

Supplemental Digital Content 1

Development and testing of compatible ICD-9-CM and ICD-10-CM diagnosis code lists for the Functional Comorbidity Index

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SUPPLEMENTAL TABLE S1. Concordance of Individual FCI Conditions and FCI (count of conditions) by ICD Lexicon

FCI condition	Data source									
	Dual-coded Washington State hospital discharge data (ages 18+)					Washington State workers' compensation data for allowed work-related conditions (ages 18+)				
	(N=2,351)					(N=6,528)				
	N cases*	Agreement %	Expected agreement %	Kappa	SE	N cases*	Agreement %	Expected agreement %	Kappa	SE
Arthritis	235	97.92	83.68	0.87	0.02	202	98.85	95.08	0.77	0.01
Osteoporosis	91	99.70	92.83	0.96	0.02	0 [†]	NC	NC	NC	NC
Asthma	208	99.45	84.33	0.96	0.02	2 [‡]	NS	NS	NS	NS
Chronic respiratory disease	257	98.38	81.80	0.91	0.02	1 [‡]	NS	NS	NS	NS
Angina	28	99.02	98.60	0.30	0.01	0 [†]	NC	NC	NC	NC
Congestive heart failure or heart disease	551	97.58	65.41	0.93	0.02	0 [†]	NC	NC	NC	NC
Myocardial infarction	228	98.81	83.45	0.93	0.02	1 [‡]	NS	NS	NS	NS
Neurological disease	171	99.74	86.73	0.98	0.02	6 [‡]	NS	NS	NS	NS
Stroke or transient ischemic attack	116	99.79	90.81	0.98	0.02	3 [‡]	NS	NS	NS	NS
Peripheral vascular disease	97	99.74	92.32	0.97	0.02	0 [†]	NC	NC	NC	NC
Diabetes	489	99.49	67.35	0.98	0.02	2 [‡]	NS	NS	NS	NS
Upper gastrointestinal disease	513	99.36	66.24	0.98	0.02	3 [‡]	NS	NS	NS	NS
Depression	424	98.00	71.72	0.93	0.02	250	99.30	93.29	0.90	0.01
Anxiety or panic disorder	308	98.85	78.08	0.95	0.02	133	99.62	96.38	0.89	0.01
Visual impairment	19	99.87	98.52	0.91	0.02	2 [‡]	NS	NS	NS	NS
Hearing impairment	133 [§]	NS	NS	NS	NS	6 [‡]	NS	NS	NS	NS
Back disease	94	99.36	92.91	0.91	0.02	468	98.67	87.84	0.89	0.01
Obesity	381	99.70	73.04	0.99	0.02	0 [†]	NC	NC	NC	NC
FCI (count of conditions)	NA	86.52	20.06	0.83	0.01	NA [¶]	96.52	77.24	0.85	0.01

Kappa interpretation: Values ≤ 0 indicate no agreement, 0.01–0.20 indicate none to slight, 0.21–0.40 indicate fair, 0.41–0.60 indicate moderate, 0.61–0.80 indicate substantial, and 0.81–1.00 indicate almost perfect agreement. P-values were uniformly $<.00005$.

*Number of cases identified by either lexicon

[†]Kappa not calculated (NC) due to 0 cases identified by either lexicon.

[‡]Kappa not shown (NS) due to very few cases identified by either lexicon.

[§]Although there were adequate cases, kappa is not shown (NS); on inspection, it was clear that hearing impairment had not been fully coded in this data set.

^{||}The FCI had 11 categories (0 to 10).

[¶]The FCI had 4 categories (0 to 3).

FCI indicates Functional Comorbidity Index; ICD, International Classification of Diseases; N, number; NA, not applicable; NC, not calculated; NS, not shown; SE, standard error.

SUPPLEMENTAL TABLE S2. Process, Decision Rules, and Rationale Guiding Development of Functional Comorbidity Index (FCI) ICD-9-CM and ICD-10-CM Diagnosis Code Lists

FCI category	Process/decision
Overall	Started with published FCI code lists, including the ICD-9-CM code lists developed by Kumar et al (2016), ¹¹ and the ICD-10-AM code list developed by Gabbe et al (2013). ¹⁶ We also obtained unpublished ICD-9-CM and ICD-10-CM code lists used by Marcum et al (2018). ¹⁴ Where there were discrepancies between these existing lists, we used Groll et al (2005) ¹⁰ to guide decisions based on original intent, scope, and FCI category descriptions. We also reviewed the FCI literature (including later articles co-authored by Groll ²³⁻²⁵) to check for conceptual/definitional drift or refinement.
Overall	Reviewed Charlson and Elixhauser ICD-9-CM and ICD-10 comorbidity code lists published by Quan et al (2005), ⁹ and added codes as indicated. The FCI focus on chronic conditions was intentionally maintained; i.e., acute condition codes were not added. (The FCI was developed to predict long-term functional status, while the Charlson and Elixhauser tools were developed for case-mix adjustment.)
Overall	Aimed to optimize concordance between codes included on the ICD-9-CM and ICD-10-CM lists, in order to facilitate (1) measurement continuity across the lexicon change and (2) use of data sets involving both lexicons.
Overall	Using code manuals for both lexicons ²⁷⁻²⁹ and the American Academy of Professional Coders online code converter, ³⁰ translated and back-translated all codes between ICD-9-CM and ICD-10-CM, and made adjustments to ensure concordance across lexicons.
Overall	Avoided expanding definitions where feasible. For example, neck was excluded from the back/degenerative disc disease category, due to differential impact on work disability and the presentation in Groll et al (2005) ¹⁰ of back pain as the condition that was originally validated; in contrast, Gabbe et al (2013) ¹⁶ modified this category to include degenerative disc disease whether neck or back. Some minor definitional expansions were necessary to ensure concordance across lexicons.
Overall	Focused on chronic comorbidity codes, and did not include codes for acute/subacute conditions (unless a particular diagnosis usually involved relevant long-term sequelae).
Overall	Focused on comorbidities affecting adults, but included some juvenile disease codes when likely to persist into adulthood (e.g., diabetes, rheumatoid arthritis).
Overall	To the extent feasible, included diagnosis-based rather than symptom-based codes per Groll et al (2005). ¹⁰
Overall	Did not include codes for complications when the code manual specified that the underlying disease should also be coded.
Overall	Did not list the same code in more than one FCI category.

Overall	Generally, did not list codes that were a common result of certain conditions, but where underlying cause was undetermined (e.g., did not include thrombosis codes in the peripheral vascular disease category).
Overall	Generally, did not focus on inclusion/exclusion of rare conditions or conditions unlikely to be present in an adult working population.
Arthritis	Included only arthritis specified as osteoarthritis or rheumatoid arthritis.
Osteoporosis	Did not include pathologic fracture codes in the ICD-9-CM list because they sometimes mapped to causes other than osteoporosis, but included osteoporosis both with and without current pathological fracture in the ICD-10-CM list.
Asthma	Included chronic obstructive asthma.
Chronic respiratory disease (chronic obstructive pulmonary disease, chronic respiratory distress, or emphysema)	Included obstructive chronic bronchitis, bronchiectasis (all obstructive), and chronic respiratory failure; excluded acute respiratory failure; added occupational chronic respiratory diseases based on review of Charlson/Elixhauser codes listed in Quan et al (2005). ⁹
Angina	Excluded ICD-10-CM codes for atherosclerotic heart disease with angina (included in congestive heart failure or heart disease category).
Congestive heart failure or heart disease	Included: heart failure, acute/chronic ischemic heart disease. Excluded: hypertension, arrhythmias, other acute/subacute heart disease, cardiomyopathy without heart failure, valve disorders.
Myocardial infarction (heart attack)	Included acute myocardial infarction and old (documented history of) myocardial infarction.
Neurological disease	Included: multiple sclerosis, Parkinson's, parkinsonism, Huntington's and other choreas, epilepsy and recurrent seizures, spinocerebellar disease, anterior horn cell disease. After review of Charlson/Elixhauser codes, we added: paralysis codes (unless already in the stroke or transient ischemic attack category, and cauda equina syndrome [344.6x/G83.4] was excluded as a repairable surgical emergency); cerebral palsy codes; Elixhauser codes for "other neurological disorders" except unspecified encephalopathy (348.3x/G93.4x, G32.89), subacute spinal cord degeneration in diseases classified elsewhere (336.2/G32.0), nonspecific speech disturbances (784.3/R47.x), and nonspecific convulsions (780.3x/R56.x). (In contrast, Gabbe et al [2013] ¹⁶ included the entire neurological disease chapter.)
Stroke or transient ischemic attack	Included: subarachnoid hemorrhage, intracerebral hemorrhage, cerebral infarction, transient ischemic attack, late effects/sequelae. Excluded: spinal infarction, retinal infarction, transient global amnesia. Relied heavily on the American Heart Association/American Stroke Association expert consensus document, Sacco et al (2013), ²⁶ but added a few codes to improve cross-lexicon concordance after translation/back-translation (G46.0, G46.1, G46.2, I67.84x).

Peripheral vascular disease	Included unspecified peripheral vascular disease, atherosclerosis of native arteries/bypass grafts of extremities. Excluded phlebitis/thrombophlebitis (could be acute and/or due to other cause).
Diabetes (type I or II)	Included primary and secondary diabetes mellitus.
Upper gastrointestinal disease	Included: reflux, esophagitis, gastritis, upper gastrointestinal ulcer. Excluded: hernia, gall bladder disease, bowel disease (e.g., Crohn's, ulcerative colitis, irritable bowel syndrome).
Depression	Included bipolar disorders (excluded codes indicating history of manic episodes only). Included the subset of affective personality disorder ICD-9-CM codes that mapped to F34.x in ICD-10-CM. Excluded adjustment disorders from both lexicons because ICD-10-CM doesn't distinguish acute vs chronic.
Anxiety or panic disorder	Included obsessive-compulsive disorder and post-traumatic stress disorder.
Visual impairment	Included blindness and low vision. Excluded visual disturbances (e.g., color blindness, correctable conditions). Groll et al (2005) ¹⁰ specifically mentioned this category as including cataracts, glaucoma, and macular degeneration. We excluded codes for these diseases because, in the presence of untreated/chronic visual impairment, there should also be codes for blindness and low vision.
Hearing impairment	Groll et al (2005) ¹⁰ specified this category as very hard of hearing, even with hearing aids; however, ICD codes don't indicate degree of hearing impairment or correction of hearing loss.
Back disease (degenerative disc disease, spinal stenosis, or severe chronic back pain)	Included: degenerative disc disease, displaced disc, spondylosis, spinal stenosis, sciatica, radiculitis, ankylosing spondylitis. Within these included codes: included codes specifying anatomic region as thoracic, lumbar, sacral, or unspecified, and excluded codes specifying anatomic region as coccyx, cervical, or cervicothoracic. Excluded: spondylolysis and spondylolisthesis (these were included by Marcum et al [2018] ¹⁴ in their ICD-10-CM list but not their ICD-9-CM list, and were not included by Gabbe et al [2013] ¹⁶ or Kumar et al [2016] ¹¹), nonspecific back pain.
Obesity (body mass index ≥ 30)	Included codes for BMI ≥ 30 (specified as > 30 in Groll et al (2005), ¹⁰ but ICD diagnosis codes for obesity included body mass index=30). Excluded overweight <30 BMI (in contrast to Kumar et al [2016] ¹¹).

FCI indicates Functional Comorbidity Index; ICD, International Classification of Diseases.

SUPPLEMENTAL TABLE S3. FCI Distribution by State, ICD Lexicon, and Calendar Quarter (2015)

State	<u>ICD-9-CM</u>		<u>ICD-10-CM</u>	
	<u>2015 Q1</u> Mean (SD)	<u>2015 Q2</u> Mean (SD)	<u>2015 Q3</u> Mean (SD)	<u>2015 Q4</u> Mean (SD)
Arizona	1.81 (1.59)	1.81 (1.60)	1.78 (1.61)	1.82 (1.64)
Colorado	1.76 (1.65)	1.77 (1.65)	1.74 (1.66)	1.74 (1.64)
Michigan	2.31 (1.82)	2.31 (1.82)	2.28 (1.83)	2.34 (1.86)
New Jersey	1.80 (1.58)	1.77 (1.58)	1.71 (1.57)	1.77 (1.60)
New York	1.78 (1.58)	1.76 (1.58)	1.71 (1.57)	1.76 (1.60)
Utah	1.49 (1.43)	1.46 (1.44)	1.44 (1.42)	1.51 (1.45)
Washington	1.94 (1.69)	1.91 (1.71)	1.84 (1.69)	1.87 (1.69)

FCI indicates Functional Comorbidity Index; ICD, International Classification of Diseases; Q, quarter, SD, standard deviation.

SUPPLEMENTAL TABLE S4. FCI Comorbidity Frequencies by ICD Lexicon and Calendar Quarter (2015)

FCI comorbidity	<u>2015 Q1</u>	<u>ICD-9-CM</u> <u>2015 Q2</u>	<u>2015 Q3</u>	<u>ICD-10-CM</u> <u>2015 Q4</u>	<u>2015</u> <u>All quarters</u>
	<u>(N=1,405,729)</u> Percent (n)	<u>(N=1,424,145)</u> Percent (n)	<u>(N=1,409,944)</u> Percent (n)	<u>(N=1,404,902)</u> Percent (n)	<u>(N=5,644,720)</u> Percent (n)
Arthritis	11.52 (162,003)	11.54 (164,331)	11.18 (157,695)	13.60 (191,025)	11.96 (675,054)
Osteoporosis	3.07 (43,150)	2.98 (42,487)	2.87 (40,441)	2.84 (39,831)	2.94 (165,909)
Asthma	9.78 (137,505)	9.63 (137,186)	9.36 (131,910)	9.06 (127,224)	9.46 (533,825)
Chronic respiratory disease	14.34 (201,605)	13.64 (194,266)	12.51 (176,408)	15.38 (216,092)	13.97 (788,371)
Angina	0.46 (6,440)	0.46 (6,549)	0.47 (6,568)	0.15 (2,079)	0.38 (21,636)
Congestive heart failure or heart disease	27.27 (383,274)	26.49 (377,208)	25.36 (357,516)	26.00 (365,232)	26.28 (1,483,230)
Myocardial infarction	8.22 (115,552)	8.07 (114,987)	7.83 (110,388)	8.00 (112,373)	8.03 (453,300)
Neurological disease	8.78 (123,368)	8.59 (122,389)	8.50 (119,876)	8.95 (125,786)	8.71 (491,419)
Stroke or transient ischemic attack	5.08 (71,371)	5.03 (71,672)	4.94 (69,581)	5.05 (71,015)	5.02 (283,639)
Peripheral vascular disease	4.42 (62,122)	4.46 (63,488)	4.27 (60,151)	4.23 (59,358)	4.34 (245,119)
Diabetes	24.68 (346,995)	24.53 (349,334)	24.14 (340,292)	24.46 (343,583)	24.45 (1,380,204)
Upper gastrointestinal disease	20.02 (281,454)	20.19 (287,595)	19.83 (279,612)	19.97 (280,567)	20.01 (1,129,228)
Depression	17.77 (249,756)	18.05 (256,998)	18.11 (255,398)	16.35 (229,640)	17.57 (991,792)
Anxiety or panic disorder	12.26 (172,370)	12.50 (177,969)	12.67 (178,681)	12.96 (182,051)	12.60 (711,071)
Visual impairment	0.98 (13,820)	0.98 (13,890)	0.97 (13,609)	0.97 (13,643)	0.97 (54,962)
Hearing impairment	1.70 (23,939)	1.69 (24,067)	1.67 (23,496)	1.62 (22,726)	1.67 (94,228)
Back disease	4.32 (60,730)	4.37 (62,286)	4.36 (61,448)	3.88 (54,533)	4.23 (238,997)
Obesity	14.10 (198,252)	14.43 (205,555)	14.12 (199,090)	14.34 (201,531)	14.25 (804,428)

FCI indicates Functional Comorbidity Index; ICD, International Classification of Diseases; Q, quarter.