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The development of a comorbidity index with physical function as the outcome

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Abstract

Background and Objectives: Physical function is an important measure of success of many medical and surgical interventions. Ability to adjust for comorbid disease is essential in health services research and epidemiologic studies. Current indices have primarily been developed with mortality as the outcome, and are not sensitive enough when the outcome is physical function. The objective of this study was to develop a self-administered Functional Comorbidity Index with physical function as the outcome.

Methods: The index was developed using two databases: a cross-sectional, simple random sample of 9,423 Canadian adults and a sample of 28,349 US adults seeking treatment for spine ailments. The primary outcome measure was the SF-36 physical function (PF) subscale.

Results: The Functional Comorbidity Index, an 18-item list of diagnoses, showed stronger association with physical function (model $R^2 = 0.29$) compared with the Charlson (model $R^2 = 0.18$), and Kaplan-Feinstein (model $R^2 = 0.07$) indices. The Functional Comorbidity Index correctly classified patients into high and low function, in 77% of cases.

Conclusion: This new index contains diagnoses such as arthritis not found on indices used to predict mortality, and the FCI explained more variance in PF scores compared to indices designed to predict mortality.

Keywords: Comorbidity; Index; Measurement; Physical function

1. Introduction

Physical function, health status, and perceived quality of life are important indicators, from the patient's perspective, of the success of medical and surgical interventions. As a result, condition-specific and generic measures of health are used ubiquitously to evaluate medical and surgical interventions [1]. However, in many types of research it is essential to adjust for other diseases, called comorbid diseases, in addition to the disease of concern, which may be related to the outcome(s) of interest. This is of particular importance in research conducted in older populations where many chronic illnesses may be present in the same patient [2–14]. Without this adjustment outcomes cannot be attributed to investigative interventions as the patients themselves may differ substantially in prognostic expectations due to their initial comorbid illnesses [2].

Prior comorbidity indices have been developed primarily to predict mortality or administrative outcomes such as length of stay in acute care or disease-specific populations [2,15–38]. These indices typically include diagnoses, often asymptomatic, such as hypertension, that are important in predicting mortality, and exclude diagnoses, such as arthritis, that impact physical function but are unlikely to result in short-term mortality. Research using indices designed to predict mortality have concluded that comorbid illnesses have little relationship with physical disability [39,40], a finding that seems intuitively false but underscores the need to consider the purpose for which an index was designed.

The purpose of this study was to develop a self-administered, general population index of comorbid diseases with physical function as the outcome of interest. The underlying premise was that diagnoses associated with physical function would be, at least in part, different from those associated with mortality, and therefore, an index designed with physical function as the outcome would perform better than indices designed with mortality as the outcome of interest.

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2. Methods

The Functional Comorbidity Index was developed in two stages.

2.1. Stage I: identifying potential factors associated with physical function

The strategy for item generation, using a published protocol [41], was to compile an extensive pool of items through a comprehensive literature review and focus groups of patients and clinicians.

2.2. Literature review

We updated a previous systematic review, published in 1999 by Stuck et al. [42], which identified risk factors for functional status decline in community-living elderly patients in journal articles published from 1985–1997 (the complete list of articles reviewed is available upon request). Our strategy, similar to that of Stuck, searched MEDLINE, EMBASE (Excerpta Medica), PSYCINFO (Psychological abstracts), and SOCA (Sociological abstracts). Keyword, title, and abstract were searched using the terms "aged," "disabled," "impaired," "limited," or "decline," in combination with "function," and "study" or "trial." Additional search terms included risk, lifestyle, quality of life, health status, geriatric assessment, and activities of daily living. Our updated search from 1998–2001 resulted in 35 studies in addition to the 78 identified by Stuck.

An attempt was made to identify any existing indices developed with physical function as the development outcome. Twenty-five [2,15–38] comorbidity indices were identified through MEDLINE using the search terms "comorbidity," "measurement," "index," in combination with "physical function," and "development." The search did not place limits on date of publication, but only articles published in French and English were reviewed. Severity of illness indices were excluded. Reference lists of the identified articles were examined, as were "related articles" identified by the MEDLINE search engine. All indices identified were developed with mortality or administrative outcomes (such as length of stay) as their primary endpoint. One index was found that was developed exclusively for stroke inpatients, with length of stay and disability as end points [33].

2.3. Focus groups

Six focus groups were conducted. Each focus group was limited to a maximum of 10 and a minimum of 6 participants [43]. Three focus groups consisted of members of the public who had to have at least one chronic illness, diagnosed by a physician. Participants needed to be adults (over age 18), and were excluded if they were unable to complete a 2-hr focus group, or unable to speak and understand English. In total, 8 male and 16 female members of the public participated.

The remaining three focus groups consisted of health care professionals (nurses, physicians, and rehabilitation therapists), and where possible, with at least one representative from the following fields: neurology, cardiology, orthopaedics, rheumatology, gerontology, physical medicine, psychiatry, respiratory medicine, family practice, or general internal medicine. All nurses ($n = 10$) and rehabilitation therapists ($n = 8$) were female; five physicians were male, and four were female. Participants were asked to identify activities of daily living that they (or their patients) have difficulty performing due to health problems. These were discussed and participants ranked them according to what they considered to be most important.

2.4. Stage II: development of index

The items generated through the focus groups and literature review were grouped according to clinical and diagnostic similarity. For example, "Chronic Obstructive Pulmonary Disease (COPD)" was grouped with other respiratory variables such as "asthma" and "emphysema." Nonspecific items (signs and symptoms) such as "shortness of breath" were excluded. After combining results from the focus groups and the literature review, 40 diagnoses remained (Table 1).

Table 1
Frequency of comorbid illnesses in the CaMos and NSN populations

	CaMos ($N = 9,423$)		NSN ($N = 28,348$)	
Comorbidities	*n*	%	*n*	%
Arthritis	3,097	32.9	6,488	22.9
Hypertension	2,668	28.4	5,469	19.3
Hearing impairment	1,024	10.9		
Upper gastrointestional disease	939	10.0	3,421	12.1
COPD	768	8.2	1,685	5.9
Osteoporosis	723	7.8	1,594	5.6
Angina	685	7.3		
Anemia			872	3.1
Depression	668	7.1	5,232	18.5
Diabetes	640	6.8	1,879	6.6
MI	587	6.2		
Asthma	541	5.7	102[c]	4.3
Bowel disease	539	5.7	1,606	5.7
Dementia	528	5.6		
Peripheral vascular disease	528	5.6	875	3.1
Visual impairment	511	5.4	55[c]	3.2
Cancer	494	5.2	1,008	3.6
Anxiety	492	5.2	43[c]	1.8
Stroke/TIA	359	3.8		
Neurologic disease	254	2.7	645	2.3
Liver disease	235	2.5	345	1.2
Congestive heart failure (CHF)	213	2.3	3,185	11.2[a]
Kidney disease	140	1.5	398	1.4
Migraine	43	0.5	5,597	19.7[b]
Back pain			19,466	68.7

Abbreviations: COPD, chronic obstructive pulmonary disease; MI, myocardial infarct; TIA, transient ischemic attack.

[a] Includes all heart disease, not only CHF.

[b] Coded as "frequent headaches" not migraine.

[c] From a subsample on which additional comorbidity data was collected, $n = 2,348$.

A diagnosis-based, rather then a symptom-based, index was developed for two primary reasons. First, symptoms and signs are less specific and can be subjective, so that one disease may have many symptoms (heart disease may have pain, shortness of breath, and/or dizziness) or one symptom may be associated with many diseases (pain is associated with numerous diagnoses, and is subjective in nature). Second, diagnostic based indices can be more readily adapted for use with administrative databases, as diagnoses are usually what is coded and collected.

Two databases were used to develop the Functional Comorbidity Index. The Canadian Multi Centre Osteoporosis Study (CaMos) [44] is a simple random sample of the adult Canadian population designed to identify predictors of osteoporosis. The CaMos population consists of 9,423 noninstitutionalized individuals 25 years of age and older, selected at random by using random digit dialing. Females were over sampled 2:1. Data were collected using an in-person, interviewer–administered questionnaire, with over 900 variables including sociodemographic information, personal and family (parents, children, and sibling) medical history, diet, exercise, lifestyle information, and the SF-36 [45,46].

Of the 40 identified diagnoses from the literature and the focus groups, 27 were present in the CaMos database. CaMos health information was derived from medication lists provided by the patient and gathered by self-report. Patients answered yes, no, or don't know to "has a doctor ever told you that you have any of the following conditions." Patients were considered to be suffering memory loss if they scored below 26 of 30 on the Mini Mental State Exam [47], or described their usual ability to remember things as "unable to remember anything at all," or their usual ability to think and solve day-to-day problems as "unable to think and solve day-to-day problems." Patients were considered to have impaired vision if they stated they were unable to see ordinary newsprint or recognize a friend on the other side of the street even with glasses or contact lenses. Similarly, patients were considered to be hearing impaired if they were unable to hear a conservation in a group or in a quite room, even with a hearing aid.

The second database was obtained from National Spine Network (NSN) [48], a nonprofit organization with a nationwide membership including academic institutions, hospitals, private physician practices, and individual physicians. The NSN database contains demographic, employment, and comorbidity information, in addition to the SF-36, on 28,349 patients from 26 participating centres in the United States. Comorbidity information was collected by patient self-report, with patients answering "yes" or "no" to the question "do you have this problem?" The NSN database contained six diagnoses missing from the CaMos database. Of the 40 diagnoses from Stage I, only schizophrenia, amputation, spinal cord injury, fibromyalagia, polio, hernia, and HIV/AIDS were not in either database.

Individual diagnoses that were combined in either of the original databases were then collapsed into categories for analysis. For example, arthritis contains osteoarthritis and rheumatoid arthritis, diabetes contains types I and II, neurologic disease contains Multiple Sclerosis and Parkinson's, resulting in 25 independent variables.

The physical function subscale of the SF-36 [45,46] Version I was chosen as the dependent variable as it is widely used in studies of long-term general health status as a functional status outcome measure, and has been found to be significantly associated with other measures of general and condition specific physical function [49,50]. The SF-36 questionnaire is a validated, 36-item, generic health status measure with eight subscales of physical functioning, role physical, role emotional, emotional well-being, energy, general health, pain, and mental health. The Physical Function subscale of the SF-36, made up of 10 items relating to walking, climbing stairs, lifting, and bathing and dressing.

2.5. Analyses

All analyses were performed using Excel (Microsoft Corp.) and SPSS (Chicago, IL) version 10.1. Independent variables significantly associated (Spearman's correlation coefficient, $p < .1$) with the PF subscale score were then included in the regression analysis. Using the physical function subscale of the SF-36 as the dependent variable and the diagnoses identified in the CaMos database, multiple linear regression models were developed using forward, backwards, and stepwise independent variable entry, with a cutoff p-value = .05. Comorbid illnesses were treated as binary, 1 = present, 0 = absent.

This process was then repeated using the NSN database to identify any significant variables associated with physical function that were not present in the CaMos database. The SF-36 Physical Function subscale was used as the outcome.

Multicollearnity in the final model was tested using eigen values and condition indices. None of the independent variables were found to be highly correlated, and thus multicollinearity was not identified.

The ability of the index to correctly classified patients with "high" and "low" physical function was determined using SPSS discriminant analysis. Individuals were dichotomized into "low" function, if they scored 66 or less on the SF-36 physical function subscale, and "high" as everyone else. This cutoff point was chosen as five point difference in PF score has been identified as clinically significant change [46], and we wanted to ensure there would be meaningful difference between groups.

Receiver Operator Curves (ROC) were also analyzed using different cutpoints for the SF-36 physical function subscale to examine the impact on the performance of the index. Cutoff points tested ranged from 55 to 75, with the area under the curve increasing as the physical function scores decreased.

The amount of variance in the SF-36 physical function score explained by the FCI, and two other commonly used

indexes; the Kaplan-Feinstein [2] Index (KFI), and the Charlson [17] index (CI), was compared using the CaMos database. The KFI had been developed to predict 5-year mortality in a cohort of male diabetic patients and contains 12 categories of conditions. Within each category a severity rating of 0–3 is assigned based on severity of symptoms. The CI was developed in a cohort of 559 internal medicine patients to predict 1-year mortality. The CI contains a list of 19 conditions each of which is given a weighting of 1 to 6. Weights are based on the adjusted relative risks from the Cox proportional hazard regression model used in the development of the index.

Scores were calculated using the methods identified in their original papers (Charlson [17] and Kaplan-Feinstein [2]). As the data collected in CaMos does not include severity it was assumed that patients were on the mild end of the disease spectrum whenever a choice was required (as in mild vs. moderate or severe liver disease, and diabetes vs. diabetes with end-organ damage). Similarly the scoring of the Kaplan-Feinsten index suffers from the inability to rate severity based on the information in the databases, so where a disease was present, in the absence of other information, it was given a "cogent severity" of 1. Uncertainty about severity is common to all secondary or administrative databases.

In all analyses, Body Mass Index (BMI), was used as a measure of obesity and was calculated by taking weight in kg divided by height^2 in meters (w/h^2). BMI score was then dichotomized with a score of $\geqslant$30 as obese and $<$30 as nonobese.

2.6. Ethics

This protocol received ethical approval from the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board and the University of Toronto Research Ethics Board.

3. Results

Forty unique diagnoses were identified in both literature review and focus groups (Table 1). Table 2 shows the demographic characteristics of participants in the CaMos and NSN patients. The average age of CaMos participants was 62 years (range 25 to 103 years), while the average age of NSN patients was 49 years (range18 to 97 years). Six thousand seven hundred thirty-four (71.5%) of the CaMos patients and 19,362 (68.3%) of the NSN patients had at least one comorbid illness and the mean number of diagnoses was 1.7 (SD 1.7) and 1.7 (SD 1.9), respectively.

3.1. Index development

Multiple linear regression identified seventeen variables from the CaMos database that were significantly ($p < .001$) associated with the SF-36 physical function score (adjusted $R^2 = 0.28$); arthritis, osteoporosis, asthma, chronic obstructive pulmonary disease (COPD), angina, congestive heart failure (CHF), prior heart attack (MI), neurologic disease (multiple sclerosis, Parkinson's disease), prior stroke or transient ischemic attack (TIA), peripheral vascular disease (PVD), diabetes, upper gastrointestinal disease (including ulcers and gastroesophageal reflux), depressed mood, anxiety, visual impairment, hearing impairment, and obesity (see Table 3).

Diagnoses available in the NSN that were found to be significantly correlated with physical function (Spearman's $p < .1$) were entered into multiple linear regression (Table 4). The adjusted R^2 for the NSN model was 0.12. Back pain, the only variable of those entered that was collected in the NSN but not in the CaMos database, was found to be significantly associated with physical function ($p < .001$), and was included in the final Functional Comorbidity Index (Table 5).

Although not considered comorbidities, both age and gender were also evaluated in the regression analysis. Age increased the adjusted R^2 from 0.28 to 0.33; adding age and gender increased it to 0.34.

3.2. Scoring

The Functional Comorbidity Index was scored as both a simple count (yes/no) and a weighted count of the diagnoses. "Weights" were derived from the standardized beta coefficients from the regression analysis (see Table 4). The standardized beta coefficients show the relative importance of each variable in the model, for example, instead of assigning a "1" for each occurrence of disease, arthritis was assigned 0.221 and COPD was assigned 0.071, thereby giving arthritis more "weight."

The comorbidity scores for each patient, derived by a simple count and then derived from a weighted count, were entered into separate multiple linear regression analysis with physical function as the outcome variable. Using the simple count and the weighted count of patient comorbidities provided similar results in terms of variance explained (simple count model $R^2 = 0.28$ vs. weighted count model $R^2 = 0.30$), and thus, for ease of use we chose and report the simple count of the number of comorbidities.

The Functional Comorbidity Index scores were correlated with both the SF-36 physical function and role physical subscale scores ($-.53$, $p < .0001$, and $-.31$, $p < .0001$), respectively. When the SF-36 physical function subscale score was dichotomized into "high" and "low," the Functional Comorbidity Index simple count correctly classified 76.6% of people, whereas using a weighted count, the Functional Comorbidity Index correctly classified 77.0%.

Compared with the Charlson [17] and Kaplan-Feinstein [2] indices The Functional Comorbidity Index accounted for more variation in the physical function subscale scores ($R^2 = 0.29$, 0.18, and 0.07%, respectively).

Table 2
Characteristics of the CaMos and NSN populations

Characteristic	CaMos *N* (%)	NSN *N* (%)
Male	2,884 (30.6)	14,970 (52.8)
Female	6,539 (69.4)	13,379 (47.2)
Mean age(SD, range)	62.1 (13.4, 25–103)	49.0 (15.3, 18–97)
Mean number of comorbid Illnesses (mean, SD, range)	1.7 (1.7, 0–11)	1.7 (1.9, 0–21)
Race (Caucasian)	8,941 (94.9)	23,860 (84.0)
Single/widowed/divorced (Yes)	2,830 (30.0)	8,002 (31.0)
Education		
Less than high school	1,205 (12.8)	2,676 (10.3)
High school	5,597 (59.4)	14,698 (56.6)
After high school	2,620 (27.8)	8,561 (32.0)
Employment status		
Employed (full or part-time)	3,227 (34.2)	12,284 (43.3)
Not employed (home maker, student, unemployed)	1,799 (19.1)	7,575 (26.7)
Disability	139 (1.5)	4,910 (17.3)
Retired	4,253 (45.1)	3,761 (13.4)
Mean SF-36 scores (SD, range)		
Physical functioning	76.1 (24.6, 0–100)	43.0 (28.5 0–100)
Role physical	76.5 (36.8, 0–100)	17.1 (31.3, 0–100)
Bodily pain	72.9 (24.2, 0–100)	29.8 (21.1, 0–100)
General health	74.0 (18.7, 0–100)	59.1 (22.9, 0–100)
Energy	64.3 (19.4, 0–100)	38.8 (22.5, 0–100)
Social functioning	86.4 (20.7, 0–100)	50.8 (29.5, 0–100)
Role emotional	84.7 (31.1, 0–100)	57.1 (44.5, 0–100)
Mental health	78.8 (15.2, 0–100)	63.5 (21.8, 0–100)
PCS	46.35 (11.2, 1.8–73.8)	30.6 (9.7, 6–65)
MCS	51.7 (9.96, 2.6–75.6)	N/A

Abbreviations: CaMos, Canadian Multi Centre Osteoporosis Study; NSN, National Spine Network; PCS, Physical Component Subscale; MCS, Mental Component Subscale.

4. Discussion

The Functional Comorbidity Index was developed specifically for use in the general population with physical function, not mortality, as the outcome of interest. The Functional Comorbidity Index can be used to adjust for the effect of comorbidity on physical function in the same manner that other indices are used to adjust for the effect of comorbidity on mortality. The Functional Comorbidity Index contains diseases such as visual impairment, osteoporosis, and arthritis, which do not appear in indices such as the Charlson or the Kaplan-Feinstein. These differences in diagnoses may explain why prior studies concluded that comorbidity has little relationship with physical function [40,41] and that the development of an index with physical function as an outcome has been suggested [51]. One index, the "Comorbidity Scale for Stoke Outcomes" (CSSO) [33], which, in addition to length of hospital stay, identifies Functional Independence Measure (FIM) scores as an outcome. However, the CSSO was developed specifically for stroke inpatients and hospital-based rehabilitation outcomes, and thus did not diminish the need for a population-based general comorbidity index.

The Functional Comorbidity Index (Table 5) contains 18 diagnoses scored by adding the number of "yes" answers, with a score of 0, indicating no comorbid illness, and a score of 18, indicating the highest number of comorbid illnesses. The weighted count did not perform much better, and simple counts would be much easier to score and use. The FCI does not take into consideration the severity of the diagnoses. Authors debate the usefulness of severity in terms of explanatory power against the additional cost and potential for further misclassification. It is agreed that severity ratings are likely to provide better adjustment, but that the documentation of symptoms and disease severity varies greatly, and many clinicians do not use structured severity ratings. Similarly, indices that weight individual items using population-derived coefficients have been found to be less accurate when transporting the index to a different population [52].

The relationship of the Functional Comorbidity Index to physical function was evaluated using percent of variance explained and ability to correctly classify into high and low function. The ability of the Functional Comorbidity Index to account for variance in physical function score was comparable or better than other comorbidity indices ability to account for variance in mortality. For example, the Charleson index accounted for 19.5% of variance in breast cancer mortality [17], and the Index of Coexistent Disease (ICED) [24], previously recommended for adjustment of comorbid disease when functional status is the outcome of interest [53], accounted for 14% of the variance in the occurrence of serious in hospital complications and only 7% of the variance in functional status scores of patients after hip replacements

Table 3
Results of multiple linear regression showing the CaMos variables and their relative association with physical function score

Variable	Standardized beta coefficient	Significance *p*-value
Arthritis	−0.221	<.0001
Osteoporosis	−0.152	<.0001
Stroke/TIA	−0.116	<.0001
Heart attack	−0.101	<.0001
Neurologic disease	−0.100	<.0001
Hearing impairment	−0.098	<.0001
Angina	−0.097	<.0001
Obese (BMI >30)	−0.096	<.0001
Vision impairment	−0.093	<.0001
Diabetes	−0.083	<.0001
COPD	−0.079	<.0001
Congestive heart failure	−0.071	<.0001
Peripheral vascular disease	−0.065	<.0001
Anxiety	−0.059	<.0001
Asthma	−0.047	<.0001
Upper gastrointestinal disease	−0.043	<.0001
Depression	−0.041	<.0001

Abbreviations: BMI, body mass intex; CaMos, Canadian Multi Centre Osteoporosis Study; COPD, chronic obstructive pulmonary disease; TIA, transient ischemic attack.

Adjusted $R^2 = 0.29$.

Negative beta coefficients indicate an inverse relationship with physical function, that is, the presence of arthritis is associated with a decreased physical function score.

[24]. However, the ICED was developed to predict multiple outcomes including in-hospital complications and length of stay [24], and requires trained personnel to administer the index. The strength of association (correlation coefficient = 0.53) of the Functional Comorbidity Index with physical function is also similar to the association of the CSSO [33], the Chronic Disease Score [21], and the General Medical Health Rating (GMHR) [35] with mortality (correlation coefficient −0.45, 0.46, and 0.47, respectively).

Table 4
Results of multiple linear regression showing the NSN variables and their relative association with physical function score

Variable	Standardized beta coefficient	Significance *p*-value
Obesity (BMI >30)	−.146	<.0001
Back pain	−.141	<.0001
Depression	−.115	<.0001
Arthritis	−.100	<.0001
Osteoporosis	−.062	<.0001
Lung disease	−.054	<.0001
Diabetes	−.050	<.0001
Heart disease	−.044	<.0001
Nervous system disorders	−.037	<.0001
Circulatory system disorders	−.036	<.0001
Ulcer or stomach disease	−.032	<.0001

Abbreviations: BMI, body mass index; NSN, National Spine Network.

Adjusted $R^2 = 0.12$.

Negative beta coefficients indicate an inverse relationship with physical function, that is, the presence of arthritis is associated with a decreased physical function score.

Table 5
The functional comorbidity index

1	Arthritis (rheumatoid and osteoarthritis)
2	Osteoporosis
3	Asthma
4	Chronic obstructive pulmonary disease (COPD), acquired respiratory distress syndrome (ARDS), or emphysema
5	Angina
6	Congestive heart failure (or heart disease)
7	Heart attack (myocardial infarct)
8	Neurological disease (such as multiple sclerosis or Parkinson's)
9	Stroke or TIA
10	Peripheral vascular disease
11	Diabetes types I and II
12	Upper gastrointestinal disease (ulcer, hernia, reflux).
13	Depression
14	Anxiety or panic disorders
15	Visual impairment (such as cataracts, glaucoma, macular degeneration)
16	HearingiImpairment (very hard of hearing, even with hearing aids)
17	Degenerative disc disease (back disease, spinal stenosis, or severe chronic back pain)
18	Obesity and/or body mass index >30 (weight in kg/height in meters^2) height_____(cm or inches?) weight_____(kg or lbs?) BMI =

Abbreviations: TIA, transient ischemic attack.

The study has potential limitations. First, this study relied on secondary data sources for development, and thus may have overlooked some diagnoses associated with functional status. For example, HIV/AIDS was not explicitly collected in either database, and may contribute significantly to functional disability. Future prospective studies that include other patient groups need to be conducted; however, no index can include all possible diagnoses because feasibility and ease of administration will always conflict with exhaustiveness. Lack of comprehensiveness is an issue for all comorbidity indices including those that have mortality as an outcome. For example, a disease such as Ebola has extremely high mortality rates but occur so infrequently that they do not warrant inclusion in any index of mortality. Acknowledging the limitations of using secondary data sources, that is, missing variables, these two databases covered the majority of diagnoses identified in the focus groups and the literature. However, the Functional Comorbidity Index includes most of the common diagnoses found in two large, multisite, national, general databases that encompassed the population and the outcome measure of interest. Future validation of the FCI for prediction needs to occur using a prospective cohort, with comprehensive ascertainment of all comorbidities.

The use of cross-sectional data is limiting in that a cross-sectional study design makes it impossible to determine a causal relationship between the comorbidities and the functional status. However, because the purpose of the index is primarily for adjustment, determination of causation is not

essential. A longitudinal study of the comorbidity index is needed to validate the Functional Comorbidity Index and determine if the Functional Comorbidity Index will predict future function.

The third potential limitation was the use of the SF-36 as the measure of physical function. The SF-36 was chosen due to its widespread use in current health services research. Furthermore, studies [1,15] have shown that the SF-36 physical function subscale is highly correlated with other measures of physical function and other quality of life measures, suggesting that other measures of physical function would have obtained similar results. However, future prospective studies using other means of measuring physical function are required.

In summary, the Functional Comorbidity Index, the only known index designed with physical function, is the explicit outcome of interest. The Functional Comorbidity Index contains diagnoses such as arthritis and asthma, not commonly found in existing comorbidity indices and accounts for more of the variance in physical function scores than indices developed with mortality as an end point. It demonstrates similar strength of association with physical function as other indices do with mortality, and is easy to administer and score. The FCI is currently undergoing further validation and should be a useful tool for both health professionals and researchers.

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