Supplementary material
Lindgren et al. Predictive validity of psychosis risk models when applied to adolescent psychiatric patients

Contents

Supplement 1: Confirmatory factor analyses of symptom items

For the two published models [1,2] that used CAARMS subscales, we performed confirmatory factor analysis (CFA) of symptom dimensions, using factor analysis of categorical indicators in Mplus 8.3 [3] to obtain the two- and single-dimensional factor solutions, respectively. The CAARMS variables were replaced by their SIPS equivalents, when available. Factor model fit was quantified with the root mean square error of approximation (RMSEA), and the comparative fit index (CFI). The derived *maximum a posteriori* factor scores were used in the analyses testing the prediction models.

Negative symptom and Disorganization/cognitive symptom factors

Following the model by Demjaha *et al.* [1]. Factor model fit was poor (RMSEA = 0.180, CFI = 0.87), but the model explained 49% of the variance in the included variables. The correlation between factors was 0.72.

Demjaha *et al.* two-factor model

Factor	CAARMS item	SIPS equivalent	Standardized factor loading
Negative symptoms	Social isolation	N1 Social Anhedonia	0.66
	Anhedonia	G2 Dysphoric Mood [a]	0.63
	Impaired role of function	N6 Role Functioning	0.72
	Observed blunted affect	N3 Expression of Emotion	0.74
	Depression	G2 Dysphoric Mood [a]	-
	Avolition/apathy	N2 Avolition	0.81
	Disorganizing/odd/stigmatizing behavior	D1 Odd Behavior or Appearance	0.56
Disorganization / cognitive symptoms	Observed cognitive change	N5 Ideational Richness	0.72
	Subjective cognitive change	D3 Trouble with Focus and Attention	0.84
	Disorganized speech	P5 Disorganized Communication	0.54

[a] Depression and Anhedonia were replaced by the single SIPS G2 Dysphoric mood item.

Mplus script

```
VARIABLE:
  NAMES ARE P1delus P2parano P3grandi P4halluc P5disorg N1socanh
    N2avolit N3expres N4experi N5ideati N6role D1odd D2bizarr D3attent
    D4hygien G1sleep G2dyspho G3motor G4stress ;
  USEVARIABLES ARE
    N1socanh N6role N3expres G2dyspho N2avolit D1odd
    N5ideati D3attent P5disorg;
  CATEGORICAL ARE
    N1socanh N6role N3expres G2dyspho N2avolit D1odd
    N5ideati D3attent P5disorg;
ANALYSIS: ESTIMATOR IS WLSMV ;
MODEL:
  ! The * indicates that also the loadings and thresholds of the 1st items are freely estimated
  negative BY N1socanh* N6role N3expres G2dyspho N2avolit D1odd ;
  disorg   BY N5ideati* D3attent P5disorg ;
  ! The latent factors are standardized.
  negative@1 ; [negative@0] ;
    disorg@1 ;   [disorg@0] ;
```

Disorganization symptom factor

Following the model by Raballo *et al.* [2]. This model consisted of "items with same co-aggregation pattern" (part of same factor in baseline and 1-month assessments). The factor model fit was acceptable (RMSEA 0.07, CFI 0.987), and the model explained 47% of the variance.

Raballo *et al.* negative symptom factor model

CAARMS item	SIPS equivalent	Standardized factor loading
Disorganized speech	P5 Disorganized Communication	0.63
Alogia	N3 Expression of Emotion [a]	0.59
Disorganizing/odd/stigmatizing behavior	D1 Odd Behavior or Appearance [b]	0.70
Mania	*No SIPS equivalent*	-
Observed cognitive change	N5 Ideational Richness	0.73
Subjective cognitive change	D3 Trouble with Focus and Attention	0.74
Observed inappropriate affect	D1 Odd Behavior or Appearance [b]	-
Observed blunted affect	N3 Expression of Emotion [a]	-
Unusual thought content & non-bizarre ideas	P1 Unusual Thought Content / Delusional Ideas	0.70

[a] Alogia and Observed blunted affect were replaced by the single SIPS N3 Expression of Emotion item.
[b] Disorganizing/odd/stigmatizing behavior and Observed inappropriate affect were replaced by the single SIPS D1 Odd Behavior or Appearance item.

Mplus script

```
VARIABLE:
  NAMES ARE P1delus P2parano P3grandi P4halluc P5disorg N1socanh
    N2avolit N3expres N4experi N5ideati N6role D1odd D2bizarr D3attent
    D4hygien G1sleep G2dyspho G3motor G4stress ;
  USEVARIABLES ARE P5disorg N3expres D1odd N5ideati D3attent P1delus;
   CATEGORICAL ARE P5disorg N3expres D1odd N5ideati D3attent P1delus;
ANALYSIS: ESTIMATOR IS WLSMV ;
MODEL:
  ! The * indicates that also the loadings and thresholds of the 1st item are freely estimated.
  disorg BY P5disorg* N3expres D1odd N5ideati D3attent P1delus;
  ! The latent factor is standardized.
  [disorg@0]; disorg@1;
```

Supplement 2: Weights

The weights were developed to take into account gender, participation rate, and screening outcome of the participants, so that the results can be generalized to all adolescent psychiatric patients in public units in Helsinki at the time of the study [4]. The weights were used in the regression models and AUC analyses when the whole sample or the subsample with cognitive data was used.

Weights were calculated separately for males and females.

The calculations for the full sample were as follows (and analogous for the subsample with cognitive data):

1. Screening weight for the screen-positives was 1 (as they were all selected to the study).
   For the screen-negatives, the screening weight was:
   returned PQ's (538) / selected cases (86) = 6.256.

2. Attrition weights were calculated for the screen-positives as
   total number (145) / number interviewed (114) = 1.272
   and for the screen-negatives in the same way:
   538 / 60 = 8.967[5].

3. Total weights were calculated by multiplying
   *screening weights * attrition weights*
   and scaling into analysis weights so that their sum was = N.

Supplement 3: Exploratory prediction models

Standardized and unstandardized log odds coefficients using LASSO, predicting psychosis or first hospitalization, with 4, 3, 2, or 1 predictors.

	Psychosis standardized				Psychosis unstandardized				Hospitalization standardized				Hospitalization unstandardized			
	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1
(Intercept)	-1.769	-1.777	-1.793	-1.82	-2.187	-2.068	-1.971	-1.862	-1.116	-1.146	-1.205	-1.207	-1.407	-1.332	-1.245	-1.244
CHR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Both APS and GRD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GRD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIPS schizotypal personality features	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIPS P1	0	0	0	0	0	0	0	0	.113	.078	0	0	.079	.055	0	0
SIPS P1 >3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIPS P2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIPS P2 >2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIPS P5 ≥2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIPS P5 ≥3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIPS P5 ≥4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIPS Positive symptoms sum	.095	.07	.043	0	.021	.016	.01	0	0	0	0	0	0	0	0	0
SIPS Positive symptoms sum >16	.013	0	0	0	.149	0	0	0	0	0	0	0	0	0	0	0
SIPS N5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIPS Negative symptoms sum	.157	.108	.07	.025	.034	.023	.015	.006	0	0	0	0	0	0	0	0
SIPS D2 >2	.069	.036	0	0	.255	.135	0	0	0	0	0	0	0	0	0	0
SIPS D3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIPS D3 >2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SIPS G1 >2	0	0	0	0	0	0	0	0	.038	0	0	0	.075	0	0	0
GAF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GAF <40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GAF <44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GAF <50	0	0	0	0	0	0	0	0	.126	.099	.042	.039	.251	.198	.083	.077
GAF <61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GAF 12 month maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Psychosis standardized				Psychosis unstandardized				Hospitalization standardized				Hospitalization unstandardized			
	4	3	2	1	4	3	2	1	4	3	2	1	4	3	2	1
Global Functioning: Social scale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Global Functioning: Social scale <7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Demjaha Negative symptom factor score	0	0	0	0	0	0	0	0	.058	.04	.003	0	.106	.074	.006	0
Demjaha Disorg. symptom factor score	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Raballo Disorg. symptom factor score	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Duration of untreated symptoms >2 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Duration of untreated symptoms >5 years	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Any substance-related diagnosis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No alcohol abuse or dependency	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: To obtain a maximum number of participants, the cognitive predictors were left out of the exploratory models. The standardized coefficients of the LASSO analysis indicate the log odds difference in the outcome probability associated with 1 standard deviation difference in the predictor variable when estimating the coefficients using the selection and shrinkage method of LASSO.

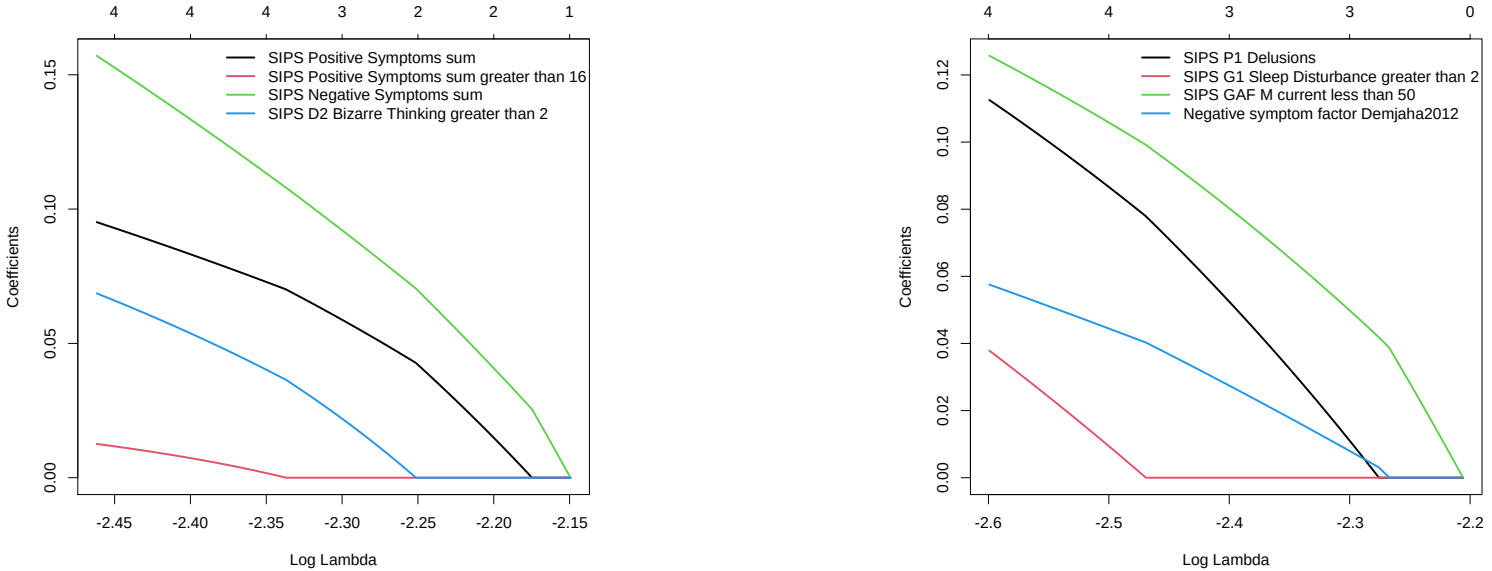

Figure S1. Images illustrating the standardized coefficients at the relevant ranges of λ predicting psychosis (left) and hospitalizations (right). The number of variables at each point is shown on top.

Supplement 4: The performance of models in predicting first psychiatric hospitalization in the whole sample and in the CHR subsample

		Whole sample, n=153				CHR subsample, n=50			
Model	Parameter	log OR [95% CI]	p	AIC[a]	AUC[a]	log OR [95% CI]	p	AIC[a]	AUC[a]
Miller [6]	*CHR status*	0.89 [-0.12, 1.85]	0.08	-0.99	0.57	-		-	-
Previous hospitalization [b]		2.61 [1.67, 3.69]	<0.01	-30.92	0.70	-		-	-
Auther [7]	SIPS Positive symptoms sum	0.10 [0.00, 0.21]	0.05	-1.98	0.63	-0.02 [-0.29 , 0.25]	0.89	1.98	0.49
Buchy [8]	No alcohol abuse or dependency	-0.54 [-1.61, 0.64]	0.35	1.14	0.53	-0.12 [-1.74 , 1.73]	0.89	1.98	0.50
Cannon [9] 1. model (best 4 by HR)	SIPS P1 >3	0.76 [-1.12, 2.46]	0.40	6.33	0.59	0.85 [-0.53 , 2.31]	0.23	5.34	**0.68**
	Substance-related diagnosis	-0.48 [-1.85, 0.64]	0.42			0.16 [-1.78 , 1.91]	0.86		
	SIPS P2 >2	-0.50 [-2.11, 0.79]	0.47			-0.85 [-2.35 , 0.59]	0.25		
	GRD	0.69 [-4.41, 4.55]	0.71			-0.47 [-5.56 , 2.74]	0.79		
Cannon 2. model (best 3 by HR)	SIPS P1 >3	0.51 [-1.27, 2.01]	0.54	4.61	0.57	0.86 [-0.48 , 2.25]	0.21	4.26	0.62
	Substance-related diagnosis	-0.37 [-1.74, 0.76]	0.54			0.41 [-1.47 , 2.12]	0.65		
	Social Functioning <7	0.31 [-0.63, 1.21]	0.50			0.11 [-1.34 , 1.50]	0.88		
Demjaha [1]	Negative symptom factor score	0.49 [-0.66, 1.63]	0.40	-1.85	0.67	0.17 [-1.64 , 1.93]	0.85	3.74	0.57
	Disorg. symptom factor score	0.52 [-0.54, 1.59]	0.34			-0.51 [-2.66 , 1.55]	0.62		
DeVylder [10] 1. model	SIPS P5 ≥2	-1.28 [-4.62, 0.54]	0.20	0.33	0.54	-1.23 [-3.55 , 0.45]	0.16	**0.04**	0.62
DeVylder 2. model	SIPS P5 ≥3	-0.71 [-5.62, 1.64]	0.61	1.74	0.52	-1.15 [-6.08 , 1.30]	0.40	1.30	0.55
DeVylder 3. model	SIPS P5 ≥4	0.77 [-4.31, 4.54]	0.68	1.83	0.50	-0.23 [-5.24 , 2.78]	0.89	1.98	0.52
Lin [11] 1. model	Visual Reproduction I	0.16 [-0.02, 0.36]	0.09	-0.23	0.63	-0.19 [-0.50 , 0.09]	0.18	1.14	0.67
	GAF	-0.02 [-0.06, 0.01]	0.20			0.06 [-0.03 , 0.17]	0.20		
Lin 2. model	Matrix Reasoning	0.10 [-0.02, 0.23]	0.09	**-3.47**	**0.68**	0.06 [-0.08 , 0.24]	0.40	**0.38**	**0.71**
	SIPS P1	0.39 [0.06, 0.72]	0.02			0.63 [-0.06 , 1.44]	0.07		
Nelson [12]	Untreated symptoms >2 years	-1.11 [-3.12, 0.28]	0.13	0.92	0.58	0.24 [-2.24 , 2.37]	0.83	3.82	0.57
	GAF <44	0.47 [-0.88, 1.70]	0.47			-0.23 [-1.63 , 1.13]	0.74		
Perkins [13] equation [c]	Sum of SIPS P1, P2, N5, D3	0.13 [0.00, 0.27]	0.06	-1.62	0.63	0.00 [-0.27 , 0.26]	0.99	2.00	0.49

		Whole sample, n=153				CHR subsample, n=50			
Model	Parameter	log OR [95% CI]	p	AIC[a]	AUC[a]	log OR [95% CI]	p	AIC[a]	AUC[a]
Perkins, separately	SIPS P1	0.50 [0.04, 0.99]	0.03	0.37	**0.70**	0.75 [0.03 , 1.61]	0.04	1.12	**0.80**
	SIPS P2	-0.36 [-0.94, 0.16]	0.18			-0.44 [-1.20 , 0.22]	0.20		
	SIPS N5	0.12 [-0.42, 0.62]	0.64			-0.42 [-1.24 , 0.25]	0.23		
	SIPS D3	0.16 [-0.37, 0.73]	0.56			0.16 [-1.01 , 1.51]	0.79		
Piskulic [14]	SIPS Negative symptoms sum	0.06 [-0.03, 0.15]	0.18	0.23	0.60	-0.04 [-0.22 , 0.11]	0.60	1.72	0.53
Raballo [2]	Disorg. symptom factor score	0.52 [0.02, 1.04]	0.04	**-2.14**	0.65	-0.24 [-1.57 , 0.94]	0.70	1.85	0.51
Ruhrmann [15] separately [c]	SIPS D2 >2	2.35 [0.39, 4.65]	0.02	**-4.70**	**0.70**	4.69 [0.96 , 10.54]	0.01	**-3.79**	**0.86**
	SIPS G1 >2	1.32 [0.39, 2.32]	0.01			2.06 [-0.02 , 5.19]	0.05		
	SIPS schizotypal personality	-1.71 [-5.76, 1.05]	0.26			-3.12 [-9.08 , 0.86]	0.13		
	GAF 12 month max	0.00 [-0.04, 0.04]	0.98			0.08 [0.01 , 0.18]	0.02		
Ruhrmann modified [d]	SIPS Positive symptoms sum	0.06 [-0.06, 0.18]	0.34	**-3.63**	**0.72**	0.12 [-0.21 , 0.50]	0.47	**-2.09**	**0.87**
	SIPS D2 >2	1.95 [-0.12, 4.34]	0.06			4.44 [0.89 , 10.26]	0.01		
	SIPS G1 >2	1.23 [0.29, 2.23]	0.01			1.91 [-0.14 , 5.00]	0.07		
	SIPS schizotypal personality	-1.85 [-5.83, 0.87]	0.21			-3.43 [-9.47 , 0.64]	0.10		
	GAF 12 month max	0.00 [-0.04, 0.04]	0.92			0.09 [0.02 , 0.19]	0.01		
Ruhrmann equation [e]		0.66 [0.08, 1.30]	0.03	**-3.01**	**0.67**	-0.22 [-1.13 , 0.53]	0.58	1.69	0.54
Thompson [16] equation [c]	2 of: SIPS P1 >3, GAF <50, GRD	0.77 [-1.19, 2.47]	0.40	1.30	0.51	0.84 [-0.59 , 2.28]	0.24	**0.65**	0.60
Thompson, separately	SIPS P1 >3	0.16 [-1.67, 1.72]	0.85	-0.75	0.64	0.75 [-0.62 , 2.16]	0.28	4.71	0.61
	GRD	1.29 [-3.82, 5.17]	0.51			-0.13 [-5.30 , 3.32]	0.95		
	GAF <50	1.10 [0.23, 2.01]	0.01			-0.19 [-1.89 , 1.72]	0.83		
Velthorst [17]	GAF<61	-0.71 [-1.95 , 0.60]	0.28	0.95	0.64	0.00 [-0.24 , 0.24]	>0.99	6.01	0.51
	SIPS Positive symptoms sum	0.10 [-0.02 , 0.23]	0.11			0.00 [-0.21 , 0.00]	0.99		
	SIPS Negative symptoms sum	0.03 [-0.09 , 0.15]	0.60			0.00 [0.00 , 0.12]	>0.99		
Velthorst modified	SIPS Positive symptoms sum	0.09 [-0.03 , 0.22]	0.14	-0.05	0.63	0.00 [-0.28 , 0.28]	>0.99	3.72	0.53
	SIPS Negative symptoms sum	0.02 [-0.10 , 0.13]	0.78			-0.04 [-0.22 , 0.12]	0.61		
Walder [18]	SIPS Positive symptoms sum	0.11 [0.01, 0.22]	0.04	-0.45	0.62	0.00 [-0.28 , 0.28]	0.99	3.22	0.59
	Social Functioning	0.12 [-0.21, 0.48]	0.49			0.23 [-0.27 , 0.82]	0.38		

		Whole sample, n=153				CHR subsample, n=50			
Model	Parameter	log OR [95% CI]	p	AIC*	AUC*	log OR [95% CI]	p	AIC*	AUC*
Yung [19]	SIPS D3 >2	0.08 [-1.13, 1.16]	0.89	5.07	0.57	0.56 [-0.85 , 2.04]	0.44	7.03	0.62
	GAF <40	1.17 [-0.43, 2.76]	0.15			-0.43 [-2.06 , 1.05]	0.58		
	Untreated symptoms >5 years	-0.82 [-5.73, 1.52]	0.55			-0.29 [-5.36 , 2.85]	0.86		
	Both APS and GRD	0.75 [-4.36, 4.61]	0.69			-0.29 [-5.36 , 2.85]	0.86		
Four-predictor exploratory model [f]		2.86 [1.08, 4.77]	<0.01	-8.09	0.72	2.51 [-1.67 , 7.47]	0.25	0.67	0.63

[a] for the whole model. The five best values in the AIC and AUC columns are in boldface.
[b] Previous hospitalization predicting rehospitalization (those with previous hospitalizations not excluded, in contrast to all other hospitalization analyses).
[c] Models presented as an equation such as sum of the predictor scores were used both as an equation as well as using the predictors individually.
[d] The Ruhrmann model included a criterion of sum of positive symptoms >16, but as only one person fulfilled this criterion, the model was run with this predictor replaced by the SIPS Positive symptoms sum (used in other models) and these results are presented as "Ruhrmann modified" model.
[e] Ruhmann equation: 1.571* SIPS Positive symptoms sum >16) + (0.865* SIPS D2 >2) + (0.793* SIPS G1 >2) + (1.037* SIPS schizotypal personality) + (0.033*(100- GAF 12 month max.-34.64)).
[f] GAF <50, Demjaha Negative symptom factor score, SIPS P1, SIPS G1 >2

Abbreviations in supplementary material

AIC, Akaike Information Criterion
AUC, Area Under the Curve
APS, Attenuated Psychotic Symptoms risk group
CAARMS, Comprehensive Assessment of At-Risk Mental States
CHR, Clinical High-Risk
DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, version IV
GAF, Global Assessment of Functioning
GRD, Genetic Risk and Deterioration (functional decline) risk group
HR, Hazard Ratio
log OR, Logarithmic Odds Ratio
PAS, Premorbid Adjustment Scale
SANS, Scale for the Assessment of Negative Symptoms
SIPS, Structured Interview for Prodromal Syndromes
WAIS-III, Wechsler Adult Intelligence Scale III
WASI, Wechsler Abbreviated Scale of Intelligence
WMS-R, Wechsler Memory Scale, Revised

References for supplementary material

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