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Original Research

Incremental predictive value of intrinsic capacity and environmental characteristics in the risk prediction of incident disability

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A R T I C L E I N F O

Keywords:
Incremental predictive value
Intrinsic capacity
Environmental characteristics
Risk prediction
Disability

A B S T R A C T

Objective: To examine the incremental value of intrinsic capacity (IC) and environmental characteristics in the risk prediction of disability.
Method: Secondary analysis was performed on a longitudinal sample of individuals aged 50 years or above. The selected subsample was ambulant and cognitively intact, and did not have any disabilities in instrumental activities of daily living (IADL) at baseline. A set of 18 indicators were first used to assess conditions associated with declines in IC and environmental characteristics. Participants were then followed up for approximately one year, and the IADL status (i.e., disabled or not) was treated as the outcome variable in the logistic regression models. The incremental predictive value of IC was examined by comparing the baseline model that only included traditional risk factors (e.g., health conditions and lifestyle factors), against the full model that also included the aforementioned 18 indicators. The comparison was performed using the change in area under the receiver operating characteristic curve (ROCAUC) and the continuous net reclassification index (NRI).
Results: Among 10,993 participants (mean age = 73.3, 82.1 % women), 680 (6.2 %) developed disability during the concerned period. The full model significantly outperformed the baseline model, with the ROCAUC improving from 0.707 to 0.729 (change = 0.021; 95 % CI: 0.013–0.030). The continuous NRI was 0.361 (95 % bootstrap CI: 0.280–0.450).
Conclusions: Measurements of IC and environmental characteristics have a significant incremental value in predicting disability. In practice, the full model can be implemented as a calculator for identifying older populations at risk of disability in the community settings.

1. Introduction

With life expectancy increasing over the last decades, promotion of healthy ageing also becomes more important, because living longer does not entail that the added years are accompanied by healthy lives [1,2]. As age increases, numerous physiological changes occur, some of which may manifest as decreased physiological reserve and increased risk of disability. Limitations in activities of daily living (ADL; e.g., bathing, dressing, and toileting) and instrumental ADL (IADL; e.g., using the phone, shopping, and preparing meals) are considered the major and most prominent forms of disability [3], which can predict dependence and admission to nursing homes [4]. For this reason, a considerable amount of studies were conducted to identify the risk factors of ADL and IADL disabilities, such that targeted preventive interventions can be provided in a more timely and efficient manner. Traditionally, risk factors under consideration included medical conditions (e.g., hypertension and diabetes), lifestyle behaviours (e.g., smoking and physical activity), falls, prior history of hospital admissions, and polypharmacy [5–11]. Notwithstanding the significance and merits of these studies, especially in terms of the development of risk prediction algorithms, they did not incorporate the concept of intrinsic capacity (IC) and environmental characteristics, which have been heavily advocated by the World Health Organization (WHO) in recent years for their relevance and importance to promoting healthy ageing.

Introduced in 2015, IC is defined as “the composite of all the physical and mental capacities that an individual can draw on.”[12] According to this definition, IC determines, in conjunction with environmental characteristics, an individual’s functional ability, which is the “health-related attributes that enable people to be and to do what they value.” IC can be conceptually decomposed into five domains, namely cognitive, locomotor, sensory, vitality, and psychological [13], and its construct has been validated in various cohort studies [14–17]. Following the

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WHO's philosophy, it is conceivable that IC and environmental characteristics may be valuable to various risk prediction models of disability. However, to the best of our knowledge, the incremental predictive value of IC and environmental characteristics with respect to traditional risk factors considered in clinical practice has not been widely examined. In addition, most of the previous studies on the association between IC and disability were confined to older populations (e.g., adults aged 65 years or above), which did not fully appreciate the fact that IC is a concept closely tied with the life-course approach, and that IC tends to decline from midlife onwards and thereby may result in disability at much earlier ages [12].

To improve strategies for primary prevention of disability and promoting healthy ageing, and to extend the applicability of risk prediction models to populations at midlife, this study examined the incremental value of conditions associated with declines in IC in conjunction with environmental characteristics related to neighbourhood facilities in predicting incident IADL disability in a sample of community-dwelling adults aged 50 years or above. It was hypothesized that adding measurements of IC and availability of neighbourhood facilities would significantly improve the predictive performance beyond traditional risk factors.

2. Methods

2.1. Data and participants

The sample was drawn from an ongoing community-based primary care project, consisting of Chinese individuals aged 50 years or above who were members of various elderly centres in Hong Kong. A total of 157 centres were included (out of 251), which were distributed across all 18 districts in Hong Kong [18]. Briefly, the project was designed to apply digital technologies to empower older people in health management, as well as to promote integrated care and primary health services. The longitudinal cohort employed in the present study was part of the project aiming to identify and monitor the needs of older people. Baseline data was collected for 31,856 individuals during March 1 to November 30, 2023. The follow-up measurement was intended to be conducted nine to 15 months after the baseline one. In other words, the possible period of conducting a valid follow-up measurement started on December 1, 2023, and will continue until February 28, 2025. For this study, data collected as of August 31, 2024, was retrieved for analysis.

The inclusion criteria of the present study are as follows. At baseline, participants should not have disability in any of the IADL items (see subsequent section), should be able walk independently, should not have moderate or severe cognitive impairment, should not be receiving disability allowance under the Social Security Allowance Scheme, and should have complete data in all variables under consideration (see subsequent section). As regards the follow-up, the measurement interval should fall within nine to 15 months, and participants should have complete data in all IADL items. The flow of participants is shown in Figure S1. The study was approved by the Survey and Behavioral Research Ethics Committee of The Chinese University of Hong Kong. All participants have given informed consent.

2.2. Disability outcome

The outcome measure was incident IADL disability at follow-up. IADL disability was assessed at both baseline and follow-up, using five items (i.e., telephoning, use of transportation, shopping, food preparation, and financial behaviour) extracted from the Lawton's IADL scale [19] with a modified anchor and scoring system. For each item, participants were asked if they were able to complete the corresponding daily task independently, or with occasional help, or if they were completely unable to do so, in the last three months. The latter two response categories were used to indicate IADL disability.

2.3. Traditional risk factors

A number of traditional risk factors were selected, based on published evidence, to establish the baseline risk prediction model for comparison. These included sociodemographic factors, health conditions, lifestyle factors, prior hospital services utilization and medication use [5–11]. Regarding sociodemographic factors, six indicators were included, namely age, gender, marital status (categorized as married or not married), educational attainment (categorized as no formal schooling, primary, secondary, or tertiary), financial assistance status (categorized as recipient or non-recipient of financial assistance under the Comprehensive Social Security Assistance (CSSA) Scheme, and perceived financial adequacy (categorized as very inadequate, inadequate, just enough, or adequate or very adequate). Regarding health conditions, participants reported whether they were diagnosed by a western medical practitioner as having each of the following chronic diseases: hypertension, diabetes, high cholesterol, heart disease, stroke, chronic obstructive pulmonary disease (COPD), and renal disease. Regarding lifestyle factors, participants reported the amount of time that they spent in moderate physical activities (categorized as <150 or ≥150 min/week). Regarding prior hospital services utilization, participants reported whether they had been hospitalized in the previous 12 months. Last, regarding medication use, participants reported the total number of drugs that they were currently taking (categorized as none, 1–4, or ≥5).

2.4. Conditions associated with declines in IC

With reference to the WHO ICOPE screening tool [20], conditions associated with declines in IC were assessed using a set of 13 items, 12 of which were used to represent the five IC domains, and the remaining one of which was used to capture urinary incontinence. First, the cognitive domain was assessed with a brief memory test that requires the participants to recall three words (categorized as being able to recall all three words or not) and two questions related to orientation in time and space, namely "what is the full date today?" and "where are you now (home, clinic, etc.)?" (categorized as being able to answer both questions correctly or not). Second, the locomotor domain was assessed with the chair stand test (categorized as being able to finish the test within 12 sec or not) [21] and a yes-no question "do you have any difficulty walking several hundred yards alone and without aids?" Third, the vitality domain was assessed with three yes-no questions, namely "have you unintentionally lost 3 kgs over the last three months?", "have you experienced loss of appetite?" and "did you feel tired most of the time during the past 4 weeks?" Fourth, the sensory (vision) domain was assessed using a Likert item "do you see things clearly?" (1 = very poor, 6 = very good), whereas the sensory (hearing) domain was likewise assessed using the Likert item "do you hear things clearly?" (1 = very poor, 6 = very good). Both Likert items were further dichotomized into two categories, namely <4 and ≥4. Fifth, the psychological domain was assessed with two yes-no questions for capturing depressive symptoms, namely "over the past two weeks, have you been bothered by feeling down, depressed or hopeless?" and "over the past two weeks, have you been bothered by little interest or pleasure in doing things?", as well as with the Generalized Anxiety Disorder 2-item (GAD-2) for capturing anxiety symptoms, namely "over the last two weeks, how often have you been bothered by feeling nervous, anxious or on edge?" and "over the last two weeks, how often have you been bothered by not being able to stop or control worrying?" (0 = not at all, 1 = several days, 2 = more than half the days, 3 = nearly every day). The GAD-2 score, which ranged from 0 to 6, was then obtained by summing the scores of the two constituent items [22]. Last, urinary incontinence was assessed with a yes-no question "do you experience urine leakage related to urgency?" All of the above items were measured at both the baseline and follow-up, but only the former ones were considered in the participant inclusion criteria and subsequent analyses.

2.5. Environmental characteristics

Following the approach adopted by some of the previous studies [23,24], availability of neighborhood facilities was used as the representative of environmental characteristics. It was operationalized by the number of facilities located within the corresponding district of each participant's affiliated community elderly centre. Five types of facilities were counted, including parks, indoor sport centres, outdoor fitness corners, public libraries, and primary healthcare clinics.

2.6. Statistical analysis

Logistic regression was used to model incident IADL disability. To examine the incremental predictive value of IC and environmental characteristics, two models were constructed. The baseline model only included traditional risk factors, whereas the full model also included the 13 variables related to declines in IC and the five variables related to availability of neighbourhood facilities. The comparison was performed using two widely known metrics, namely the change in area under the receiver operating characteristic curve (ROCAUC) and the continuous net reclassification index (NRI). In essence, this continuous version of NRI indicates whether, among individuals who actually developed incident IADL disability, the full model predicted a higher risk than the baseline model, and vice versa. In addition, sensitivity analysis was performed to examine whether the results were robust with respect to how the possible follow-up period was defined. To this end, all analyses were repeated using an alternative sample in which the window of follow-up period was set to be narrower (i.e., 10 to 14 months). All statistical analyses were performed using the SPSS (version: 28.0.1.0) and R. A *p*-value of <0.05 was considered statistically significant.

3. Results

3.1. Basic characteristics of participants

Table 1 shows the individual-level (i.e., not including availability of neighbourhood facilities) baseline characteristics of participants. A total of 10,993 participants (mean age = 73.3, 82.1 % women) were retained in the final sample. At baseline, it was not uncommon for participants to be already experiencing some forms of IC declines. For instance, about 25.7 % of participants failed to complete the memory test for the cognitive domain. During a mean follow-up period of 342.6 days, 680 participants developed IADL disability, implying an incident rate of 6.2 %. Among them, 255 (37.5 %) reported disability in more than one IADL items. Comparison of baseline characteristics between those with and without incident disability was also shown in the table.

3.2. Predictors of incident IADL disability

Table 2 shows the odds ratios and the corresponding 95 % confidence intervals for the predictors included in the baseline and full models, respectively. In the baseline model, older age, women, having diabetes, having stroke, having COPD, prior hospital services utilization, and taking more medications were significantly associated with incident IADL disability (all *ps* < .05). In the full model, in addition to some of the aforementioned traditional risk factors, many IC indicators (at least one from each domain) were also identified as significant predictors of incident IADL disability. These included poor orientation in time and space, inability to complete the chair stand test, difficulty in walking several hundred yards, self-perceived fatigue, hearing impairment, and anxiety symptoms (all *ps* < .05). Urinary incontinence was also a significant predictor ($p = .019$). Furthermore, the number of outdoor fitness corners and public libraries were significantly and negatively associated with the risk of developing disability (all *ps* < .05).

3.3. Incremental predictive value of conditions associated with declines in IC

The predictive performances of the baseline and the full models are shown in Fig. 1. The full model significantly outperformed the baseline model, with the ROCAUC improving from 0.707 to 0.729 (change = 0.021; 95 % CI: 0.013–0.030). The continuous NRI was 0.361 (95 % bootstrap CI: 0.280–0.450). Results of the sensitivity analysis (n = 7,798) showed that the incremental predictive value was quite robust with respect to how the follow-up period was defined, with the corresponding ROCAUC improving from 0.703 to 0.725 (change = 0.021; 95 % CI: 0.011–0.031), and the continuous NRI being 0.319 (95 % bootstrap CI: 0.254–0.462) (Figure S2).

4. Discussion

Predicting the risk of disability is essential to preventing functional decline and promoting healthy ageing. Using data from a community-based cohort study in Chinese adults aged 50 years or above, it was found that conditions associated with declines in IC as well as availability of neighbourhood facilities demonstrated their abilities in predicting incident disability at an approximate one-year time interval, on top of other traditional risk factors that have already been widely adopted in clinical practice and social care services. This finding adds to the growing body of evidence on the predictive value of IC and environmental factors, and reinforces the importance of these concepts. It also suggests that incorporating IC-related conditions and availability of neighbourhood facilities is useful for disability risk stratification, which has great potential in informing and guiding intervention strategies in this regard.

Many previous prospective studies have shown that IC measurements provide predictive information about the risk of developing disability [25–29]. A recent meta-analysis even showed that longitudinal improvement of IC is associated with decreased risk of disability [30]. Similarly, environmental characteristics, such as the number of neighbourhood facilities, have also been associated with trajectories of functional ability [24]. However, the incremental predictive value of IC and environmental characteristics with respect to traditional risk factors has seldom been examined. In the present study, at least one indicator from each of the IC domains, urinary incontinence, and availability of neighbourhood facilities (fitness corners and libraries) were found to be significant predictors of incident disability. More importantly, the incremental predictive value of IC in conjunction with environmental characteristics was formally established using the change in ROCAUC and continuous NRI metrics.

There were several features of the present study that deserve special mention. First, while most of the previous studies were conducted among older populations (i.e., 65 years old or above) [31], this study also included those who were 50–64 years old, which constituted about 9.7 % of the total sample. The underlying rationale for this was that IC is an upstream factor that may start to decline and thereby result in disability at times earlier than what is assumed to be an "old age." For example, the Whilehall's cohort study suggested that cognitive capacity (e.g., memory and reasoning) can deteriorate starting from an age of 45 [32]. Second, it should be noted that the operationalization and measurement of IC are still evolving. While the present study have included the typical indicators as recommended by the WHO ICOPE handbook [20], it also included several other conditions associated with declines in IC, for example self-perceived fatigue for the vitality domain and anxiety symptoms for the psychological domain. The underlying rationale was that these indicators have been considered important attributes that can capture the aspects of their respective domains that may not be reflected by the typical indicators. Self-perceived fatigue characterizes the depletion of physiological capacity [33] and has been shown to be a predictor of several adverse health outcomes [34,35]. It has been included in the WHO's recently proposed working definition of vitality capacity [36], and its measurement properties has also been documented

Table 1
Baseline characteristics of participants.

Variables	Mean (sd)/*n* (%)			*p*
	Total (*n* = 10,993)	No IADL disability at follow-up (*n* = 10,313)	IADL disability at follow-up (*n* = 680)	
Sociodemographic factors				
Age	73.3 (7.0)	73.0 (6.8)	77.9 (7.4)	<.001
Gender, women	9,023 (82.1)	8,466 (82.1)	557 (81.9)	.906
Marital status, non-married	5,272 (48.0)	4,914 (47.6)	358 (52.6)	.012
Educational attainment, primary or below	5,607 (51.0)	5,183 (50.3)	424 (62.4)	<.001
Financial assistance status, recipient of CSSA	886 (8.1)	816 (7.9)	70 (10.3)	.027
Perceived financial adequacy				
Very inadequate	154 (1.4)	142 (1.4)	12 (1.8)	.259
Inadequate	1,824 (16.6)	1,695 (16.4)	129 (19.0)	
Just enough	7,597 (69.1)	7,139 (69.2)	458 (67.4)	
Adequate or very adequate	1,418 (12.9)	1,337 (13.0)	81 (11.9)	
Presence of chronic diseases				
Hypertension	6,145 (55.9)	5,687 (55.1)	458 (67.4)	<.001
Diabetes	2,569 (23.4)	2,353 (22.8)	216 (31.8)	<.001
High cholesterol	5,616 (51.1)	5,213 (50.5)	403 (59.3)	<.001
Heart disease	1,350 (12.3)	1,233 (12.0)	117 (17.2)	<.001
Stroke	444 (4.0)	397 (3.8)	47 (6.9)	<.001
COPD	136 (1.2)	119 (1.2)	17 (2.5)	.002
Renal disease	232 (2.1)	214 (2.1)	18 (2.6)	.315
Lifestyle factors				
Physical activity, <150 min/week	4,321 (39.3)	4,019 (39.0)	302 (44.4)	.005
Prior hospital services utilization and medication use				
Hospitalization	1,582 (14.4)	1,438 (13.9)	144 (21.2)	<.001
Number of medications				
0	2,516 (22.9)	2,440 (23.7)	76 (11.2)	<.001
1–4	7,083 (64.4)	6,622 (64.2)	461 (67.8)	
5 or above	1,394 (12.7)	1,251 (12.1)	143 (21.0)	
Conditions associated with declines in IC				
Cognitive domain				
Poor orientation	1,325 (12.1)	1,188 (11.5)	137 (20.1)	<.001
Poor delayed recall	2,821 (25.7)	2,584 (25.1)	237 (34.9)	<.001
Locomotor domain				
Chair stand test ≥12sec	6,428 (58.5)	5,934 (57.5)	494 (72.6)	<.001
Difficulty in walking 500–600m	1,053 (9.6)	921 (8.9)	132 (19.4)	<.001
Vitality domain				
Weight loss	218 (2.0)	196 (1.9)	22 (3.2)	.016
Appetite loss	1,059 (9.6)	970 (9.4)	89 (13.1)	.002
Self-perceived fatigue	4,481 (40.8)	4,125 (40.0)	356 (52.4)	<.001
Sensory domain				
Poor vision	2,236 (20.3)	2,065 (20.0)	171 (25.1)	.001
Poor hearing	1,766 (16.1)	1,598 (15.5)	168 (24.7)	<.001
Psychological domain				
Feeling down	3,231 (29.4)	2,987 (29.0)	244 (35.9)	<.001
Little interest in doing things	2,624 (23.9)	2,430 (23.6)	194 (28.5)	.003
GAD-2 score	0.7 (1.2)	0.7 (1.1)	0.9 (1.4)	<.001
Urinary incontinence	3,176 (28.9)	2,907 (28.2)	269 (39.6)	<.001

Note. CSSA = Comprehensive Social Security Assistance; COPD = chronic obstructive pulmonary disease; GAD-2 = Generalized Anxiety Disorder 2-item.

[37]. Similarly, it has been shown that anxiety symptoms can lead to increased risks of disability and various chronic conditions [38,39]. WHO has stated that while psychological capacity is “mostly related to emotional functions,” particularly depression, it also includes other aspects such as anxiety and coping [40]. Therefore, while self-perceived fatigue and anxiety symptoms may not be considered the standard indicators for operationalizing IC, they do align with its conceptual framework and may be used to provide a more comprehensive measurement. Last, this study included urinary incontinence, although it is beyond the scope of the five IC domains. The underlying rationale was that this condition is again related to declines in IC, as evidenced by its associations with cognitive decline, loss of mobility, and depression [41–45]. It also has a significant impact on the risk of disability [46,47] and quality of life [48]. Indeed, it is included in the ICOPE training programme currently being developed to support the assessment and management of IC declines [49]. The WHO has also published the evidence profile of various interventions on urinary incontinence [50]. Therefore, the inclusion of this variable in the prediction model could be justified.

As regards the implications of the present study, it reinforces the need for assessment of IC in primary care, in addition to the usual focus on chronic diseases detection and prevention. In terms of practical applications, the full model can be converted into an easy-to-use, digital calculator to be deployed via a mobile app, which enables older adults to predict and monitor their risks of developing disability, thereby facilitating the self-management of health at the individual level. At the community level, such calculator may facilitate the routine comprehensive assessment of older people. The data collected from and results generated by this calculator can be stored inside a database, which can be used by service providers to inform and guide their intervention strategies. In Hong Kong, an ICOPE-based mobile app, namely the iHealth screen [51], is already freely available, which allows older people to assess their IC and geriatric conditions, as well as to obtain personalized recommendations. The disability risk calculator constructed from the present study can precisely be incorporated into this kind of mobile app to further enhance its functionality and usefulness.

Table 2
Baseline and full models on incident IADL disability (*n* = 10,993).

Variables	Odds ratio (95 % CI)	
	Baseline model	Full model
Sociodemographic factors		
Age	**1.097 (1.084–1.111)***	**1.087 (1.074–1.102)***
Gender, women	**1.271 (1.015–1.592)**	1.174 (0.933–1.476)
Marital status, non-married	0.880 (0.739–1.047)	0.858 (0.720–1.023)
Educational attainment, primary or below	1.043 (0.875–1.241)	0.958 (0.800–1.146)
Financial assistance status, recipient of CSSA	0.961 (0.734–1.257)	0.939 (0.714–1.236)
Perceived financial adequacy		
Inadequate	0.839 (0.447–1.576)	0.877 (0.464–1.659)
Just enough	0.748 (0.406–1.377)	0.836 (0.450–1.554)
Adequate or very adequate	0.868 (0.455–1.656)	1.033 (0.536–1.991)
Presence of chronic diseases		
Hypertension	0.905 (0.742–1.104)	0.892 (0.730–1.090)
Diabetes	**1.262 (1.044–1.525)***	**1.213 (1.001–1.469)***
High cholesterol	1.012 (0.843–1.215)	1.006 (0.837–1.210)
Heart disease	1.000 (0.794–1.258)	0.944 (0.748–1.192)
Stroke	**1.401 (1.008–1.948)***	1.363 (0.977–1.899)
COPD	**1.860 (1.088–3.181)***	1.717 (0.997–2.955)
Renal disease	1.034 (0.622–1.716)	0.981 (0.588–1.637)
Lifestyle factors		
Physical activity, <150 min/week	1.171 (0.997–1.375)	1.076 (0.914–1.267)
Prior hospital services utilization and medication use		
Hospitalization	**1.287 (1.051–1.575)***	1.182 (0.962–1.451)
Number of medications		
1–4	**1.616 (1.204–2.168)****	**1.547 (1.151–2.078)****
5 or above	**2.048 (1.404–2.987)*****	**1.874 (1.281–2.740)****
Conditions associated with declines in IC		
Cognitive domain		
Poor orientation	/	**1.287 (1.041–1.590)***
Poor delayed recall	/	1.087 (0.911–1.298)
Locomotor domain		
Chair stand test ≥12sec	/	**1.336 (1.110–1.608)****
Difficulty in walking 500–600m	/	**1.420 (1.142–1.765)****
Vitality domain		
Weight loss	/	1.321 (0.818–2.132)
Appetite loss	/	1.039 (0.806–1.338)
Self-perceived fatigue	/	**1.236 (1.035–1.476)***
Sensory domain		
Poor vision	/	0.935 (0.766–1.140)
Poor hearing	/	**1.249 (1.023–1.525)***
Psychological domain		
Feeling down	/	1.049 (0.848–1.297)
Little interest in doing things	/	0.852 (0.671–1.080)
GAD-2 score	/	**1.119 (1.039–1.206)****
Urinary incontinence	/	**1.225 (1.034–1.453)***
Number of neighborhood facilities		
Parks	/	0.992 (0.919–1.071)
Indoor sports centres	/	1.019 (0.961–1.080)
Outdoor fitness corners	/	**0.973 (0.950–0.997)***
Public libraries	/	**0.936 (0.881–0.996)***
Primary healthcare clinics	/	1.011 (0.986–1.037)

Note. CSSA = Comprehensive Social Security Assistance; COPD = chronic obstructive pulmonary disease; GAD-2 = Generalized Anxiety Disorder 2-item.
* = $p<.05$; ** = $p<.01$; *** = $p<.001$.

The present study may also serve as a useful reference for future studies or clinical trials. For instance, the estimated ROCAUC and NRI, when viewed as a general measure of effect size for the logistic regression model [52], can potentially be used to inform sample size and power calculations. Furthermore, the present study may also contribute to health economics evaluation (e.g., cost-benefit analysis), in the sense that the risk prediction model can be used to estimate the prevalence of disability in the population, which in turn can be used to compute metrics such as disability-adjusted life year (DALY), using the Sullivan's method.

It is noteworthy that the present findings supported the WHO's conceptual framework that functional ability depends on not only IC, but also the surrounding environmental characteristics. Therefore, to promote healthy ageing in a more holistic manner, the importance of urban planning cannot be overlooked. For instance, improving the availability and accessibility of fitness corners and libraries in the community may provide older people with further opportunities for exercise, learning, and volunteering, which in turn contribute to improving their IC and reducing the risk of disability. In Hong Kong, a recently concluded initiative based on the WHO Age-friendly Cities framework precisely served this purpose by empowering older people to remain engaged in their community and allowing them to gain easy access to various kinds of services and activities [53]. However, it is conceivable that the influences of environmental characteristics on functional ability (or the loss thereof) may be susceptible to cultural differences. For this reason, future studies may re-examine such associations in other samples, or even across multiple populations, to validate the results of the present study.

The present study had several merits that deserve mention. First, it had a sufficiently large sample that spanned across different age groups (i.e., from middle age to old-old) and districts in Hong Kong. Second, this study incorporated self-perceived fatigue and anxiety symptoms in

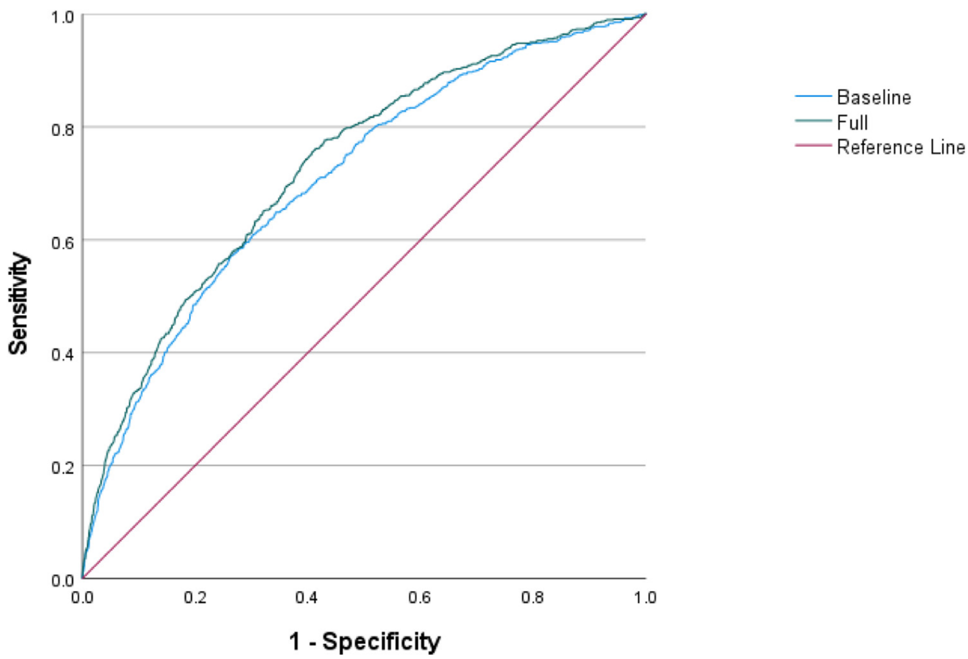

Fig. 1. ROC curves of the baseline and full models on incident IADL disability (n = 10,993).
Note. AUC for the baseline model is 0.707. AUC for the full model is 0.729.

the vitality and psychological domains, respectively, in addition to the more traditional indicators. These indicators did not only align with the existing conceptual framework of IC, but also provided a more comprehensive measurement. Third, this study examined IC and environmental characteristics simultaneously, advancing existing literature that only focused on each of these factors separately. However, this study also had several limitations. First, the sample was drawn from community centres, implying that it was disproportionately predominated by female and relatively active participants. Thus, the findings might not be applicable to the general older populations, especially the non-community-dwelling ones. Future studies should recruit more diverse samples to better represent the institutionalized older people or those who are not as involved in centre-based activities. Second, due to data limitations, some important traditional risk factors, such as smoking and alcohol intake, were not included to establish the baseline model for comparison. Similarly, some potential IC indicators, such as balance for the locomotor domain [54] and resilience for the psychological domain [55], as well as other commonly studied environmental characteristics, such as walkability, air quality, and green space [24,56–59], were not available. For example, consider green space. If readily available and adapted to the needs of older people, it can encourage physical activities and social participation, which may ultimately reduce the risk of disability. Because of that, omission of such a factor might have influenced the risk estimation, and thus the comparison between the baseline and full models. Third, due to constraints in the original project design, there were noticeable variations in the follow-up time. Despite our efforts to confine the follow-up time to a certain period (i.e., nine to 15 months), the findings may not genuinely indicate the one-year predictive performance of IC. In addition, there might be systematic differences between those who followed the project instructions and completed the follow-up within the designated period and those who did not, thus leading to biased results. Although sensitivity analysis showed that the same main conclusion can be drawn when the sample was replaced by those whose follow-up measurements were conducted 10 to 14 months (instead of nine to 15 months) after the baseline one, future studies should ideally set up a more stringent requirement in its data collection procedure to enable the construction of a more reasonable and accurate risk prediction model. Fourth, the outcome variable (i.e., IADL disability) was a binary indicator capturing only whether the participants were unable to perform certain tasks related to basic needs, but reflected neither the severity nor the other dimensions (e.g., ability to learn or make decisions) of disability [60]. In view of this, future studies may consider using alternative or complementary outcome measures that can also capture the, say, cognitive, emotional, and social domains of disability. Last, the use of unconventional indicators (i.e., self-perceived fatigue and anxiety symptoms) that are not listed in the ICOPE screening tool, while advantageous from the aforementioned perspective, may also make comparison of results across studies more difficult.

5. Conclusions

Risk prediction of disability is essential to the development and implementation of effective and targeted interventions for promoting healthy ageing. The present study demonstrated that the value of IC in conjunction with environmental characteristics in predicting disability was beyond those of the traditional risk factors, lending support to the notion that functional ability is determined by IC and the environment a person inhabits. This suggests that the measurement of IC and environmental characteristics can be incorporated into risk prediction models in this regard, which, in practice, can be converted into an easy-to-use calculator to promote self-management of health among older people. Data collected through this calculator can be used by service providers to guide intervention strategies and referrals in the community settings.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ruby Yu reports financial support was provided by The Chinese University of Hong Kong. Ruby Yu reports a relationship with The Chinese University of Hong Kong that includes: employment. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Ruby Yu: Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Grace Leung:** Writing – review & editing, Formal analysis. **Derek Lai:** Writing – review & editing, Formal analysis. **Lok-yan Tam:** Writing – review & editing, Project administration. **Clara Cheng:** Writing – review & editing, Project administration. **Sara Kong:** Writing – review & editing, Project administration. **Cecilia Tong:** Writing – review & editing, Conceptualization. **Jean Woo:** Writing – review & editing, Conceptualization.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jarlif.2025.100004.

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