Risk stratification in Dutch primary care: a promising approach to manage population health

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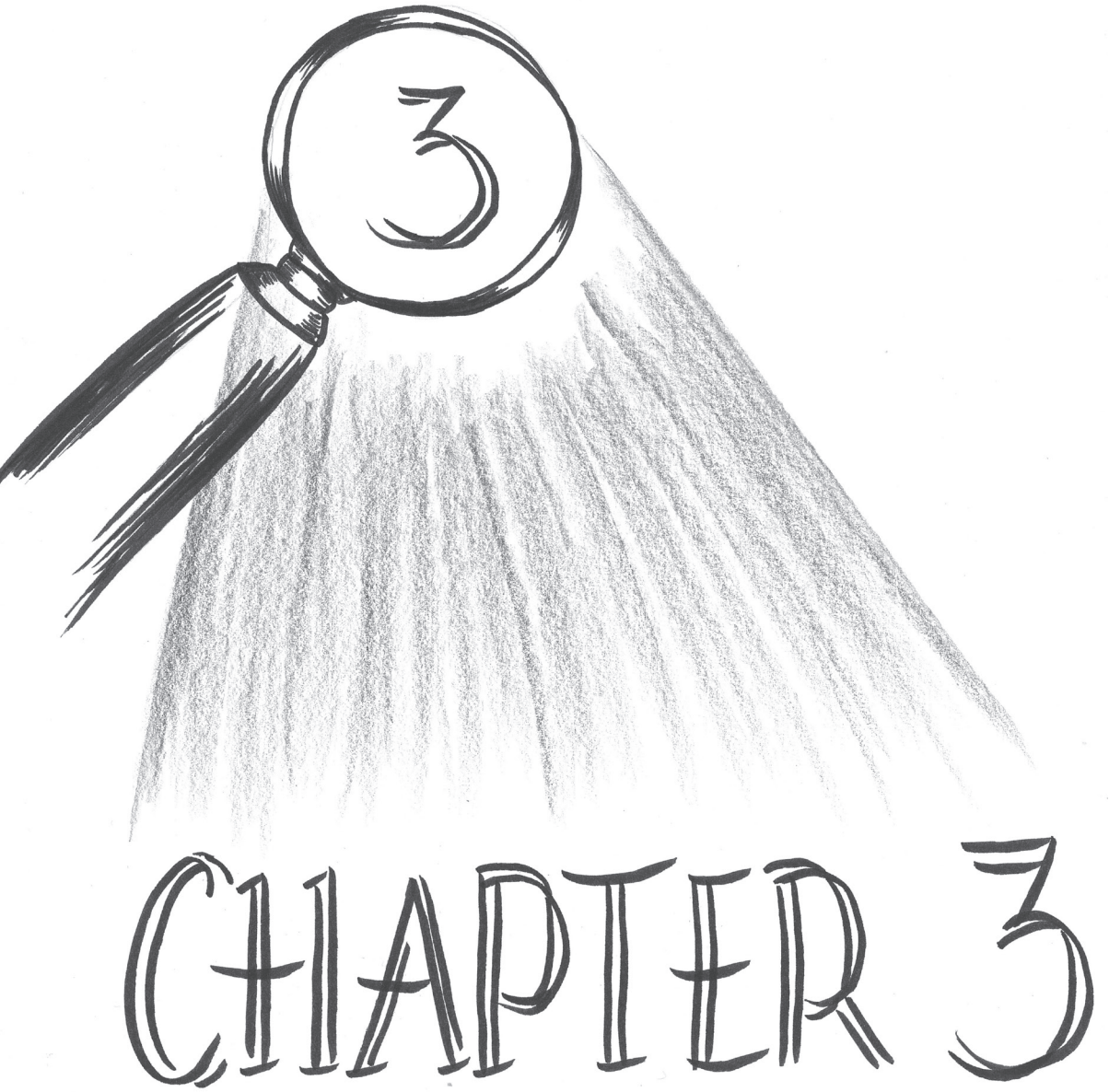

CHAPTER 3

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ASSESSMENT OF THE ADJUSTED CLINICAL GROUPS SYSTEM IN DUTCH PRIMARY CARE USING ELECTRONIC HEALTH RECORDS: A RETROSPECTIVE CROSS-SECTIONAL STUDY

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Published in BMC Health Services Research. 2021 Mar 10;21(1):217. doi: 10.1186/s12913-021-06222-9

Abstract

Introduction

Within the Dutch health care system the focus is shifting from a disease oriented approach to a more population based approach. Since every inhabitant in the Netherlands is registered with one general practice, this offers a unique possibility to perform Population Health Management analyses based on general practitioners' (GP) registries. The Johns Hopkins Adjusted Clinical Groups (ACG) System is an internationally used method for predictive population analyses. The model categorizes individuals based on their complete health profile, taking into account age, gender, diagnoses and medication. However, the ACG system was developed with non-Dutch data. Consequently, for wider implementation in Dutch general practice, the system needs to be validated in the Dutch healthcare setting. In this paper we show the results of the first use of the ACG system on Dutch GP data. The aim of this study is to explore how well the ACG system can distinguish between different levels of GP healthcare utilization.

Methods

To reach our aim, two variables of the ACG System, the Aggregated Diagnosis Groups (ADG) and the mutually exclusive ACG categories were explored. The population for this pilot analysis consisted of 23,618 persons listed with five participating general practices within one region in the Netherlands. ACG analyses were performed based on historical Electronic Health Records data from 2014 consisting of primary care diagnoses and pharmaceutical data. Logistic regression models were estimated and AUC's were calculated to explore the diagnostic value of the models including ACGs and ADGs separately with GP healthcare utilization as the dependent variable. The dependent variable was categorized using four different cut-off points: zero, one, two and three visits per year.

Results

The ACG and ADG models performed as well as models using International Classification of Primary Care chapters, regarding the association with GP utilization. AUC values were between 0.79 and 0.85. These models performed better than the base model (age and gender only) which showed AUC values between 0.64 and 0.71.

Conclusion

The results of this study show that the ACG system is a useful tool to stratify Dutch primary care populations with GP healthcare utilization as the outcome variable.

Introduction

With rising health care utilization and costs, a shift from disease oriented to population based approaches is being advocated worldwide. With the upcoming need for improved organization and management of healthcare and the increasing possibilities of big data, strategies based on health registry analyses are becoming popular. One use of health registry data in population health management strategies is risk stratification. With risk stratification, differences in individual health risks can be screened for, and used to assign interventions to the population and individuals that will benefit the most. With rising pressure on medical services provided by general practitioners (GPs) in most European countries (1), primary care can benefit from proven advantages of risk stratification approaches, such as improved care management (2), resource allocation (3) and identification of sub-populations for tailored care interventions (4).

Despite the proven benefits of using risk stratification, especially in primary care, there is no evidence for application of internationally used risk stratification tools in Dutch primary care. Risk stratification approaches using Dutch GP registry data can be especially beneficial due to the gatekeeper's function of Dutch GPs, providing the opportunity to overview a near total population.

Different tools for risk stratification are used worldwide, amongst which the Adjusted Clinical Groups (ACG) tool developed by the Johns Hopkins University. The ACG system is an internationally used tool for risk stratification on a generic level and is one of the most frequently used risk stratification tools in primary care. Evidence has also shown stronger statistical validity for the ACG compared with other risk stratification tools, regarding predictions of different healthcare utilization outcomes (5-7).

The ACG system uses registered diagnoses over a twelve month period, to assign individuals to one of 98 ACG categories, based on their healthcare profiles and expected health utilization (8). ACG categories are based on combinations of diagnoses types. Registered diagnoses processed by the ACG system, can include the International Classification of Primary Care (ICPC) coded (9), a commonly used registration method for diagnoses in primary care (10).

In this study we explored the potential use of Johns Hopkins University ACG System in routine registration data extracted from Dutch primary care practices. The aim of this study is to explore how well the ACG system, compared to the 17 chapters of

the ICPC coding system, can distinguish between different levels of GP healthcare utilization in Dutch general practice registries.

Methods

Study design and data

For this retrospective cross-sectional study, we used data from patients registered with one of the five participating GP practices during the whole of 2014 in Nijkerk, the Netherlands. Data for 30,596 patients over the year 2014extracted from the practices' electronic health records.included age, gender, and coded healthcare procedures, diagnoses and pharmaceutical data. Diagnoses were registered as ICPC-1 diagnoses codes, as used in the Netherlands (11) and converted to ICPC-2 codes. Prescribed medication was registered as Anatomical Therapeutic Chemical (ATC) codes (12),GP visits were defined as all GP encounters, including physical and telephone consults and home visits by either GPs or nurse practitioners working at the GP practices.

From the original datasets 4,289 cases were removed, due to corrupted patient identification numbers. Another 2,689 cases belonging to three specific ACG categories, were left out of the analyses: *No Diagnosis or Only Unclassified Diagnosis* (n=281), *Non-Users* (n=2,407) and *Invalid Age or Date of Birth* (n=1). The final analyses were performed with data for 23,618 persons (77% of 30,596 registered people).

Data preparation and analyses were performed with IBM SPSS Statistics 24.

ACG System software

We used the Johns Hopkins University's ACG® System software 11. The ACG® System software 11 is a risk stratification tool, assigning each patient to one of the 98 mutually exclusive ACG categories. Assignment to ACG categories is based on combinations of diagnoses types. With the ACG system the diagnoses for each patient are grouped into 32 Aggregated Diagnosis Groups (ADGs), based on type of diagnoses rather than on specific diagnoses, i.e. specific ICPC codes. Individuals' patterns of ADGs determine the assignment of patients to one of the 98 mutually exclusive ACG categories (8).

Assessment of the ACG system

To assess the applicability of the ACG system in Dutch primary care, we looked at two aspects: face validity and model performance.

Face Validity

According to Mosier (13) an important aspect of the testing of an instrument lies in the 'consumer acceptance'. The first step in effective use of a test, is the actual selection for use and acceptance of the results. Mosier describes one of the translations of face validity as the appearance of validity: the test must appear valid in addition to the statistical validity. In this study we defined face validity as this appearance of validity described by Mosier (13).

We assessed the ACG system's face validity by exploring the actual ACG categorization with regard to age. Face validity was assessed on recognition of multimorbidity in relation to age within ACG categories. The ACG categories are grouped according to the number of ADGs: one, two to three, four to five, six to nine and lastly ten plus ADGs.

Model Performance

To investigate the impact of the ACG system in Dutch primary care, four different logistic regression models were estimated.

Dependent variable

The outcome variable, number of GP visits, was transformed into binary variables according to four definitions. According to the first definition, *no GP visits* was defined as *no utilization of care*, whereas *one or more GP visits* were defined as *utilization of care*. With the second definition, a distinction between *zero or one GP visit* and *two or more GP visits* was made. With the third definition, a distinction between *zero to two GP visits* and *three or more GP visits* was made. Accordingly, for the final definition the outcome was defined as a distinction between *zero to three* and *four or more GP visits*. The performance of each of these models was investigated.

Independent variables

In the null or base model only *age* as a continuous variable and gender were included as explanatory variables.

Model 1 included age, gender and ICPC chapters as independent variables. ICPC diagnosis codes are divided into 17 different chapters including *'General and unspecified'*, '*Blood, blood forming organs, lymphatics, spleen'*, *'Digestive'*, *'Eye'*,

'Ear', *'Circulatory'*, *'Musculoskeletal'*, *'Neurological'*, *'Psychological'*, *'Respiratory'*, *'Skin'*, *'Endocrine metabolic and nutritional'*, *'Urology'*, *'Pregnancy, childbirth, family planning'*, *'Female genital system and breast'*, *'Male genital system'* and *'Social problems'*. Different ICPC chapters can be registered to a single person. Therefore, the ICPC chapters were added to the model as 17 different dummy variables.

Model 2 included age, gender and ADG diagnoses as independent variables. As an individual can have more than one ADG, the 32 ADGs were added to the model as 32 dummy variables.

Model 3 included age, gender and mutually exclusive ACGs. Before estimating the logistic regression, the numbers of individuals in each ACG category were checked. Aggregation of some ACG categories was necessary due to categories with small numbers of individuals. In supplementary table 1 the aggregation of the original ACG categories is presented.

To select the best model, the performance of each logistic regression with outcome variable as defined above, was investigated. The Area Under the Curve (AUC) values were calculated for each model.

Ethics approval and patients' consent

The need for ethical approval was waived by the medical ethical committee of Leiden University Medical Center (CME - LUMC), the Netherlands.

Participants were not asked for their consent because we used routinely collected de-identified data.

Results

Population characteristics

A total of 23,618 patients registered with a GP, were included in this study. 48.1% of the patients was male. The mean age of the included patients was 41.8 years old with a standard deviation of 22.2 years. 67.7% of the patients had at least one GP visit in 2014. The mean number of GP visits was 3.5 with a standard deviation of 5.0 and the maximum number of GP visits was 92. In figure 1 the distribution of the number of GP visits within the study population is presented. As expected, this is a skewed distribution, where most of the population has had zero or one GP visits.

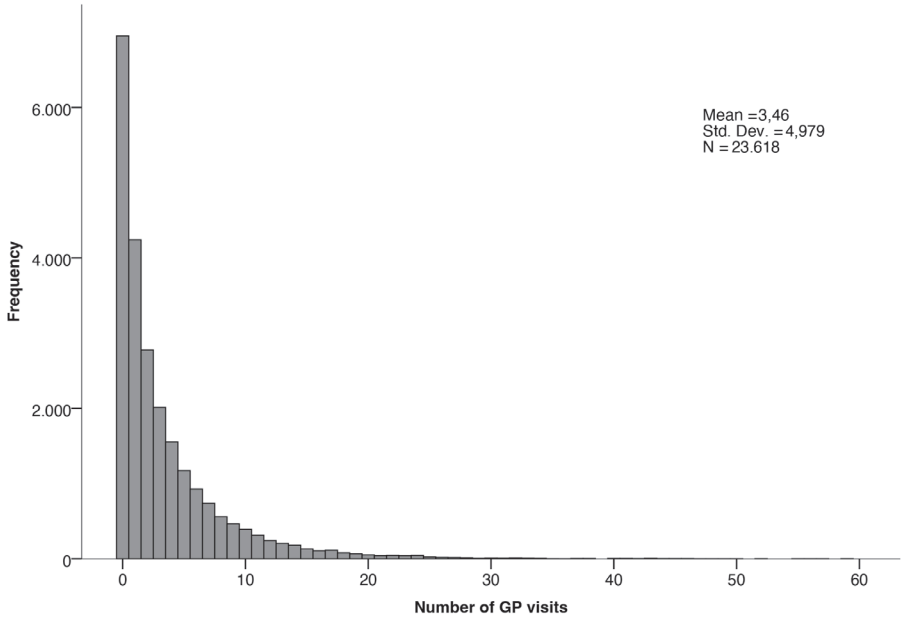

Figure 1: Distribution of the number of general practitioner (GP) visits within the study population

Figure 2 shows the health problems within the study population according to the 17 chapters of the ICPC registry system. The percentages of the study population with at least one diagnosis code corresponding to a specific ICPC chapter, are presented in the figure. ICPC chapters *Musculoskeletal* (L), *Respiratory* (R) and *Skin* (S) had the highest frequencies, with percentages between 43 and 49.

Face validity of ACG categorization

In figure 3 the distribution of age within each ACG category is presented with boxplots. Each group of ACGs corresponds with a different color, red being the highest numbers of ADGs. The figure shows that the number of ADGs gradually goes up with increasing age. Mean ages of the ACG categories with only one ADG *(green)* are mostly under 30. Exceptions are the ACG categories *Chronic medical: Stable* and *Eye/*Dental, which have mean values above 50. The mean age of ACGs with two to three ADGs *(yellow)* is mostly between 30 and 40, with the exception of ACG category *Acute Minor and Chronic Medical: Stable* (mean age of 50+). For three out of four of the ACG categories with four to five ADGs, the mean ages are between 50 and 62. However, the ACG category *Acute Minor/Acute Major/Likely Recur/Psychosocial* has a mean age of under 40. The ACG categories with

six to nine ADGs have a mean age of around 63, whereas the mean age of ACG categories with ten or more ADGs is above 70. An extended overview of individuals from each ACG category, distributed over 10 year age bands, is presented in supplementary table 2.

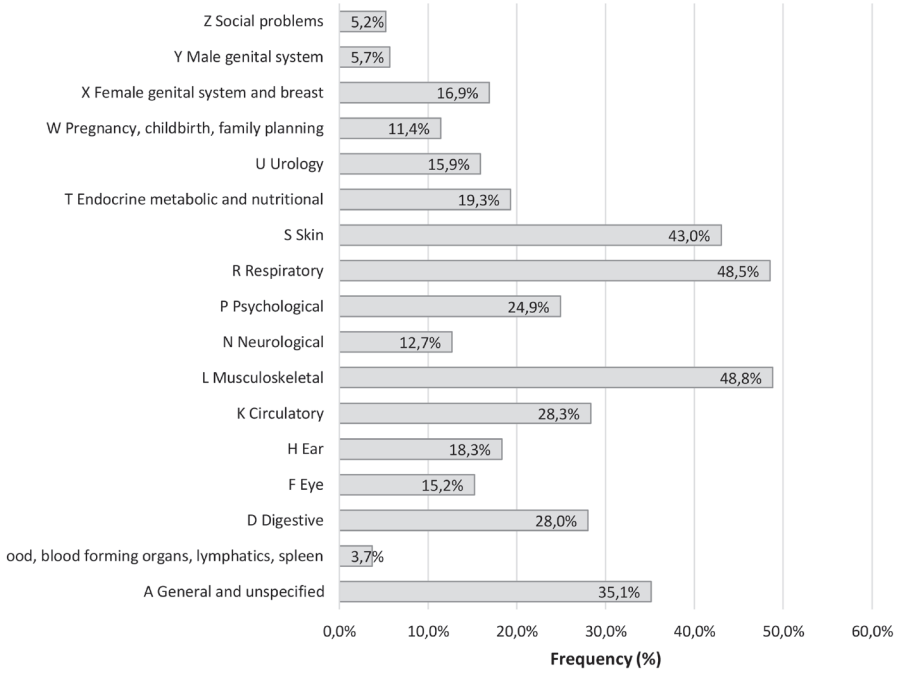

Figure 2: Overview of health problems within the study population according to the 17 main chapters of the International Classification of Primary Care (ICPC) coding system. ICPC chapters form the basis of the ICPC coding system.

Model performance

To investigate the model performances, where the outcome variable utilization of GP was defined as discussed in the methods section, AUCs along with their confidence intervals were computed.

Table 2 displays the model performances for each of the four different definitions of the outcome GP utilization. As seen in the table, model 1 and 2 perform well with AUC values between 0.79 and 0.85. They slightly perform better than model 3 with AUC values between 0.77 and 0.83. All three models outperform the null model with AUC values between 0.63 and 0.71. For all independent variables, odds ratios along with their 95% confidence intervals, are shown in supplementary tables 3 to 5.

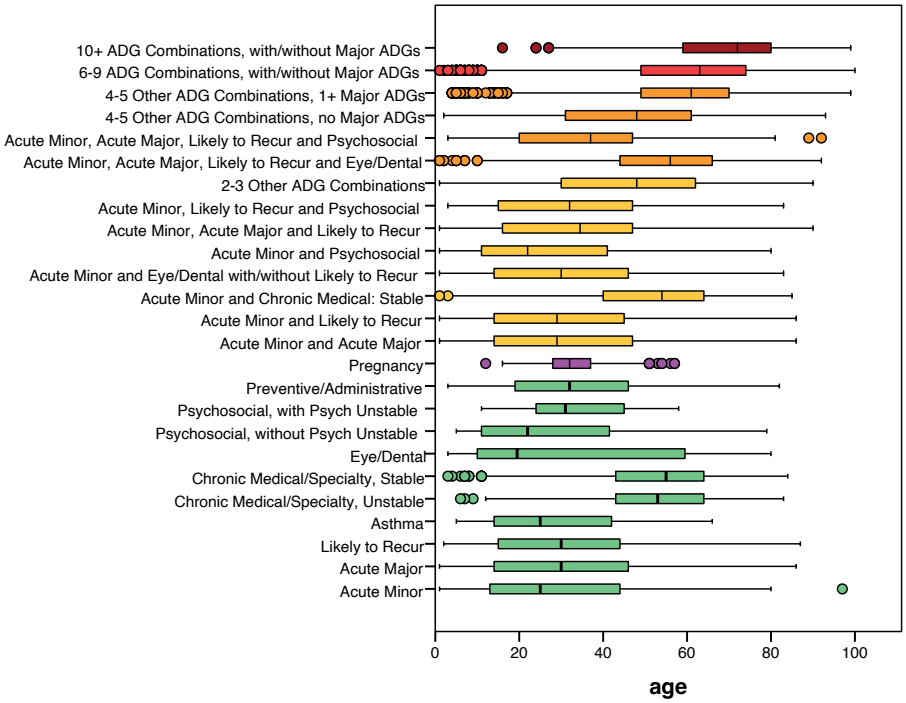

Figure 3: Age distribution per Adjusted Clinical Groups (ACG) category. ACG categories are a collapsed version of the original ACGs. Colors (with the exception of the pink one) correspond to the number of Aggregated Diagnostic Groups (ADGs): *green*=One ADG; *pink*=Pregnancy (all numbers of ADGs); *yellow*=2-3 ADGs; *orange*=4-5 ADGs; *red*=6-9 ADGs; *dark red*=10+ ADGs.

Table 3: Model performances quantified by the Area Under the ROC Curve (AUC) values along with the 95% confidence intervals (CI)

	Area Under the ROC Curve (95% Confidence Interval)			
Outcome	**Null model**	**Model 1**	**Model 2**	**Model 3**
0 vs. >=1 GPvisits	0.638 (0.630 - 0.645)	0.787 (0.781 - 0.793)	0.793 (0.787 - 0.799)	0.774 (0.768 - 0.780)
0-1 vs. >=2 GPvisits	0.675 (0.668 - 0.681)	0.816 (0.810 - 0.821)	0.818 (0.812 - 0.823)	0.799 (0.794 - 0.805)
0-2 vs. >=3 GPvisits	0.693 (0.686 - 0.700)	0.833 (0.828 - 0.838)	0.832 (0.828 - 0.837)	0.814 (0.809 - 0.819)
0-3 vs. >=4 GPvisits	0.711 (0.704 - 0.718)	0.848 (0.842-0.853)	0.848 (0.842 - 0.853)	0.829 (0.824 - 0.834)

'Outcome' is based on the four definitions of the outcome general practice (GP) healthcare utilization

Discussion

The results of this study suggest that the ACG system can be applied to Dutch primary care data, when regarding both face validity and model performance. With regard to the face validity, it can be concluded that the assignment of ACG categories is as expected: the ACG categories which indicate higher multimorbidity and thus higher expected care burden, are found amongst older patients. With respect to model performance, results showed that distinctions between the different levels of GP healthcare utilization can be made with the ACG system. The ACG and ADG categories, as well as the ICPC chapters (the commonly used primary care coding system), are highly associated with GP utilization. However, the ACG system is at patient level and provides a variety of other risk stratification variables, such as multimorbidity measures, risks of hospitalization and high costs, making the use of the ACG as risk stratification tool a good addition to the use of the ICPC coding system.

Comparison of the results of this study to previous research is challenging, as most previous studies investigating the association of the ACG system with continuous utilization outcome measures. Some previous studies were carried out on dichotomous variables however and showed C-statistics and AUC values between 0.73 and 0.82 for the ACG as predictor for hospitalization (5, 6, 14). In addition, the study by Haas et al. presented C-statistics of 0.67 for emergency department visitation and 0.76 for top 10% healthcare costs (5).

Adding to the above mentioned studies, this study suggests that the ACG system is applicable in primary care. Analyzing primary care data in such a manner is of great importance for the understanding of efficiency of healthcare systems that are under increased physical and financial pressure. A study by Sibley et al. showed that administrative data can be used to determine morbidity burden, an important indicator for future care utilization (15). Kristensen and colleagues assessed the use of the ACG system as a morbidity based casemix adjustment system amongst type 2 diabetes patients in order to allocate resources according to degree of co-morbidity (3). They stated that the Danish healthcare system, which is based on fee for service incentives, would profit from a morbidity based casemix adjustment system. The ACG has also proven to be effective for identifying inequities in healthcare utilization by Shadmi et al. (7). Identifying inequities is the first step towards minimizing unwarranted care gaps. With risk stratification tools such as the ACG, case finding

for inclusion in population-level interventions can be performed in more health systems worldwide. A study by Soto-Gordoa used risk stratification to select cases for a patient-centered intervention for multimorbid patients with the goal to lower hospitalization. The approach avoided nine percent of hospitalization when cases were selected with the ACG tool (4).

With our study, a first step towards validation of the ACG system, a tool to shift from disease oriented to population based approaches, is revealed for use in the Netherlands. This is opening up a variety of opportunities to reorganize and manage Dutch primary care in an efficient way.

Although the ACG seems an excellent tool to be used in the Netherlands, local adjustment of the software is of eminent importance. A limitation of this study might be the availability of only GP data (without, for example, hospital and mental health care data), forcing us to restrict healthcare utilization outcomes to GP visits, whereas healthcare utilization may be better defined as a total overview of healthcare use. With our research we were not able to explore other types of healthcare utilization, for example defined by total healthcare costs or more costly types of healthcare utilization such as hospitalization and emergency department visitation. Consequently, a full adjustment of the ACG system for use with Dutch data was not possible yet. Further exploration of the ACG system with the use of different data sources will follow.

Moreover, the quality of data needs to be considered. For this study, routine data from GP registries were used. Risk stratification with routinely collected primary care data is an easy and practical way to perform risk stratification on a large scale. Data quality for risk stratification purposes can be improved and strengthened by linkage with different data sources such as hospital and social care registries. The exclusion of social data, such as ethnicity and underlying socio-economic variables, is another limitation of this study. Ethnicity and even more the underlying socio-economic aspect thereof, may have important aspects on patient's health profiles. The addition of social variables and thus more complete patient profiles are of added value in risk stratification approaches. However, we were unable to include these data in our models, as they were not available in the GP data.

Policy implication

Even though the use of the ACG system typically recommends the use of both primary care and hospital care data, this study shows that the ACG is very promising with the use of solely primary care data, especially in a primary care system with mandatory GP listing. With the possibility of applying risk stratification tools to such primary care based healthcare systems, without the need to link data from different sectors, the information security issues can be avoided. Patients' personal information is already available to GP's for optimal caregiving purposes.

With addition of other data sources on individual patient's level, regulations need to be considered to allow the linkage of personal data. As the value of adding hospital data is still to be explored, further research on both content-specific and regulatory aspects is desirable.

Altogether, applications such as the ACG, are very promising for healthcare systems, as their ability to predict future health utilization can be beneficial for person-tailored health intervention strategies, such as screenings for care management interventions, as well as local, regional or even nationwide healthcare management.

Further research

Before applying the ACG system in Dutch primary care, further research is required. This study showed associations between just two components of the ACG system, the ADG and ACG categories, and GP visitation. Risk scores, for example, for future hospitalization and total healthcare costs were outside the scope of this study. To justify the use of the ACG system as risk stratification tool in Dutch primary care, studies validating the ACG risk scores should be conducted. In addition, the ACG models need to be adjusted and improved for use with Dutch primary care data.

Conclusions

This study showed that the ACG is applicable as risk stratification tool in Dutch primary care using routinely registered data from general practitioners' registries. The ACG system yields good results compared to the traditional ICPC classification. Country specific adjustments in the classification and validation of specific risks are necessary.

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Supplementary Material

Supplementary table 1: Aggregation of the original ACG categories for logistic regression model 3.

Recoded ACG	Description recoded ACG	Original ACG	Description original ACG
300	Acute Minor (all ages)	100	Acute Minor, Age 1
		200	Acute Minor, Age 2 to 5
		300	Acute Minor, Age > 5
400	Unchanged	400	Acute Major
500	Unchanged	500	Likely to Recur, w/o Allergies
600	Unchanged	600	Likely to Recur, with Allergies
700	Unchanged	700	Asthma
800	Unchanged	800	Chronic Medical, Unstable
900	Chronic Medical/Specialty, Stable	900	Chronic Medical, Stable
		1000	Chronic Specialty, Stable
1100	Unchanged	1100	Eye/Dental
1200	Unchanged	1200	Chronic Specialty, Unstable
1300	Unchanged	1300	Psychosocial, w/o Psych Unstable
1400	Psychosocial, with Psych Unstable, with or without Psych Stable	1400	Psychosocial, with Psych Unstable, w/o Psych Stable
		1500	Psychosocial, with Psych Unstable, w/ Psych Stable
1600	Unchanged	1600	Preventive/Administrative
1711	Unchanged	1711	Pregnancy: 0-1 ADGs, delivered
1712	Unchanged	1712	Pregnancy: 0-1 ADGs, not delivered
1721	Pregnancy: 2+ ADGs, with or without Major ADGs, delivered	1721	Pregnancy: 2-3 ADGs, no Major ADGs, delivered
		1731	Pregnancy: 2-3 ADGs, 1+ Major ADGs, delivered
		1741	Pregnancy: 4-5 ADGs, no Major ADGs, delivered
		1751	Pregnancy: 4-5 ADGs, 1+ Major ADGs, delivered
		1761	Pregnancy: 6+ ADGs, no Major ADGs, delivered
		1771	Pregnancy: 6+ ADGs, 1+ Major ADGs, delivered

Supplementary table 1: Continued

Recoded ACG	Description recoded ACG	Original ACG	Description original ACG
1722	Pregnancy: 2+ ADGs, with or without Major ADGs, not delivered	1722	Pregnancy: 2-3 ADGs, no Major ADGs, not delivered
		1732	Pregnancy: 2-3 ADGs, 1+ Major ADGs, not delivered
		1742	Pregnancy: 4-5 ADGs, no Major ADGs, not delivered
		1752	Pregnancy: 4-5 ADGs, 1+ Major ADGs, not delivered
		1762	Pregnancy: 6+ ADGs, no Major ADGs, not delivered
		1772	Pregnancy: 6+ ADGs, 1+ Major ADGs, not delivered
1800	Unchanged	1800	Acute Minor and Acute Major
1900	Acute Minor and Likely to Recur, Age 1 to 5	1900	Acute Minor and Likely to Recur, Age 1
		2000	Acute Minor and Likely to Recur, Age 2 to 5
2100	Unchanged	2100	Acute Minor and Likely to Recur, Age > 5, w/o Allergy
2200	Unchanged	2200	Acute Minor and Likely to Recur, Age > 5, with Allergy
2300	Unchanged	2300	Acute Minor and Chronic Medical: Stable
2400	Unchanged	2400	Acute Minor and Eye/Dental
2500	Acute Minor and Psychosocial, with/without Psych Stable/Unstable	2500	Acute Minor and Psychosocial, w/o Psych Unstable
		2600	Acute Minor and Psychosocial, with Psych Unstable, w/o Psych Stable
		2700	Acute Minor and Psychosocial, with Psych Unstable and Psych Stable
2800	Acute Minor/Likely to Recur/Eye & Dental	2800	Acute Minor and Likely to Recur
		3400	Acute Minor/Likely to Recur/Eye & Dental
3000	Acute Minor/Acute Major/Likely to Recur, Age 1 to 5	2900	Acute Minor/Acute Major/Likely to Recur, Age 1
		3000	Acute Minor/Acute Major/Likely to Recur, Age 2 to 5

Supplementary table 1: Continued

Recoded ACG	Description recoded ACG	Original ACG	Description original ACG
3100	Unchanged	3100	Acute Minor/Acute Major/Likely to Recur, Age 6 to 11
3200	Unchanged	3200	Acute Minor/Acute Major/Likely to Recur, Age > 11, w/o Allergy
3300	Unchanged	3300	Acute Minor/Acute Major/Likely to Recur, Age > 11, with Allergy
3500	Unchanged	3500	Acute Minor/Likely to Recur/Psychosocial
3600	Unchanged	3600	Acute Minor/Acute Major/Likely Recur/Eye & Dental
3700	Unchanged	3700	Acute Minor/Acute Major/Likely Recur/Psychosocial
3800	Unchanged	3800	2-3 Other ADG Combinations, Age < 18
3900	Unchanged	3900	2-3 Other ADG Combinations, Males Age 18 to 34
4000	Unchanged	4000	2-3 Other ADG Combinations, Females Age 18 to 34
4100	Unchanged	4100	2-3 Other ADG Combinations, Age > 34
4210	Unchanged	4210	4-5 Other ADG Combinations, Age < 18, no Major ADGs
4220	Unchanged	4220	4-5 Other ADG Combinations, Age < 18, 1+ Major ADGs
4310	Unchanged	4310	4-5 Other ADG Combinations, Age 18 to 44, no Major ADGs
4320	4-5 Other ADG Combinations, Age 18 to 44, 1+ Major ADGs	4320	4-5 Other ADG Combinations, Age 18 to 44, 1+ Major ADGs
		4330	4-5 Other ADG Combinations, Age 18 to 44, 2+ Major ADGs
4410	Unchanged	4410	4-5 Other ADG Combinations, Age > 44, no Major ADGs
4420	Unchanged	4420	4-5 Other ADG Combinations, Age > 44, 1+ Major ADGs
4430	Unchanged	4430	4-5 Other ADG Combinations, Age > 44, 2+ Major ADGs

Supplementary table 1: Continued

Recoded ACG	Description recoded ACG	Original ACG	Description original ACG
4510	6-9 Other ADG Combinations, with/without Major ADGs	4510	6-9 Other ADG Combinations, Age < 6, no Major ADGs
		4520	6-9 Other ADG Combinations, Age < 6, 1+ Major ADGs
		4610	6-9 Other ADG Combinations, Age 6 to 17, no Major ADGs
		4620	6-9 Other ADG Combinations, Age 6 to 17, 1+ Major ADGs
		4710	6-9 Other ADG Combinations, Males, Age 18 to 34, no Major ADGs
		4720	6-9 Other ADG Combinations, Males, Age 18 to 34, 1+ Major ADGs
		4730	6-9 Other ADG Combinations, Males, Age 18 to 34, 2+ Major ADGs
		4810	6-9 Other ADG Combinations, Females, Age 18 to 34, no Major ADGs
		4820	6-9 Other ADG Combinations, Females, Age 18 to 34, 1+ Major ADGs
		4830	6-9 Other ADG Combinations, Females, Age 18 to 34, 2+ Major ADGs
		4910	6-9 Other ADG Combinations, Age > 34, 0-1 Major ADGs
		4920	6-9 Other ADG Combinations, Age > 34, 2 Major ADGs
		4930	6-9 Other ADG Combinations, Age > 34, 3 Major ADGs
		4940	6-9 Other ADG Combinations, Age > 34, 4+ Major ADGs
5030	10+ Other ADG Combinations, with/without Major ADGs	5030	10+ Other ADG Combinations, Age 1 to 17, 2 Major ADGs
		5040	10+ Other ADG Combinations, Age > 17, 0-1 Major ADGs
		5050	10+ Other ADG Combinations, Age > 17, 2 Major ADGs
		5060	10+ Other ADG Combinations, Age > 17, 3 Major ADGs
		5070	10+ Other ADG Combinations, Age > 17, 4+ Major ADGs

For the purpose of this study, some ACG categories were collapsed together. The recoded ACG categories are presented within the table. When the description field of the recoded ACG reads 'unchanged' the ACG category remained the original ACG category.

Supplementary table 2: Distribution of persons over ACG categories taking age into account

	Age categories (10yr bands)									Total
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80+	
One Aggregated Diagnostic Group	***724***	***1294***	***1314***	***1521***	***1243***	***697***	***399***	***117***	***18***	***7327***
Acute Minor (all ages)	361	583	345	293	378	240	104	24	5	2333
Acute Major	126	184	137	109	170	94	53	20	2	895
Likely to Recur	134	267	167	171	222	112	56	13	1	1143
Asthma	8	19	17	9	12	5	7	0	0	77
Chronic Medical or Specialty, Unstable	3	9	3	14	41	31	35	18	4	158
Chronic Medical/Specialty, Stable	7	23	22	26	54	108	105	33	2	380
Eye/Dental	8	10	5	1	0	3	5	3	1	36
Psychosocial, w/o Psych Unstable	55	90	42	38	48	25	11	3	0	312
Psychosocial, with Psych Unstable, with or without Psych Stable	0	3	11	6	4	5	0	0	0	29
Preventive/Administrative	22	94	79	70	90	50	23	3	3	434
Pregnancy	***0***	***6***	***243***	***392***	***112***	***12***	***0***	***0***	***0***	***765***
Pregnancy: delivered or not delivered	0	6	243	392	112	12	0	0	0	765
Two-Three Aggregated Diagnostic Groups	***1051***	***1490***	***1040***	***1049***	***1616***	***1326***	***1065***	***404***	***106***	***9137***
Acute Minor and Acute Major	193	270	176	166	194	166	80	18	10	1273
Acute Minor and Likely to Recur	207	332	221	191	264	162	80	16	2	1465
Acute Minor and Chronic Medical: Stable	12	23	44	30	70	99	115	42	10	445
Acute Minor and Eye/Dental with or w/o Eye & Dental	98	121	93	83	124	63	31	15	1	629
Acute Minor and Psychosocial, with/without Psych Stable/Unstable	77	98	52	36	51	36	14	0	1	365
Acute Minor/Acute Major/Likely to Recur, with or w/o Allergy	199	228	168	188	266	157	102	26	8	1342
Acute Minor/Likely to Recur/Psychosocial	49	61	37	43	58	47	13	3	2	313
2-3 Other ADG Combinations	216	357	249	312	589	596	630	284	72	3305

Supplementary table 2: Continued

	Age categories (10yr bands)									Total
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80+	
Four-Five Aggregated Diagnostic Groups	***200***	***304***	***274***	***384***	***727***	***894***	***967***	***577***	***213***	***4540***
Acute Minor/Acute Major/Likely Recur/Eye & Dental	11	45	48	57	136	193	209	113	32	844
Acute Minor/Acute Major/Likely Recur/Psychosocial	48	52	48	84	101	55	32	5	4	429
4-5 Other ADG Combinations, no Major ADGs	107	167	117	160	274	313	282	134	50	1604
4-5 Other ADG Combinations, 1+ Major ADGs	34	40	61	83	216	333	444	325	127	1663
Six-Nine Aggregated Diagnostic Groups	***54***	***93***	***102***	***139***	***369***	***533***	***647***	***668***	***382***	***2987***
6-9 Other ADG Combinations, with/without Major ADGs	54	93	102	139	369	533	647	668	382	2987
Over 10 Aggregated Diagnostic Groups	***0***	***1***	***7***	***15***	***32***	***48***	***76***	***111***	***102***	***392***
10+ Other ADG Combinations, with/without Major ADGs	0	1	7	15	32	48	76	111	102	392
Total	**2029**	**3176**	**2484**	**2716**	**3875**	**3486**	**3154**	**1877**	**821**	**23618**

Distribution of individuals within the ACG categories. Some ACG categories are regrouped, due to small numbers in said categories. ACG categories are grouped according to number of ADG's and disaggregated in 10-year age categories.

Supplementary table 3: Odds Ratio with 95% confidence intervals for dependent variables in model 1 with the second definition for GP utilization.

Variables	***Odds Ratio***	***95% Confidence intervals***	
		Lower	**Upper**
Gender	0,925	0,861	0,994
Age	1,003	1,001	1,005
ICPC chapter A *General and unspecified*	1,42	1,33	1,516
ICPC chapter B *Blood, blood forming organs, lymphatics, spleen*	2,017	1,658	2,454
ICPC chapter D *Digestive'*	1,836	1,706	1,975
ICPC chapter F *Eye'*	1,324	1,206	1,454
ICPC chapter H *Ear'*	1,453	1,338	1,578
ICPC chapter K *Circulatory'*	2,701	2,48	2,942
ICPC chapter L *Musculoskeletal'*	1,87	1,758	1,988
ICPC chapter N *Neurological'*	1,713	1,55	1,893
ICPC chapter P *Psychological'*	1,985	1,843	2,139
ICPC chapter R *Respiratory'*	1,736	1,63	1,85
ICPC chapter S *Skin'*	1,974	1,855	2,101
ICPC chapter T *Endocrine metabolic and nutritional*	2,466	2,245	2,709
ICPC chapter U *Urology'*	1,759	1,597	1,938
ICPC chapter W *Pregnancy, childbirth, family planning*	1,886	1,701	2,091
ICPC chapter X *Female genital system and breast*	1,509	1,374	1,657
ICPC chapter Y *Male genital system*	1,619	1,406	1,864
ICPC chapter Z *Social problems*	2,624	2,241	3,073
Constant	0,123		

Odds Ratio's and Confidence Intervals of the variables in model 1 (including ICPC chapters) are presented for outcome 2 (zero or one GP visit versus two or more GP visits).

Supplementary table 4: Odds Ratio with 95% confidence intervals for dependent variables in model 2 with the second definition for GP utilization.

Variables	*Description*	*Odds Ratio*	*95% Confidence intervals*	
			Lower	**Upper**
Gender		0,85	0,797	0,906
Age		1,008	1,006	1,01
ADG01	Time Limited: Minor	1,489	1,382	1,605
ADG02	Time Limited: Minor-Primary Infections	1,788	1,655	1,932
ADG03	Time Limited: Major	1,273	0,918	1,764
ADG04	Time Limited: Major-Primary Infections	1,817	1,468	2,249
ADG05	Allergies	1,354	1,223	1,5
ADG06	Asthma	1,677	1,479	1,902
ADG07	Likely to Recur: Discrete	1,653	1,518	1,799
ADG08	Likely to Recur: Discrete-Infections	1,566	1,426	1,72
ADG09	Likely to Recur: Progressive	1,487	1,133	1,951
ADG10	Chronic Medical: Stable	2,881	2,66	3,12
ADG11	Chronic Medical: Unstable	1,921	1,723	2,143
ADG12	Chronic Specialty: Stable-Orthopedic	1,704	1,279	2,27
ADG13	Chronic Specialty: Stable-Ear,Nose,Throat	1,335	0,983	1,813
ADG14	Chronic Specialty: Stable-Eye	1,303	1,079	1,573
ADG16	Chronic Specialty: Unstable-Orthopedic	1,636	1,333	2,008
ADG17	Chronic Specialty: Unstable-Ear,Nose,Throat	0,708	0,417	1,203
ADG18	Chronic Specialty: Unstable-Eye	1,227	0,887	1,699
ADG20	Dermatologic	1,968	1,819	2,129
ADG21	Injuries/Adverse Effects: Minor	1,828	1,646	2,031
ADG22	Injuries/Adverse Effects: Major	1,416	1,235	1,625
ADG23	Psychosocial: Time Limited, Minor	2,335	2,044	2,668
ADG24	Psychosocial:Recurrent or Persistent,Stable	1,945	1,775	2,132
ADG25	Psychosocial:Recurrent or Persistent,Unstable	1,564	1,183	2,066
ADG26	Signs/Symptoms: Minor	1,877	1,766	1,996
ADG27	Signs/Symptoms: Uncertain	2,086	1,96	2,22
ADG28	Signs/Symptoms: Major	1,588	1,382	1,825
ADG29	Discretionary	1,523	1,358	1,709
ADG30	See and Reassure	1,99	1,72	2,303
ADG31	Prevention/Administrative	1,501	1,397	1,614
ADG32	Malignancy	1,515	1,276	1,798
ADG33	Pregnancy	1,605	1,351	1,907
ADG34	Dental	1,312	0,891	1,932
Constant		0,108		

Odds Ratio's and Confidence Intervals of the variables in model 2 (including ADGs) are presented for outcome 2 (zero or one GP visit versus two or more GP visits).

Supplementary table 5: Odds Ratio with 95% confidence intervals for dependent variables in model 3 with the second definition for GP utilization.

Variables	*Description*	*Odds Ratio*	*95% Confidence intervals*	
			Lower	**Upper**
Gender		0,779	0,732	0,83
Age		1,009	1,007	1,011
ACG 300	Acute Minor (all ages)			
ACG 400	Acute Major	0,933	0,761	1,143
ACG 500	Likely to Recur, w/o Allergies	0,851	0,691	1,048
ACG 600	Likely to Recur, with Allergies	0,559	0,372	0,84
ACG 700	Asthma	1,153	0,649	2,05
ACG 800	Chronic Medical, Unstable	1,287	0,835	1,985
ACG 900	Chronic Medical/Specialty, Stable	2,206	1,738	2,798
ACG 1100	Eye/Dental	0,124	0,017	0,911
ACG 1200	Chronic Specialty, Unstable	0,395	0,14	1,112
ACG 1300	Psychosocial, w/o Psych Unstable	1,382	1,038	1,84
ACG 1400	Psychosocial, with Psych Unstable, with or without Psych Stable	1,207	0,487	2,987
ACG 1600	Preventive/Administrative	0,141	0,082	0,243
ACG 1711	Pregnancy: 0-1 ADGs, delivered	1,065	0,483	2,349
ACG 1712	Pregnancy: 0-1 ADGs, not delivered	0,323	0,099	1,057
ACG 1721	Pregnancy: 2+ ADGs, with or without Major ADGs, delivered	9,108	7,067	11,739
ACG 1722	Pregnancy: 2+ ADGs, with or without Major ADGs, not delivered	5,159	4,044	6,581
ACG 1800	Acute Minor and Acute Major	3,214	2,755	3,75
ACG 1900	Acute Minor and Likely to Recur, Age 1 to 5	4,958	3,144	7,816
ACG 2100	Acute Minor and Likely to Recur, Age > 5, w/o Allergy	3,244	2,759	3,813
ACG 2200	Acute Minor and Likely to Recur, Age > 5, with Allergy	3,249	2,535	4,165
ACG 2300	Acute Minor and Chronic Medical: Stable	4,024	3,235	5,006
ACG 2400	Acute Minor and Eye/Dental	1,835	0,907	3,714
ACG 2500	Acute Minor and Psychosocial, with/without Psych Stable/Unstable	3,144	2,482	3,981
ACG 2800	Acute Minor/Likely to Recur/Eye & Dental	2,806	2,303	3,418
ACG 3000	Acute Minor/Acute Major/Likely to Recur, Age 1 to 5	5,957	3,913	9,066
ACG 3100	Acute Minor/Acute Major/Likely to Recur, Age 6 to 11	6,406	4,48	9,16
ACG 3200	Acute Minor/Acute Major/Likely to Recur, Age > 11, w/o Allergy	7,442	6,238	8,879
ACG 3300	Acute Minor/Acute Major/Likely to Recur, Age > 11, with Allergy	6,738	5,083	8,931

Supplementary table 5: Continued

Variables	*Description*	*Odds Ratio*	*95% Confidence intervals*	
			Lower	**Upper**
ACG 3500	Acute Minor/Likely to Recur/Psychosocial	7,892	6,112	10,19
ACG 3600	Acute Minor/Acute Major/Likely Recur/Eye & Dental	14,665	11,933	18,024
ACG 3700	Acute Minor/Acute Major/Likely Recur/Psychosocial	12,683	9,929	16,202
ACG 3800	2-3 Other ADG Combinations, Age < 18	3,131	2,529	3,875
ACG 3900	2-3 Other ADG Combinations, Males Age 18 to 34	3,395	2,591	4,448
ACG 4000	2-3 Other ADG Combinations, Females Age 18 to 34	5,346	3,944	7,247
ACG 4100	2-3 Other ADG Combinations, Age > 34	4,34	3,762	5,007
ACG 4210	4-5 Other ADG Combinations, Age < 18, no Major ADGs	6,971	5,289	9,187
ACG 4220	4-5 Other ADG Combinations, Age < 18, 1+ Major ADGs	10,412	6,073	17,852
ACG 4310	4-5 Other ADG Combinations, Age 18 to 44, no Major ADGs	10,637	8,422	13,435
ACG 4320	4-5 Other ADG Combinations, Age 18 to 44, 1+ Major ADGs	7,881	5,954	10,432
ACG 4410	4-5 Other ADG Combinations, Age > 44, no Major ADGs	11,398	9,367	13,869
ACG 4420	4-5 Other ADG Combinations, Age > 44, 1+ Major ADGs	9,907	8,237	11,915
ACG 4430	4-5 Other ADG Combinations, Age > 44, 2+ Major ADGs	11,045	8,035	15,181
ACG 4510	6-9 Other ADG Combinations, with/without Major ADGs	29,765	25,175	35,192
ACG 5030	10+ Other ADG Combinations, with/without Major ADGs	76,667	45,043	130,493
Constant		0,195		

Odds Ratio's and Confidence Intervals of the variables in model 3 (including ACGs) are presented for outcome 2 (zero or one GP visit versus two or more GP visits).