupational physicians

87

88 The occupational physicians had been trained to use the EMS (Neo-6[®], model 4000, Vitalograph,
89 Ennis, Ireland) and the spirometer (SpiroWin[®], FIM medical, Spl10 USB S/N:01824, Villeurbanne,
90 France), which was followed by annual updating. Spirometry testing (without bronchodilator
91 challenge) was performed in accordance with standard American Thoracic Society/European
92 Respiratory Society protocol.¹⁹ A minimum of three blows that met test quality criteria (including an
93 expiration maintained for more than 6 s) were performed by each participant. Spirometry results were
94 reviewed by two pulmonologists from Rennes University Hospital.

95

96 2.4 Definition of COPD and absence of bronchial obstruction

97

98 Those subjects whose health check-up revealed at least one evocative symptom (chronic cough,
99 chronic bronchitis, wheezing, dyspnea [mMRC \geq 1]) and/or a ratio $FEV_1/FEV_6 < 80\%$ with the EMS
100 were considered to be "at-risk of bronchial obstruction". A higher cut-off was chosen for FEV_1/FEV_6
101 because mild forms of limited airflow can be missed using a 70% cut-off.²⁰ "At-risk" farmers were
102 referred to the nearest pulmonologist for further examination, including spirometry with a reversibility
103 test. COPD was diagnosed if the post-bronchodilator $FEV_1/$ forced vital capacity (FVC) ratio was
104 $< 70\%$ (GOLD criterion).²¹ The control population was farmers not "at-risk" and those "at-risk" at
105 screening who were subsequently not found to be suffering from a chronic obstructive disease and

106 were assumed to be free of bronchial obstruction. Any control subject diagnosed with asthma was
107 excluded from the current study. Asthma was ascertained after a thorough medical record review by
108 the same trained pulmonologist by means of history of allergic disposition, episodes of paroxysmal
109 wheezing, asthma medication use, spirometry, and/or methacholine challenge test.

110

111 **2.5 Statistical analyses**

112

113 A logistic regression model containing only the CAT sum score as predictor was first prepared
114 (univariate model). Other independent COPD predictors were then selected according to a two-step
115 strategy: i) the candidate covariates collected during the occupational health check-up (questionnaire,
116 mMRC) were selected at $p < 0.20$ on the basis of relevant univariate tests, ii) a bootstrap method was
117 then used to identify the best subset of independent predictors of COPD. This was done by repeated
118 sampling with replacement from the original entire dataset, followed by stepwise logistic regression
119 based on Akaike's Information Criterion in each of 1000 subsamples. The decision rule for selecting
120 the predictors included in the final model is based on the frequency at which they appeared in the
121 multiple bootstrap models ($> 60\%$ in our study, as recommended²²). Continuous variables were not
122 transformed if they were found to be linear. Subjects were divided into two groups according to their
123 body mass index (BMI): above or below 21 kg/m^2 , as in the BODE mortality index.²³⁻²⁴ The
124 diagnostic performance of the univariate and multivariate models was assessed by measuring the area
125 under the receiver operating characteristic curve (AUC). However, a predictive model may be too
126 optimistic if it is tested on the same dataset as that used to develop it. We used a 1000-fold bootstrap
127 resampling including the previously selected predictors to obtain optimism-corrected AUCs. An
128 optimal cut-off point was determined to obtain the best sensitivity by minimizing the number of false
129 negatives.

130 The second step involved building a decision tree with the predictors from the previous
131 multivariate model using the Classification And Regression Tree (CART) method.²⁵ Briefly, CART
132 uses successive iterations to divide the study sample into smaller binary subgroups. Each step
133 investigates all possible splits among the variables to create two subgroups. The variable with the
134 optimal threshold leading to the most homogeneous partitioning with respect to the dependent
135 variable (COPD in the current study) is selected. The same variable can be chosen several times,
136 based on different thresholds because all predictors are considered at each step. Decision trees are
137 sensitive to the imbalance in the numbers of events and non-events. A weighting of misclassified
138 subjects (false positives and negatives) was thus used to improve sensitivity. False negatives and false
139 positives were each weighted by the inverse of the frequencies of events and non-events in the
140 sample.

141 The predictive model and CART analyses were first prepared with the CAT sum score and then
142 with each of the CAT items most strongly linked to COPD ($P < 0.05$). All statistical analyses were

143 performed with R software, version 3.5.0 (R Foundation for Statistical Computing, Vienna, Austria,
144 URL <https://www.R-project.org/>).

145

146 **3. RESULTS**

147

148 **3.1 Population**

149

150 The 1231 farmers who underwent the occupational health check-up included 28 who met an exclusion
151 criterion (poultry farmer (5); pig farmer (5); arable farmer (1); recent treatment with antibiotics or
152 corticosteroids (7); immunosuppressive treatment (4); no signed consent (1); incomplete questionnaire
153 (5)), leaving 1203 for analyses (Figure 1). The occupational health check-up showed that 525 farmers
154 were "at-risk of bronchial obstruction", of these 432 were seen by the pulmonologist. The 93 farmers
155 who did not go to the pulmonologist included a greater proportion of smokers (23.7%), a lower
156 FEV₁/FVC ratio (0.76) and had spent more time on-farm (47.4 years) than the 432 who were seen by
157 the pulmonologist (13.7%, $P = 0.01$; 0.78, $P < 0.01$; 44.3 years, $P < 0.01$).

158 Pulmonologist identified 16 cases of COPD (1.3%), eight of whom (50%) were non-smokers.
159 None of these subjects were known to be ill prior to the study. The mean standard spirometry test data
160 were: FEV₁/FVC ratio = 0.66 (± 0.09), FEV₁ = 2.52 (± 1.02) L and 83.6 (± 2.9) % of predicted values.
161 The distribution of the disease severity according to GOLD classification was: GOLD I = 11 subjects,
162 GOLD II = 4, GOLD III = 1.

163 The final bronchial obstruction-free group consisted of 996 (673+323) farmers: 107 were excluded
164 because they were asthmatic (9+93 in the "at-risk" group and 5 in the not "at-risk" group) (Figure 1).
165 None of the 107 asthma cases had obstruction on spirometry.

166 The farmers with COPD were significantly older (54.6 years), had spent more time on-farm (51.4
167 years) and in dairying (33.8 years, and more were current smokers (37.5%) than the controls (50.8
168 years, $P = 0.02$; 44.3 years, $P < 0.01$; 27.8 years, $P = 0.01$; 10.2%, $P = 0.02$) (Table 1). The COPD
169 farmers had a higher CAT sum score (9.6 \pm 6.2) than the controls (6.2 \pm 4.5) and higher scores for the
170 four main items (cough, phlegm, chest tightness, breathlessness) (Table 2).

171

172 **3.2 COPD predictive models**

173

174 The univariate logistic regression model constructed with the CAT sum score provided an AUC of
175 0.68 (95% confidence interval [CI]: 0.53-0.83). The independent predictors of COPD introduced into
176 the multivariate model were: time spent on-farm (continuous variable, in years), BMI (\leq or $>$ 21
177 kg/m²), smoking status (non-smoker, former smoker, current smoker), free-stall mulching (yes/no).
178 The corresponding risk estimates are shown in Table 3. The AUC of this multivariate model was 0.87

179 (95% CI: 0.75-0.98). Bootstrap resampling optimised the AUC to 0.83. Using a cut-off of 0.007 gave
180 a sensitivity of 93.8%, and a specificity of 62.4%. The ROC curves of the univariate and multivariate
181 predictive models are shown in Figure 2. One COPD farmer was misclassified with the multivariate
182 model: his CAT sum score was 3, he was a non-smoking 44-year-old farmer, had spent 33 years on-
183 farm, had a BMI of 23.9 kg/m² and reported performing free-stall mulching.

184 The predictive performances of the models including each of the four CAT items most strongly
185 associated with COPD (cough, phlegm, chest tightness, breathlessness) are shown in Table 4.
186 Independent COPD predictors were the same as those identified for the CAT sum score model
187 whatever the single CAT item model. The only multivariate regression model which performed
188 marginally better than the CAT sum score model involved breathlessness (AUC = 0.88 (95% CI:
189 0.77-0.98), cAUC = 0.84, sensitivity = 93.8% and specificity = 76.1%, for a cut-off of 0.013).

190

191 **3.3 Decision trees**

192

193 The root node of the decision tree constructed with the CAT sum score was the CAT sum score itself
194 with a cut-off value of 11 (Figure 3). Two COPD cases were misclassified traversing the tree (CAT
195 sum score < 11, BMI > 21 kg/m² and time spent on-farm < 57 years, sensitivity = 87.5% (14/16)). The
196 CART model relying on breathlessness was simpler (3 splits instead of 5 splits) and misclassified only
197 one case (sensitivity = 93.8% (1/16)) (Figure 4). The three main splits in the “breathlessness” model
198 were current smoker: yes / no; years spent on-farm: < 60 / ≥ 60; breathlessness: <2 / ≥ 2).

199

200

201 **4. DISCUSSION**

202

203 Our model that combines the CAT sum score and four independent predictors (time spent on-farm,
204 BMI, smoking status, free-stall mulching) is a highly sensitive and reasonably specific tool for
205 screening dairy farmers for COPD.

206 The main strength of the AIRBAg study is its robust methodology based on a large randomly-
207 selected sample of dairy farmers. The comprehensive questionnaire completed during the
208 occupational health visit contained many variables, some specific to dairy farming, which make it
209 possible to test many potential predictors of COPD. COPD was diagnosed using a spirometry
210 reference test rather than the mini-spirometry employed in most similar studies.¹⁴⁻¹⁵ No COPD-asthma
211 overlap was to be feared because asthma cases had no evidence of obstructive spirometry. Finally, we
212 used a sound statistical methodology based on bootstrap resampling to select the best subset of
213 independent covariates and to adjust for overfitting.

214 But this study has some limitations. First, over one-fifth (21.6%; 451/2089) of the farmers refused
215 to undergo the occupational health check-up and 17.7% (93/525) of those who were "at risk of
216 bronchial obstruction" did not visit the pulmonologist. Cases of COPD may thus have been missed. In
217 addition, the 93 subjects who did not visit the pulmonologist included a greater proportion of smokers
218 (23.7%) than the 432 who did (13.7%). Finally, the relatively few cases (16) may not have provided
219 the statistical power needed to identify other predictive factors of COPD. However, this study also
220 identified the basic predictors highlighted in other similar studies (age and smoking). As the number
221 of subjects was too small for the sample to be divided into learning and validation datasets we used an
222 internal bootstrap validation rather than a cross validation approach.

223 Early detection of COPD is essential because cases of even mild COPD are at increased risk of
224 death.²⁶ While the diagnostic performance of EMS, developed as a screening solution, is good in a
225 primary care setting, its use requires physician training for it to be reliable.⁸ In contrast, the CAT
226 questionnaire can be completed by the subject him/her self before the medical examination. Various
227 questionnaires that screen for COPD in the general population have been developed,⁹⁻¹¹ but the
228 advantage of the CAT questionnaire is its dual screening and monitoring function, which enables
229 patients to be followed-up.

230 Previous studies on other populations have assessed the performance of the CAT questionnaire for
231 COPD screening. A Japanese study on 3062 smokers over 40 years old who consulted for repeated
232 respiratory infections or to monitor their cardiovascular disease found that the CAT sum score was
233 significantly higher in those with airflow limitation.¹⁴ A study in Turkey of 648 smokers over 40 years
234 old who went to a university hospital for a check-up or visit found that the variables associated with
235 COPD were age, smoking (number of pack-years) and the CAT sum score.¹⁵ The first four CAT items
236 were also significantly associated with COPD. The AUC obtained with the CAT sum score alone was
237 similar to that reported here (0.61). A Canadian population-based study of 532 subjects over 40
238 confirmed the value of the CAT scores for defining "at-risk" subjects.¹⁶ The CAT sum score
239 performed well and the breathlessness score performed even better (although not as well as in the
240 present study). The AUC with the predictive model including breathlessness, age and smoking status
241 was 0.77; sensitivity was 77.6% and specificity was 64.9% with a cut-off of 0.096.

242 The present model contains five variables, making it slightly more complex than the three-variable
243 one constructed by Raghavan *et al.*¹⁶ However, the predictive performance of our model for dairy
244 farmers is better (cAUC = 0.83, sensitivity = 93.8%, specificity = 62.4%), with only one subject
245 misclassified. Logically, it includes the smoking status of the subjects, an influential risk factor.
246 Consistent with many previous studies,²⁷⁻³² we found a negative association between BMI and COPD
247 (while adjusting for other confounding factors). However, the observed relationship may not be causal
248 as COPD prevalence (and not incidence) was recorded in this cross-sectional study.

249 Age was not included in the multivariate selection, but the on-farm time was, suggesting that
250 agricultural exposure plays a role in COPD occurrence. Many farming tasks, such as handling hay

251 (during feeding), straw and animal feed, expose farmers to airborne contaminants and dust.³³⁻³⁴ This
252 exposure could trigger inflammatory reactions leading to the development of COPD. Finally, and
253 somewhat paradoxically, the absence of free stall mulching was predictive of COPD. Further analyses
254 showed that farmers who did not do this mulching generally performed fewer other agricultural
255 activities (results not shown). This negative association could then be also explained by a reverse
256 causal effect, as the disease at its preclinical phase may limit or hinder the execution of burdensome
257 tasks. Finally, in-depth item analyses highlighted how "breathlessness" improved the screening for
258 COPD in dairy farmers (as evidenced by a marginally increased AUC, due to a better specificity), in
259 agreement with the growing evidence showing that even subjects in the early stages of COPD
260 experience dyspnea with exertion.³⁵⁻³⁸

261 A CART analysis provides simple decision rules that are easy for physicians to use. The
262 "breathlessness" based decision tree has the double advantage of being simpler and more sensitive
263 than the "CAT sum score" tree. However, it would avoid less diagnostic spirometries (those non-
264 performed in farmers predicted not at risk of COPD) than the "CAT sum score" tree, as assessed by
265 the denominators of solid line ovals in Figures 3 and 4 (589 and $697+42+43=782$, respectively).

266 In conclusion, the predictive performance of a model that includes the CAT sum score (or even
267 only the breathlessness score), obtained from an easy-to-use questionnaire in current practice, plus
268 four other predictors that are also readily collected during an interview (smoking status, on-farm time,
269 type of farming activity) or an elementary clinical examination (BMI) was good when used to assess a
270 population of dairy farmers. We therefore believe that this combination provides a simple, low-cost
271 on-site tool for screening them for COPD. It would both benefit farmers by providing early diagnosis
272 and management of their disease and avoid unnecessary, costly spirometry.

273

ACKNOWLEDGEMENTS

We are indebted to all the dairy farmers who took part in the screening test and completed the respiratory investigation. We thank Dr Owen Parkes for editing the manuscript.

FUNDING

The AIRBag study was supported by Rennes University Hospital (COREC 2011 funding), the "Association pour les insuffisants respiratoires de Bretagne" (AIRB), the French Ministry of Labour (DIRECCTE), and Novartis Pharma (France). The sponsors played no role in the design, collection, analysis or interpretation of the data, in writing the manuscript or in the decision to submit the manuscript for publication.

ETHICS

The AIRBAG study was approved by the Rennes Ouest V Ethics Committee (11/28–817) and was registered on ClinicalTrials.gov (NCT03654469). Written informed consent was provided by all participants.

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TABLE 1 Characteristics of farmers with COPD and farmers free of bronchial obstruction

	COPD (n=16)		Bronchial obstruction free (n=996)	
Qualitative variable	n	%	n	%
Quantitative variable	m	± SD	m	± SD
Age (years)	54.6	± 7.7	50.8	± 6.5
On-farm time (years)	51.4	± 10.3	44.3	± 11.7
Gender				
Male	10	62.5	717	72.0
Female	6	37.5	279	28.0
BMI (kg/m²)				
≤ 21	5	31.3	71	7.1
> 21	11	68.7	925	92.9
Smoking status				
Never	8	50.0	701	70.4
Former	2	12.5	193	19.4
Current	6	37.5	102	10.2
Farm characteristics				
Area (Ha)	83.5	± 47.7	82.7	± 42.9
Dairy farming activities (years)	33.8	± 9.6	27.8	± 9.1
Milking cows (number)	49.8	± 24.6	51.7	± 23.7

TABLE 2 COPD assessment test (CAT) scores in dairy farmers with COPD and bronchial obstruction-free controls (Brittany, France, 2012-2017)

	COPD (n=16)	Bronchial obstruction free (n=996)	<i>P</i> value
	m ± SD	m ± SD	
Item 1: Cough	1.8 ± 0.8	1.2 ± 0.9	0.02
Item 2: Phlegm	1.4 ± 1.2	0.7 ± 0.9	< 0.01
Item 3: Chest tightness	1.0 ± 1.1	0.5 ± 0.7	0.02
Item 4: Breathlessness	1.8 ± 1.3	1.1 ± 1.0	0.03
Item 5: Activity limitation	0.8 ± 0.9	0.5 ± 0.8	0.29
Item 6: Confidence leaving home	0.4 ± 0.8	0.2 ± 0.6	0.22
Item 7: Sleep	0.8 ± 1.2	0.7 ± 0.9	0.51
Item 8: Energy	1.6 ± 1.2	1.2 ± 1.0	0.14
Sum score	9.6 ± 6.2	6.2 ± 4.5	< 0.01

Abbreviations: COPD: chronic obstructive pulmonary disease; m: mean; SD: standard deviation.

TABLE 3 Odds ratio estimates for COPD in dairy farmers (n=993, multivariate model, Brittany, France, 2012-2017)

	Odds ratio	95% CI	<i>P</i> value
CAT sum score (unitless)	1.12	1.02 - 1.21	0.02
On-farm time (years)	1.11	1.05 - 1.19	< 0.001
BMI \leq 21 kg/m ²	12.93	3.43 - 46.51	< 0.001
Smoking status			< 0.01
never	1.00	-	-
former	1.36	0.19 - 6.15	
current	12.12	3.35 - 45.26	
No free-stall mulching activity	3.35	1.01 - 10.50	0.05

Abbreviations: BMI: body mass index; CAT: COPD assessment test; CI, confidence interval; COPD: chronic obstructive pulmonary disease.

TABLE 4 Predictive performance of multivariate models including either the CAT sum score or one of four CAT items (dairy farmers, Brittany, France, 2012-2017)

	AUC (95% CI)	cAUC	Sensitivity	Specificity	Cut-off
CAT sum score	0.87 (0.75-0.98)	0.83	93.8%	62.4%	0.007
Item 1: Cough	0.86 (0.75-0.97)	0.82	93.8%	63.4%	0.008
Item 2: Phlegm	0.86 (0.74-0.97)	0.82	93.8%	70.9%	0.011
Item 3: Chest tightness	0.86 (0.75-0.98)	0.82	93.8%	74.3%	0.012
Item 4: Breathlessness	0.88 (0.77-0.98)	0.84	93.8%	76.1%	0.013

Abbreviations: CAT: chronic obstructive pulmonary disease assessment test; AUC: area under the receiver operating characteristic curve; cAUC: corrected AUC; CI: Confidence Interval.

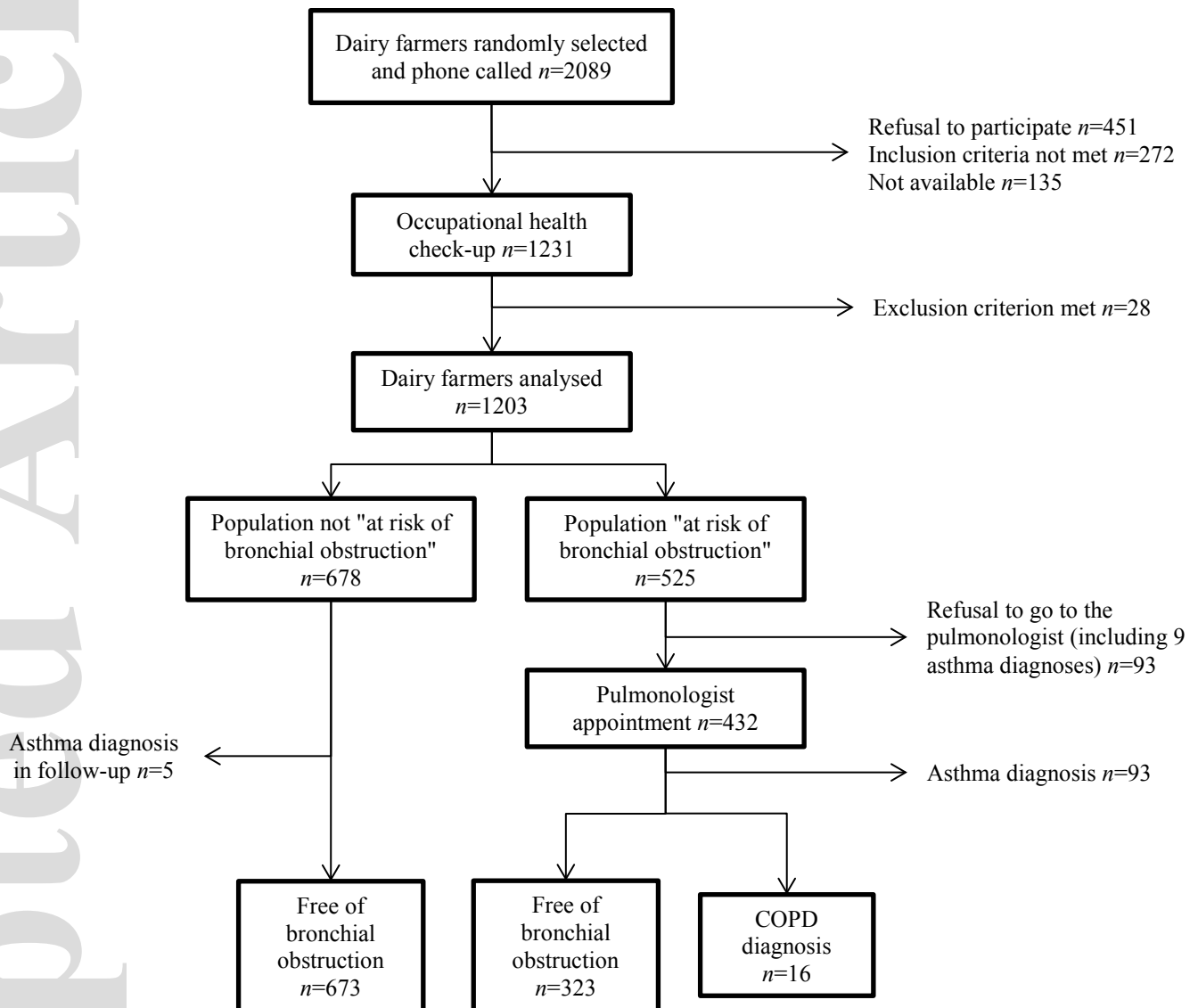
FIGURE 1 AIRBAg study flow chart (Brittany, France, 2012-2017)

FIGURE 2 Receiver operating characteristic curves of predictive models for COPD (dairy farmers, Brittany, France, 2012-2017)

Solid line: multivariate model, AUC = 0.87, 95% CI: 0.75-0.98; dotted line: univariate model, AUC = 0.68, 95% CI: 0.53-0.83.

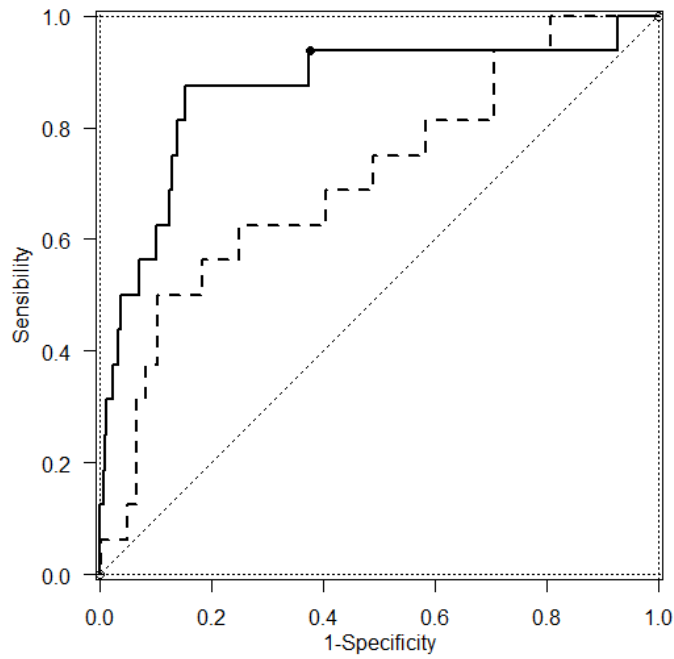


FIGURE 3 CART decision tree using the CAT sum score for predicting COPD in dairy farmers (n=993, Brittany, France, 2012-2017)

Solid line oval: farmers predicted not at-risk of COPD; dotted line oval: farmers predicted at-risk of COPD; COPD cases/group size.

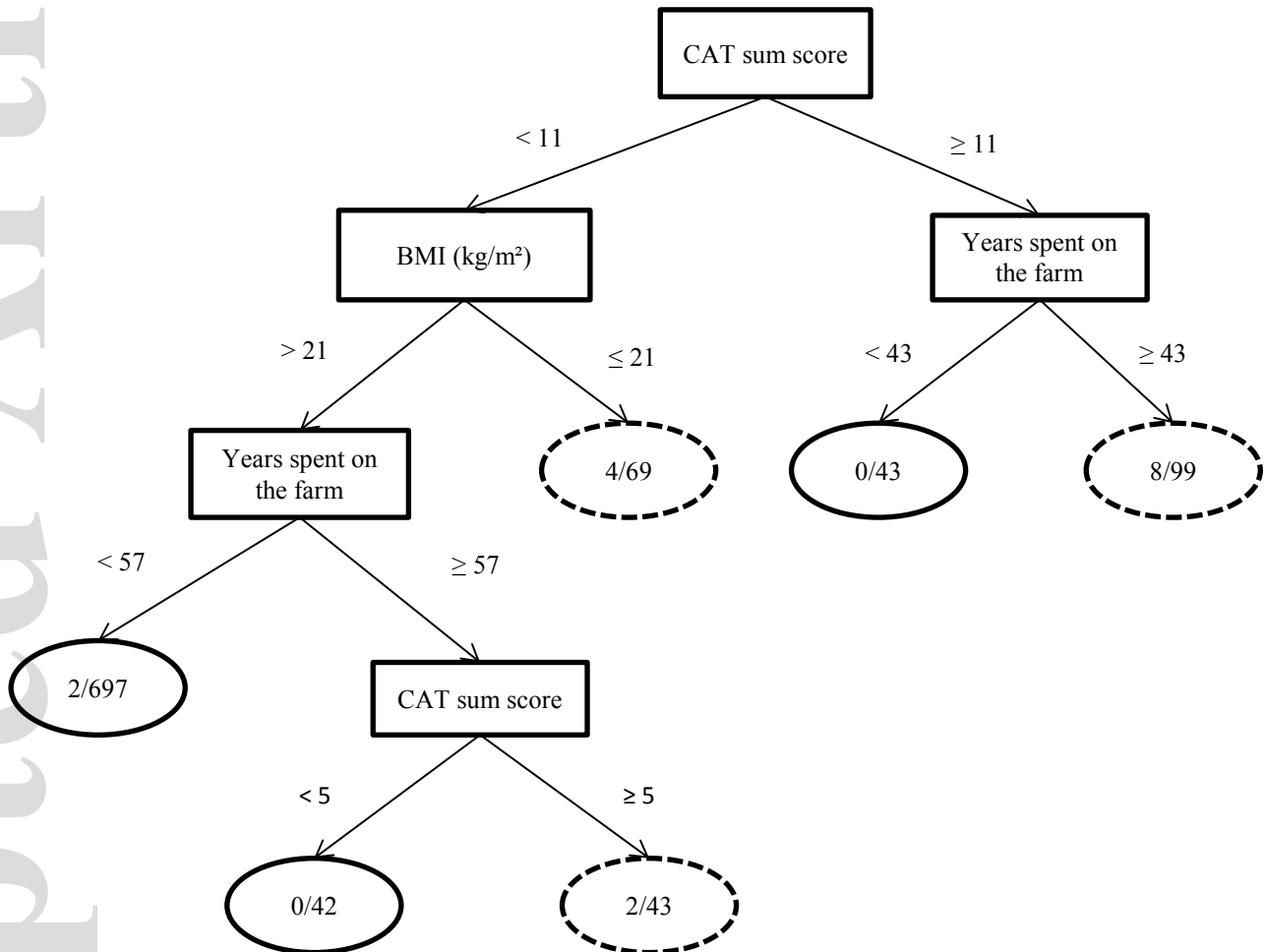


FIGURE 4 CART decision tree using the CAT breathlessness score for predicting COPD in dairy farmers (n=1004, Brittany, France, 2012-2017)

Solid line oval: farmers predicted not at-risk of COPD; dotted line oval: farmers predicted at-risk of COPD; COPD cases/group size.

