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Abstract

Purpose: The Seattle Angina Questionnaire (SAQ) is a widely used patient-reported measure of health status in patients with coronary artery disease. Comparisons of SAQ scores amongst population groups and over time rely on the assumption that its factorial structure is invariant (i.e., equivalent). This study evaluates the measurement invariance of the SAQ across different demographic and clinical groups as well as over time.

Methods: Data were obtained from the Alberta Provincial Project on Outcome Assessment in Coronary Heart Disease registry, a population-based registry of patients who received coronary angiogram in Alberta, Canada. Health-related quality of life was measured using the 16-item Canadian version of the SAQ (SAQ-CAN). Multi-group confirmatory factor analysis was used to assess configural, weak, strong, and strict measurement invariance (MI) across age groups, sex, disease type, treatment, and over time. Model fit was assessed using the comparative fit index (CFI), and root mean square error of approximation (RMSEA).

Results: Of the 8101 patients who completed the measure at baseline, 1300 (16.1%) were at least 75 years old, while 1755 (21.7%) were female, 5154 (63.6%) were diagnosed with acute coronary syndrome, while 1177(14.5%) received coronary artery bypass graft treatment. There was evidence of strict invariance across age, sex, and disease groups, but partial strict invariance was established across treatment sub-groups and over time.

Conclusion: SAQ-CAN is a valid measure for comparing health-related quality of life of coronary artery disease patients across population groups and over time.

Keywords: measurement invariance; Seattle Angina Questionnaire; coronary artery disease; confirmatory factor analysis

1. Introduction

Patient-reported outcomes measures (PROMs), which are patients' appraisals of their health status and quality of life, are widely used to evaluate the effectiveness of treatment interventions, compare the health status of population groups, and assess the quality of care provided to patients[1-3]. Such comparisons rely on the assumption that the health-related quality of life construct being measured is invariant across groups or over time (i.e., measurement invariance)[4,5]. Specifically, measurement invariance determines the extent to which a PROM construct is equivalent across groups of interest. Violation of this assumption may lead to biased and flawed conclusions about population group differences or temporal changes[6].

The Seattle Angina Questionnaire (SAQ), a cardiac disease-specific measure of quality of life, is a commonly used PROM in patients with coronary artery disease (CAD)[7-9]. Originally developed in a population of United States veterans, the SAQ has been translated into more than 52 languages, with several studies confirming its construct validity and reliability. The psychometric properties of the SAQ have been well documented, with studies reporting adequate internal consistencies ranging between 0.70 and 0.98[7,8,10,11,9]. However, a number of studies have reported suboptimal factorial validity of the SAQ and have recommended different variants of the SAQ measure in different populations. For example, Kimble et al. [12] validated the SAQ in a predominantly female sample with stable angina and showed the emergence of new subscales (e.g., division of the physical limitation subscale into two separate factors) and misfit of one of the SAQ items. Similarly, the translation and validation of the Farsi version of the SAQ yielded a

five-factor solution with subscales that were not identical to the original SAQ domains[13]. Garrath et al. [14] also reported that the original factorial structure of the SAQ was not replicated in a sample of patients with stable angina but resulted in the emergence of the 15-item United Kingdom version of the SAQ with 3 domains. Recent work by our group[15] also revealed that the original factorial structure of the SAQ was invalid in a Canadian cohort with stable angina. Instead, a four-factor measurement model consisting of 16-items provided an optimal fit called the Canadian version of the SAQ (SAQ-CAN)[15]. In addition, we are not aware of any study that has previously examined the measurement invariance of the SAQ or modified versions of the measure.

This study aims to evaluate measurement invariance properties of the SAQ across demographic (sex, age), clinical (treatment, disease type) groups, and time using a population-based cohort of patients with coronary artery disease. Specifically, we hypothesized that the 16-item SAQ would be invariant across these demographic and clinical subgroups and longitudinally. This investigation has important research and clinical implications for the use of SAQ for describing population group differences and evaluating longitudinal changes in patient outcomes in coronary artery disease.

2. Methods

2.1 Data Source

Data for this study were obtained from the Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease (APPROACH) registry, a prospective population-based registry of all

patients who had a coronary angiogram and/or revascularization in Alberta, Canada since 1995[16,17]. The registry captures detailed clinical information, including information on demographics, comorbidities, medications, indications for the procedure, the use of invasive coronary procedures (coronary artery bypass graft [CABG] or percutaneous coronary intervention [PCI]), as well as mortality, based on linkage with provincial administrative databases. Data collected during coronary angiogram included demographic characteristics (sex, age, and address), number of comorbid conditions, measures of disease severity, and coronary angiography results. The study cohort consisted of adult patients (≥18 years) who underwent coronary angiogram for coronary artery disease between January 1, 2003, and December 31, 2016, and completed data on SAQ two weeks afterward. Only patients who had complete data on the SAQ-CAN[15] were included in the analyses. This measure consists of 16-items with four domains, including indoor physical limitation (IPL – 3 items), outdoor physical limitation (OPL – 4 items), angina symptoms burden (ASB – 6 items), and treatment-related experience (TRE – 3 items). The SAQ-CAN has been shown to be valid and responsive in the Canadian population. The items are scored on 5- or 6-point Likert scales, and the sum of item scores in each domain is then transformed to scores ranging from 0 (no functioning) to 100 (highest level of functioning). Ethics approval for this study was obtained from the University of Calgary Conjoint Health Research Ethics Board (REB15-1195).

2.3 Statistical Analysis

Descriptive analysis based on means, standard deviations, and frequency distributions were used to summarize the data at baseline and longitudinally. Between group mean differences and

longitudinal differences in SAQ-CAN domain scores using (paired) t-tests and/or analysis of variance. The fit of the theoretical factorial structure for the SAQ-CAN items was evaluated using confirmatory factor analysis via robust maximum likelihood estimators. Multiple indices were examined to determine model fit: (a) likelihood ratio test, (b) the comparative fit index (CFI), and (c) the root mean square error of approximation (RMSEA) with its 90% confidence interval (90%CI). To interpret these indices, we used the critical values previously recommended[18-20]. Specifically, CFI values > 0.90 and RMSEA values of < 0.08 were considered benchmarks for acceptable fit, respectively.

Hypotheses about measurement invariance were tested for the following grouping variables, namely: (a) age groups (age ≤ 75 years vs. age > 75 years), (b) sex (female vs. male), (c) disease type (acute coronary syndrome vs. stable angina), (d) treatment received (CABG vs. PCI vs. medical management), and (e) time (2 weeks vs. 1-year follow up). Multi-group confirmatory analysis (MGCFA) with robust maximum likelihood estimation was used to examine the four forms of measurement invariance on the SAQ-CAN items, namely: configural, weak, strong, and strict invariance. A series of multi-group confirmatory factor analyses were done on the data to define each grouping variable. The MGCFA begins with the examination of configural invariance, which involves fitting the factor structure of the SAQ-CAN across subgroups of each grouping variable while freely estimating parameters (i.e., intercepts, factor loadings, error variances) for each subgroup. Configural invariance is satisfied if the factor structure of the SAQ-CAN is a good fit for the data in both groups (i.e., CFI > 0.90; RMSEA < 0.08).

Then, weak, strong, and complete invariance were tested by sequentially placing constraints on the parameters (i.e., factor loadings, intercepts, and error variances) of the configural invariance model. Weak invariance assesses the extent to which the magnitude of the factor loadings for the items are the same between groups or over time. When weak invariance is satisfied, the latent factor is being measured the same way across groups or over time. For strong invariance, the intercepts and factor loadings of the configural measurement model are constrained to be equal across groups or over time. Hence, comparisons of mean scores on the SAQ-CAN can be considered valid. Strong measurement invariance is a prerequisite for making valid between group comparisons. Strict factorial invariance holds if the factor loadings, intercepts, and error variances are invariant for the groups or over time[21].

Changes in goodness-of-fit statistics and published cut-off criteria have been proposed for assessing measurement invariance[22,23,20]. For example, the likelihood-ratio test (LRT), which is based on differences in χ^2 test statistic values for unconstrained and constrained models (i.e., $\Delta\ \chi^2$) is one way to test for measurement invariance. However, this test is known to be sensitive to sample size[22]. Differences in comparative fit index (CFI) values for nested models (i.e., ΔCFI) are alternative measures of invariance recommended in the literature. An absolute value of ΔCFI less than or equal to 0.01 indicates the null hypothesis of invariance should not be rejected, while an absolute value greater than 0.01 indicates a likely difference in fit between constrained and unconstrained models[23]. Overall, ΔCFI was given more weight than the LRT when there was disagreement between the two statistics. The full information maximum likelihood method was used to estimate model parameters in the presence of missing data[24].

All descriptive analyses were conducted using R software[25], while the MGCFA analyses were conducted in Mplus version 8.4[26].

3. Results

Table 1 describes the demographic and clinical characteristics of the study cohort at baseline. Of the 8101 patients included in this analysis, 1300 (16.1%) were at least 75 years old, 1755 (21.7%) were female, 5154 (63.6%) had acute coronary syndrome, while 1177(14.5%) received CABG.

Table 2 describes the frequency distribution of patients' responses to the SAQ-CAN 16-items. Majority of the items exhibited ceiling effects. Specifically, items on indoor physical limitation, treatment-related experience, and angina symptoms and burden domains exhibited significant ceiling effects. On the other hand, table 3 shows that female patients consistently reported significantly lower SAQ-CAN domain scores than male patients. Similarly, older patients reported significantly lower scores on indoor physical limitations and outdoor physical limitations domains than younger patients. While ACS patients generally reported higher average SAQ-CAN domain scores on outdoor physical limitations, angina stability/burden, and treatment-related experiences, there was no significant difference in indoor physical limitations domain scores for ACS and stable angina patients. Analysis of variance showed significant differences in average SAQ-CAN domain scores by the types of treatment received. Furthermore, participants generally reported improved average scores on the outdoor physical function, angina stability, and treatment experience over the one-year period but reported significantly lower average indoor physical functioning domain scores during the same period.

Factorial Validity of the SAQ-CAN

The original four-factor structure of the SAQ-CAN provided an acceptable fit to the data (CFI = 0.941; RMSEA = 0.071 (90%CI = [0.069, 0.073])). Model modification indices suggested that some improvement in model fit could be obtained by including covariances among the residual errors of some of the items on the IPL and OPL, and ASB domains. With these modifications, the modified model had a better fit to the data (CFI = 0.977; RMSEA = 0.047 (90%CI = [0.045, 0.049])). See Figure 1 for more details.

Cross-sectional Measurement Invariance

Table 4 describes the results of the tests of measurement invariance hypotheses in SAQ-CAN across sex, age, disease, and treatment subgroups. For age group comparisons, the four-factor measurement model provided a good/acceptable model fit across age subgroups when all the parameters were freely estimated across age subgroups (CFI = 0.97; RMSEA = 0.04(90%CI= [0.039, 0.043])), which implies that the assumption of configural measurement invariance was satisfied. Successive stepwise constraints of factor loadings, intercepts, and residual variances to assess weak, strong, and strict invariances revealed acceptable model fits (CFI = 0.96; RMSEA=0.04(90%CI [0.042, 0.045])) with negligible changes in CFI and RMSEA fit indices (ΔCFI $\leq$ 0.01; ΔRMSEA $\leq$ 0.01).

Using the same process as described above, successively stricter constraints were tested to evaluate configural, weak, strong, and strict measurement invariance across male and female

patients. Configural invariance was supported by fit indices meeting requirement for good/acceptable fit (CFI = .97; RMSEA = 0.04 (90%CI= [0.037, 0.041])). The assumptions of weak, strong, and strict measurement invariance were satisfied with acceptable model fits as evidenced by negligible changes in model fit for more constrained on the model (ΔCFI <0.01; ΔRMSEA <0.01).

To examine measurement invariance of the SAQ-CAN across coronary artery disease types, the measurement models were fit to subgroups of individuals with acute coronary syndrome and those with stable angina. The configural measurement invariance of the four-factor measurement model was supported with respect to good/acceptable fit indices across the two types of coronary artery diseases (CFI = 0.97; RMSEA = 0.04(90%CI= [0.039, 0.043])) with negligible changes in fit indices for the stricter models. Successively stricter constraints on the factor loadings, intercepts, and residuals were tested to evaluate strong and strict invariance and showed that weak, strong, and strict invariance could be assumed across coronary artery disease types, as evidenced by a negligible change in model fit for the stricter models (ΔCFI ≤ 0.01; RMSEA < 0.01).

Furthermore, we evaluated the four forms of measurement invariance across subgroups of patients who received CABG, PCI, or medical management for their disease. Configural invariance across these treatment groups was supported as evidenced by good/excellent fit (CFI = 0.97; RMSEA =0.04(0.040, 0.044)). Successively stricter constraints on the factor loadings and intercepts, revealed that both weak and strong measurement invariance were supported by the

data (CFI = 0.969; RMSEA =0.04(0.040, 0.044)) and (CFI = 0.961; RMSEA =0.045(0.043, 0.047)) respectively; with negligible changes in fit indices across the three groups (ΔCFI ≤ 0.01). The result suggests that comparisons of SAQ-CAN across these three treatment groups are valid. However, the assumption of strict invariance was not supported across these treatment groups fit statistics. Despite having acceptable fit indices (CFI= 0.94; RMSEA = 0.052(0.051, 0.054)), the changes in fit indices showed non-negligible change in CFI (ΔCFI = 0.02). Instead, partial strict invariance was obtained when the constraints on the error variances for three items (IPL1, IPL2 and ASB3) were relaxed (CFI= 0.96; RMSEA = 0.046(0.044, 0.048)).

Longitudinal Measurement Invariance

The longitudinal measurement invariance was conducted on individuals with complete data on SAQ-CAN items two weeks following coronary angiogram and at 1-year follow up (N = 3279). Table 5 describes the model fit indices for the four forms of measurement invariance over time. First, our analysis revealed that configural measurement model, where all parameters were freely estimated across occasions was satisfied (i.e., CFI = 0.96; RMSEA = 0.038 (90%CI=[0.036, 0.039])). Successively stricter constraints on the factor loadings intercepts, and residual variances revealed that both weak and strong measurement invariance were supported by the data (CFI = 0.96; RMSEA =0.035(90%CI [0.034, 0.037]), (CFI = 0.95; RMSEA =0.039(90%CI [0.038, 0.041]) with negligible changes in fit indices across time (ΔCFI ≤ 0.01; ΔRMSEA≤ 0.01). However, the assumption of strict longitudinal invariance was not supported by the fit indices. Specifically, the strict invariance measurement model had a poor fit to the data (i.e., CFI = 0.872; RMSEA = 0.061(0.060, 0.063)), and substantial change in CFI index. Instead, partial strict invariance was

obtained by freeing the constraints on the residual variances of the indoor physical functioning domain items and few items on the angina symptoms burden over time (CFI = 0.94; RMSEA =0.043(90%CI [0.042, 0.044]).

4. Discussion

This study investigates the measurement invariance of the SAQ-CAN across demographic groups, disease type, type of treatment received, and over time in a population-based cohort of patients with coronary artery disease. To our knowledge, this is the first study to evaluate between-group and longitudinal measurement invariance of any SAQ family of instruments in coronary artery disease. These findings confirm the factorial validity of the SAQ-CAN in a heterogeneous sample of individuals with coronary disease and support the findings from an earlier investigation of its psychometric properties in individuals with stable angina[15].

Of note is the finding that the hypothesis of strict measurement invariance of SAQ-CAN was established across sex, age, and disease groups, while partial strict measurement invariance was established across treatment groups. According to Baumgartner and Steenkamp[21], confirmation of weak and strong invariance are sufficient and necessary conditions to ensure valid comparisons of measures between groups and over time. Consequently, these results provide evidence that the latent construct being measured is invariant over time. In other words, comparison of SAQ-CAN scores across sex, age, disease, and treatment groups and over time examined in this study are valid, reflect true differences, and are not confounded by measurement non-invariance across these subgroups. These findings also buttress previously

reported subgroup comparison of SAQ scores. For example, epidemiological studies have consistently shown that, among patients who receive coronary angiograms, women report poorer SAQ scores than men, and older patients reported lower SAQ scores than younger patients[27-30]. Such differences have been previously attributed to differences in how women experience cardiac symptoms from men[29]. However, these results suggest that female patients interpret the questions in a similar manner as male patients. On the other hand, studies have also reported treatment related differences in HRQOL scores. In particular, individuals who received CABG or PCI reported significantly higher scores than those who are medically managed[31,32]. Findings from this study strengthen the case for SAQ-CAN as a valid measure of health status that can be used to make comparisons in these population subgroups.

Furthermore, the confirmation of partial strict longitudinal measurement invariance of the SAQ-CAN implies that longitudinal comparisons of patient-reported health status assessment using SAQ-CAN are valid. Previous research reported overall improvement in patient-reported physical functioning, angina stability, and satisfaction with treatment post coronary angiogram[33,32]. Also, heterogeneity in longitudinal changes in health-related quality of life has been noted in coronary artery disease patients, with more than 25% reporting a significant decrease on all domains over time despite an overall average increase in PRO domain scores[34]. The findings of this study suggest that these observed differences and changes are valid and true since strong measurement invariance was supported.

The lack of full strict longitudinal measurement invariance of the SAQ-CAN in this study can be explained by error variance, which can be attributed to how individuals with coronary artery

disease adapt to their disease following coronary angiogram. Extensive research has shown that such adaptations can influence how patients respond to the same questions about their health and well-being, leading to a change in one's internal standards of measurement, a change in one's values, or a change in one's definition of the construct, a phenomenon commonly referred to as response shift[35-37]. As a type of longitudinal measurement invariance, the confirmation of partial strict longitudinal measurement invariance indicates the presence of non-uniform recalibration response shift[38,39], which occurs when participants change their internal standards of measurements and down(or up) grade their ratings at follow up assessment. Future research will seek to quantify the resulting magnitude of non-recalibration response shift effect in this population.

A notable strength of this study is its use of population-based cohort of patients with coronary artery disease. However, this study is not without its limitations. First, our examination of measurement invariance of the SAQ-CAN across sex, age, treatment, disease type, and time was motivated partly by previous research that has mostly reported measurement non-invariance across demographic groups and partly by commonly reported comparisons of health-related quality of life across disease/treatment groups and over time in the literature. However, it is possible that the study's conclusions are not generalizable to all subgroup comparisons of the SAQ-CAN. For example, it is possible that there are other salient variables or interactions among variables for which the SAQ-CAN are not invariant across their subgroups. Future research should examine the use of latent variable mixture models to examine measurement non-invariance when relevant grouping variables are not known a priori[40-42]. Second, the validation of the

SAQ-CAN has relied on data from the APPROACH registry. Future research should seek to replicate these findings in other cohorts of patients with coronary artery disease.

In conclusion, these findings confirm that the health status constructs being measured by SAQ-CAN are perceived and interpreted in a similar way across sex, age, disease type, and treatment groups and longitudinally in a population-based sample of people with coronary artery disease. We recommend that measurement invariance analysis be conducted as part of the preliminary analyses when researchers are interested in comparisons of PROM scores among population subgroups and over time.

Table 1 Descriptive Characteristics of Study Cohort

Characteristic	**N = 8101**
Age (n, % >=75 years)	1300 (16.1)
Sex (n, %Female)	1755 (21.7)
Treatment Received	
CABG (n, % Yes)	1177 (14.5)
PCI (n, % Yes)	5163 (63.7)
Medical Management (n, % Yes)	1761 (21.7)
Disease Type (n, % Acute Coronary Syndrome)	5,078 (62.7)

NB: CABG = Coronary Artery Bypass Graft; PCI = Percutaneous Intervention

Table 2 Distribution of patients' responses to items of the SAQ-CAN

Item#	SAQ-CAN Item	1	2	3	4	5	6
	How much limitation have you had due to chest pain, chest tightness, shortness of breath, or angina over the past 4 weeks?	Extremely limited	Quite a bit limited	Moderately limited	Slightly limited	Not at all limited	Limited for other reason or did not do the activity
IPL1	Dressing yourself	23 (0.3)	50 (0.6)	202 (2.5)	687 (8.5)	6997 (86.4)	142 (1.8)
IPL2	Walking indoors on level ground	43 (0.5)	174 (2.2)	469 (5.8)	1180 (14.6)	6042 (74.6)	193 (2.4)
IPL2	Showering	49 (0.6)	106 (1.3)	256 (3.2)	703 (8.7)	6824 (84.2)	163 (2.0)
OPL1	Walking more than a block at a brisk pace	705 (8.7)	899 (11.1)	1129 (13.9)	1699 (21.0)	2920 (36.0)	749 (9.3)
OPL2	running or jogging	1837 (22.7)	1093 (13.5)	779 (9.6)	858 (10.6)	733 (9.1)	2801 (34.6)
OPL3	lifting or moving heavy objects (e.g., furniture, children)	1297 (16.01)	1109 (13.7)	1024 (12.6)	1216 (15.01)	1625 (20.1)	1830 (22.6)
OPL4	participating in strenuous sports (e.g., swimming, tennis)	1935 (23.9)	972 (12.0)	620 (7.7)	621 (7.7)	684 (8.4)	3269 (40.4)
	Compared with 4 weeks ago, how often do you have chest pain, chest tightness	Much more often	Slightly more often	About the same	Slightly less often	Much less often	NA
ASB1	Symptoms of Angina during strenuous activities	298 (3.7)	531 (6.6)	1706 (21.1)	1028 (12.7)	4538 (56.0)	NA
	Over the past 4 weeks, on average, how many times have you had	4 or more times per day	1-3 times per day	3 or more times per week but not every day	1-2 times per week	Less than once a week	None over the past 4 weeks
ASB2	chest pain, chest tightness, shortness of breath, or angina	240 (3.0)	664 (8.2)	1042 (12.9)	990 (12.2)	1695 (20.9)	3470 (42.8)

ASB3	Frequency of use of medication	61 (0.8)	222 (2.7)	337 (4.2)	394 (4.9)	1063 (13.1)	6024 (74.4)
		Not at all satisfied	Mostly satisfied	Somewhat satisfied	Mostly satisfied	Completely satisfied	NA
TRE1	Satisfaction that everything being done	86 (1.1)	170 (2.1)	612 (7.6)	2119 (26.2)	5114 (63.1)	NA
TRE2	Satisfaction with doctor's explanation	135 (1.7)	214 (2.6)	790 (9.8)	2492 (30.8)	4470 (55.2)	NA
TRE3	Overall satisfaction with treatment	102 (1.3)	201 (2.5)	705 (8.7)	2531 (31.2)	4562 (56.3)	NA
		Extremely	Quite a bit	moderately	Slightly	Not at all	NA
ASB4	Over the past 4 weeks, how much has your chest pain, chest tightness, or angina limited your enjoyment of life?	258 (3.2)	800 (9.9)	1317 (16.3)	2563 (31.6)	3163 (39.0)	NA
		Not at all satisfied	Mostly satisfied	Somewhat satisfied	Mostly satisfied	Completely satisfied	NA
ASB5	Feelings about symptoms persistent	1427 (17.6)	1138 (14.0)	1023 (12.6)	2204 (27.2)	2309 (28.5)	NA
		Can't stop thinking or worrying about it	Often think or worry about it	Occasionally think or worry about it	Rarely think or worry about it	Never think or worry about it	
ASB6	How often do you think or worry that you may have a heart attack or die suddenly?	191 (2.4)	1112 (13.7)	2819 (34.8)	2708 (33.4)	1271 (15.7)	NA

NB: SAQ-CAN=Seattle Angina Questionnaire Canadian version; IPL = Indoor physical limitation; OPL = Outdoor Physical Limitation; TRE = Treatment-related Experience; NA= Not applicable

Table 3 Descriptive characteristics of the study cohort by demographic/clinical groups and over time

Grouping Variable		IPL	OPL	ASB	TRE
Sex	Male	80.0 (8.5)	86.2 (35.6)	80.4(15.0)	84.7(15.1)
	Female	78.4 (10.3)*	80.4 (39.4)*	78.3(15.0)*	83.7(15.5)*
Age	> 75 years	78.2 (10.7)	78.3 (39.6)	81.2(14.9)	85.5(14.4)
	≤ 75 years	79.9 (8.6) *	86.2 (35.8)*	79.7(15.1)*	84.3(15.3)*
Disease Type	ACS	79.8 (9.0)	87.9 (36.4)	81.8(14.1)	85.4(14.7)
	Stable Angina	79.4 (8.9)	80.0 (36.3)*	76.8(16.0)*	83.0(15.9)*
Treatment Received	CABG	76.7 (11.2)	71.0 (38.5)	73.4(17.3)	80.7(15.8)
	PCI	80.4 (8.0)	89.1 (35.4)	82.3(13.9)	86.2(14.4)
	Medical	79.5 (9.7) *	82.0 (35.8)*	77.6(15.1)*	82.1(16.2)*
Longitudinal	Baseline	76.0 (10.1)	56.5 (32.6)	72.9(19.5)	85.3(19.2)
	1 year follow up	78.0 (7.9)*	63.0 (27.4)*	82.1(16.1)*	87.6(18.96)*

NB: IPL = Indoor physical limitation; OPL = Outdoor Physical Limitation; ASB = Angina Stability & Burden; TRE = Treatment-related Experience; * = statistically significant statistic ($p < 0.05$);
ACS = Acute Coronary Syndrome; CABG = Coronary Artery Bypass Graft; PCI = Percutaneous Intervention

Table 4 Tests of measurement invariance for SAQ-CAN two weeks after Coronary Angiogram

MI Hypothesis	χ^2	*df*	CFI	RMSEA (90% CI)	Δdf	$\Delta\chi^2$	ΔCFI
Age (≤ 75 years vs. >75 years)							
Configural	1437.1	185	0.973	0.041 (0.039, 0.043)	-	-	-
Weak	1437.4	197	0.974	0.039 (0.038, 0.041)	12	0.3*	<0.01
Strong	1600.7	209	0.970	0.041 (0.039, 0.042)	12	163.3*	<0.01
Strict	1931.9	225	0.964	0.043 (0.042, 0.045)	16	331.2*	0.01
Sex (Female vs. Male)							
Configural	1451.7	185	0.973	0.041 (0.037, 0.041)	-	-	-
Weak	1499.5	197	0.972	0.040 (0.036, 0.040)	12	37.8*	<0.01
Strong	1685.2	209	0.968	0.042 (0.038,0.042)	12	185.7*	<0.01
Strict	1828.3	225	0.966	0.042 (0.039,0.043)	16	143.1*	<0.01
Disease Type (ACS vs. Stable Angina)							
Configural	1432.6	185	0.973	0.041 (0.039, 0.043)		-	-
Weak	1580.0	197	0.970	0.042 (0.040, 0.044)	12	147.4*	<0.01
Strong	1927.3	209	0.963	0.045 (0.043, 0.047)	12	347.3*	0.01
Strict	2055.3	225	0.961	0.045 (0.043, 0.047)	16	128.1*	<0.01
Treatment (CABG vs. PCI vs. Medical Management)							
Configural	1638.3	283	0.971	0.042 (0.040, 0.044)		-	-
Weak	1751.4	307	0.969	0.042 (0.040, 0.044)	24	113.1*	<0.01
Strong	2158.9	331	0.961	0.045 (0.043, 0.047)	24	407.5*	0.01
Strict	3060.0	363	0.942	0.052 (0.051, 0.054)	32	901.1*	0.02
Partial Strict[a]	2389.1	357	0.957	0.046 (0.044, 0.048)	26	230.2	<0.01

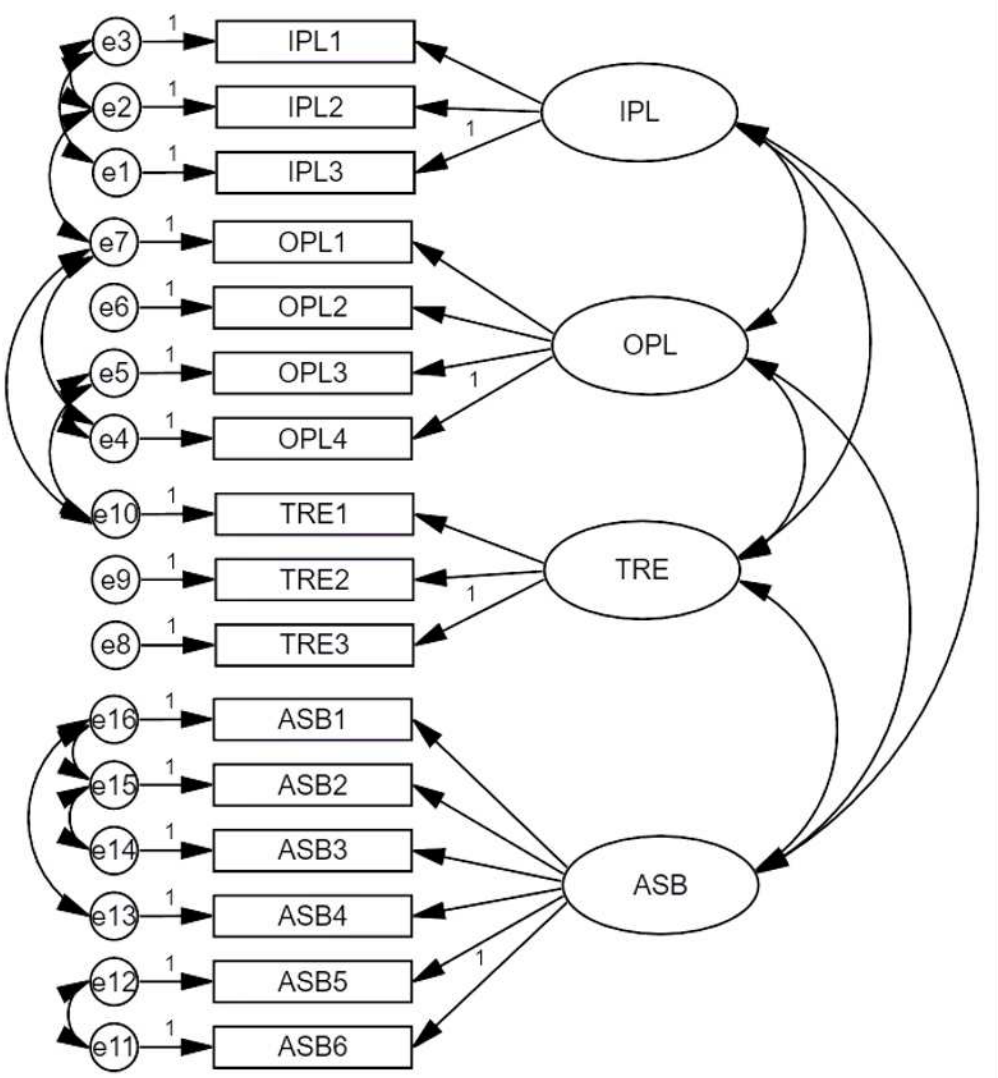
NB: SAQ-CAN=Seattle Angina Questionnaire Canadian version; MI = Measurement Invariance; *df* = degrees of freedom; CFI = Comparative fit index; RMSEA = Root mean square error of approximation; 90%CI = 90% Confidence Interval; Δdf =difference in degrees of freedom compared to the model in the previous row except for models with superscript a; $\Delta\chi^2$= difference of χ^2 statistics compared to the model in the previous row except for models with superscript a; ΔCFI= difference of CFI statistics compared to the model in the previous row except for models with superscript a; * = statistically significant statistic ($p < 0.05$); ACS = Acute coronary syndrome; CABG = Coronary Artery Bypass Graft; PCI = Percutaneous Coronary Intervention

Table 5 Tests of Longitudinal Measurement Invariance for SAQ-CAN over 1-year Follow up

MI Hypothesis	χ^2	*df*	$\Delta\chi^2$	Δdf	CFI	ΔCFI	RMSEA (90% C.I.)
Configural	2270.1	397	-	-	0.955	-	0.038(0.036, 0.039)
Weak	2074.2	405	195.9*	8	0.960	<0.01	0.035(0.034, 0.037)
Strong	2527.6	417	453.4*	12	0.950	0.01	0.039(0.038, 0.041)
Strict	5829.3	436	3301.7*	19	0.872	0.08	0.061(0.060, 0.063)
Partial Strict[a]	3045.3	431	517.7	14	0.938	0.01	0.043(0.042, 0.044)

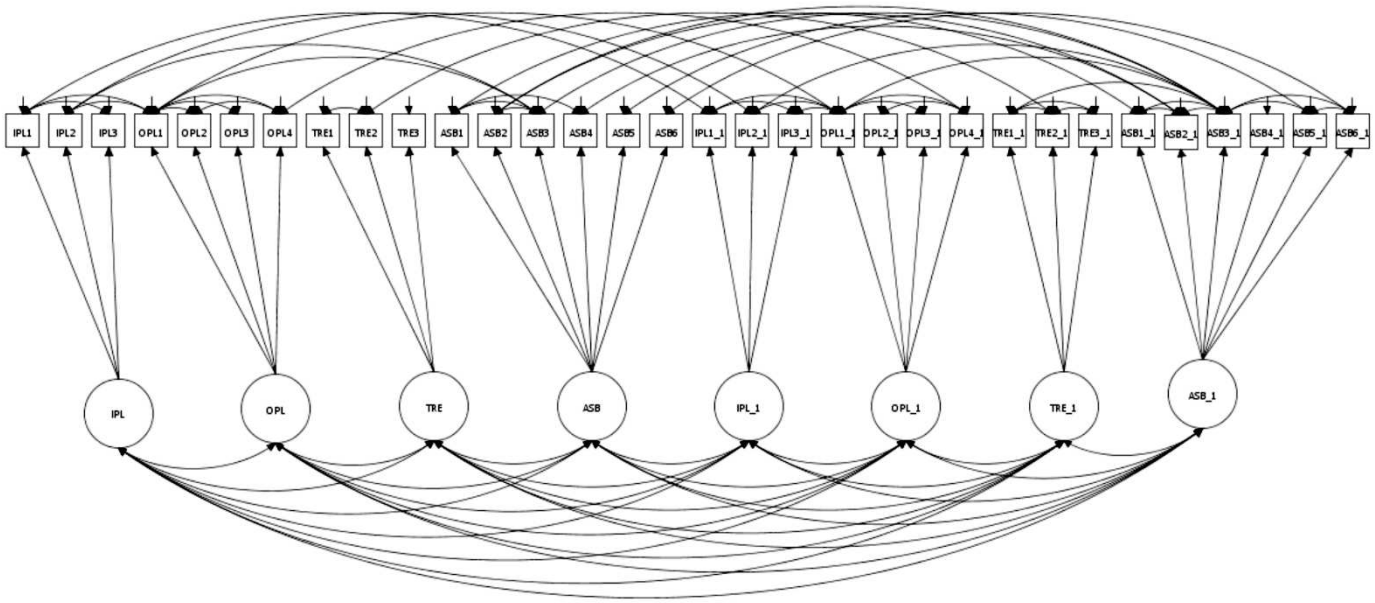
NB: SAQ-CAN=Seattle Angina Questionnaire Canadian version; MI = Measurement Invariance; *df* = degrees of freedom; $\Delta\chi^2$= difference of χ^2 statistics compared to the model in the previous row except for models with superscript a; Δdf =difference in degrees of freedom compared to the model in the previous row except for models with superscript a; CFI = Comparative fit index; ΔCFI= difference of CFI statistics compared to the model in the previous row except for models with superscript a; RMSEA = Root mean square error of approximation; 90%CI = 90% Confidence Interval; * = statistically significant statistic ($p < 0.05$)

Figure 1 Modified Configural Invariance model in SAQ-CAN across groups



NB: SAQ-CAN=Seattle Angina Questionnaire Canadian version; IPL = Indoor Physical Limitation; OPL = Outdoor Physical Limitation; TRE = Treatment-Related Experience; ASB = Angina Symptoms & Burden

Figure 2 Modified Configural Invariance model in SAQ-CAN over time



NB: SAQ-CAN=Seattle Angina Questionnaire Canadian version; IPL = Indoor Physical Limitation; OPL = Outdoor Physical Limitation; TRE = Treatment-Related Experience; ASB = Angina Symptoms & Burden

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Declarations

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Conflicts of interest/Competing interests

The authors declare that they have no competing interests

Availability of data and materials

The datasets used in this study are not publicly available but, researchers who fulfill the criteria for access, as determined and approved by the University of Calgary Conjoint Health Research Ethics Board, can have access to the data

Code availability

Available upon request from the authors

Authors' Contributions

OAL: data analysis; interpretation of result; manuscript preparation;

OA: interpretation of result; manuscript revision; supervision of OAL

MS: interpretation of result; manuscript revision; supervision of OAL

MTJ: data management; interpretation of result; manuscript revision; supervision of OAL

SBW: data collection; management; interpretation of results; manuscript revision

CMN: data collection; interpretation of results; manuscript re

LML: interpretation of result; manuscript revision;

TTS: study conceptualization, data analysis, interpretation of result, and manuscript revision.

All authors read and approved the final version of the manuscript.

Ethics approval

Ethics approval to use de-identified data from the APPROACH registry was obtained from the University of Calgary Conjoint Health Research Ethics Board.

Consent to participate

Not applicable

Consent for publication

Not applicable

Figures

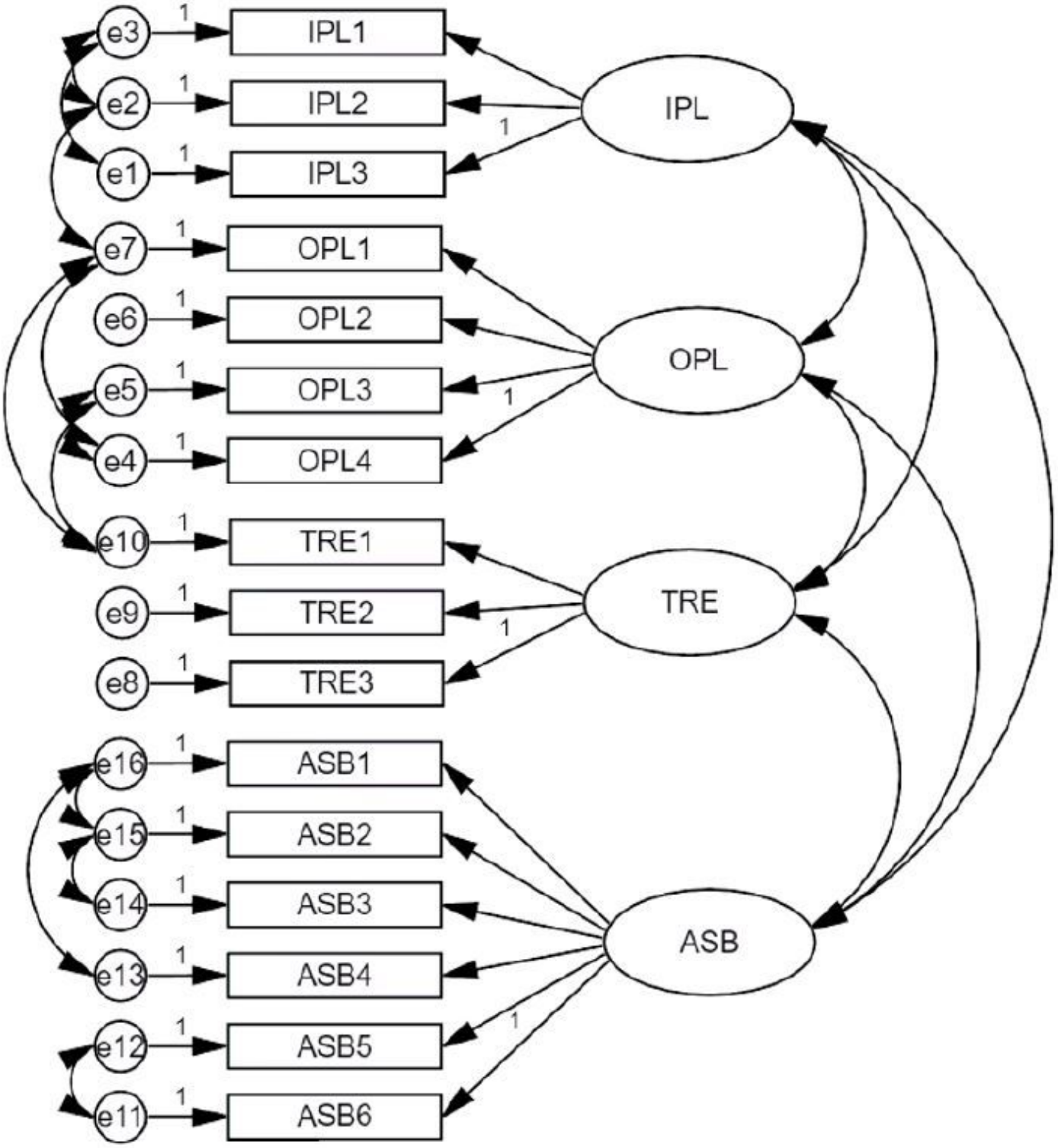

Figure 1

Modified Configural Invariance model in SAQ-CAN across groups. NB: SAQ-CAN=Seattle Angina Questionnaire Canadian version; IPL = Indoor Physical Limitation; OPL = Outdoor Physical Limitation; TRE = Treatment-Related Experience; ASB = Angina Symptoms & Burden

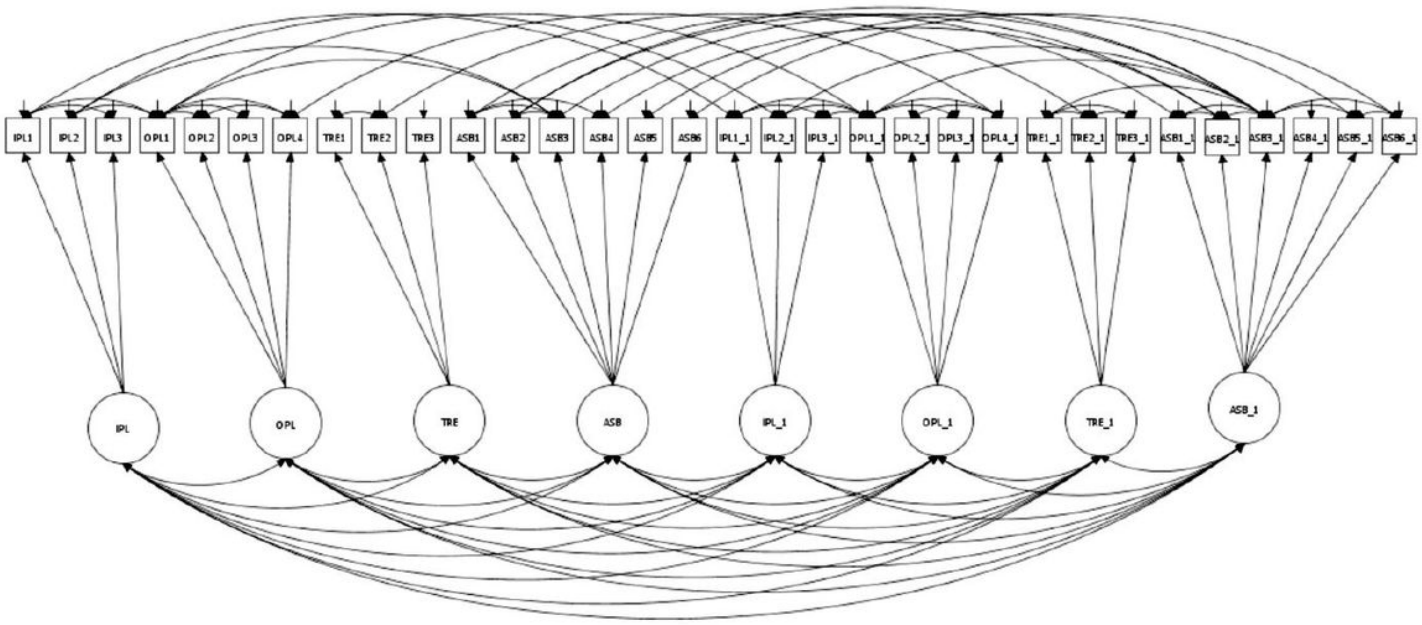

Figure 2

Modified Configural Invariance model in SAQ-CAN over time. NB: SAQ-CAN=Seattle Angina Questionnaire Canadian version; IPL = Indoor Physical Limitation; OPL = Outdoor Physical Limitation; TRE = Treatment-Related Experience; ASB = Angina Symptoms & Burden