Optimizing DyNaChron instrument for assessing chronic nasal dysfunction symptoms by Rasch analysis*

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Abstract

Background: The DyNaChron (Dysfonctionnement Nasal Chronique) questionnaire is a self-reporting 78-item instrument assessing six symptoms and their consequences of chronic nasal dysfunction. Patients complete items of a symptom domain only when it is present but in case the patient presents several or all symptoms, its length can limit its use. Here, we aimed to optimize, or shorten, the DyNaChron for clinical use.

Methods: A total of 640 patients in 14 rhinology outpatient clinics all over France completed the original DyNaChron questionnaire before the first rhinologic clinic and 15 days later. The optimization process involved Rasch analysis and then qualitative content analyses. Rasch analysis flagged items with a floor/ceiling effect or with important differential item functioning and an expert committee decided whether to retain the flagged items on the basis of clinical importance and statistical characteristics. The psychometric properties of the optimized version were studied according to classical test theory and Rasch analysis.

Results: Rasch analysis revealed 4 items with underfit, 6 with an extreme score, 2 that were highly locally dependent and 16 with differential item functioning which 5 of these 16 items were retained after content analysis. In total, 19 flagged items were removed. Factorial analysis confirmed the preservation of the initial instrument structure in the optimized scale; psychometrics properties and scale calibration were the same as or better than the original version.

Conclusion: The shortened DyNaChron optimizes the quality of assessment by deleting redundant items and reduces the burden on respondents; the structure is preserved and the psychometrics properties are improved.

Key words: chronic nasal dysfunction, questionnaire, short form, Rasch model, validity

Introduction

Patients with chronic nose and sinus functional diseases have symptoms and want to be relieved of them for better quality of life [1-3]. Different diseases (rhinitis, septal deviation, polyps…) present with similar symptoms. Thus, to better understand treatment efficacy in each specific disease, quality of life related to each symptom must be evaluated.

Numerous tools to describe the burden of chronic nasal dysfunction (CND) and treatment outcomes have been developed. A recent systematic review identified 15 tools validated for adults with chronic rhinosinusitis (CRS) [4]. The three most common are Rhinosinusitis Disability Index (RDSI), Chronic Sinusitis Survey (CSS) and Sinonasal Outcomes Test (SNOT-22) [5,6]. However, the instruments focus on emotional, physical and functional consequences without relating it to specific symptom. The RSDI and SNOT-22 are more sensitive to measuring the emotional impact of CRS, whereas the CSS examines medication use and symptoms [6]. Another instrument, The French Dysfonctionnement Nasal Chronique questionnaire (DyNaChron) allows to evaluate the role of each nasal symptom in sleep disorders associated to nasal polyposis and improvement of sleep related to each symptom after surgery or to evaluate residual symptoms after surgery [7,8].

The DyNaChron is a self-reporting 78-item instrument inclu-

ding 6 domains assessing six main nose and sinus functional symptoms and the physical and psychosocial consequences specific to each symptom. Patients complete items pertaining to a domain only when the symptom is present. The questionnaire resulted from an expert-based process and demonstrated robust psychometrics properties [9]. However, despite its comprehensiveness, its length might preclude its use in a repeated-measurement research situation or clinical practice. A shorter instrument might be beneficial.

The development of short questionnaires has largely focused on reducing existing instruments [10]. This process requires care so as not to lose valuable information. It must preserve or even improve psychometrics properties of the original instrument. The methodology for shortening existing instruments has been put into guidelines that mostly recommend a combination of content analysis and statistical approaches [10–12]. The content analysis approach — judging the relevance of individual items to the concept — is not frequently used or reported [10] but is important for preserving the content validity of the optimized scale. Generally, classical test theory (CTT) is the most frequently used approach to study the psychometrics properties of an existing instrument and is based on the total score of the dimension corresponding to the sum of responses to each dimension item, with no item hierarchy explicitly checked. Another set of modern psychometric methods such as a Rasch model for polytomous items, whereby the probability of endorsing any response category to an item depends solely on respondent ability and item difficulty [13] is used for assessing construct validity and refining item response categories, ie scale calibration [14]. Instruments developed using those modern psychometric methods improve the accuracy by which clinical change can be measured and provide accurate estimates suitable for individual measurement [15].

The purpose of this study was to optimize, or shorten, the DyNaChron questionnaire by using content analysis and Rasch model while preserving its psychometrics properties and structure.

Subjects and methods

Data from the development study for the DyNaChron questionnaire were used for shortening [8].

Patient sampling

Patients were recruited consecutively from rhinology outpatient clinics in 14 oto-rhino-laryngology centres all over France. Patients had to be older than 18 years, have nasal or sinus dysfunction for more than 3 months and be able to understand and read the French language. Patients were excluded if they presented nasal or sinus tumor or Rendu-Osler disease, or were under immediate post-operative care [9].

The national institutional review board approved the study (CNIL, no. 905469).

Measures and data collection

The DyNaChron is composed of 6 symptoms domains: nasal obstruction (12 items), anterior rhinorrhea (8 items), posterior rhinorrhea (10 items), facial pain or headache (17 items), sense of smell difficulty (12 items) and cough (10 items), defined by one to four generic questions. Generic questions are used to determine whether a patient has symptoms related to the domain. For each of them, two concepts are explored into 2 subscales: 1) the consequences of the symptom on other organic functions and organs, and 2) the psychological and social consequences induced by the symptom. Patients had to respond to only questions related to the symptoms they had. The response modalities for all items used numerical rating scale ranging from 0 to 10, 0 indicating "no discomfort" and 10 "unbearable discomfort". Patients completed the DyNaChron questionnaire before the first clinic visit and 15 days later. Patients completed also questions about their health and if they had experienced a change over the past 15 days. For each symptom domain, patient's overall assessment of a change in health state was the reference criterion to evaluate the responsiveness and reliability of the questionnaire, with responses ranging from 1, "major worsening" to 7 "major improvement" with 4 being "no change". A score ≥ 5 was considered improved health and ≤ 3 deteriorated health. Age, sex, presence and intensity of the 6 symptoms covered by DyNaChron were collected at patient inclusion. After the clinic visit, medical data about the diagnosis were collected by physicians. They were asked to classify patients in one of three groups according to their main complaint(s): 1) monosymptomatic dysfunction (one major symptom was the reason for the patient to seek medical help), 2) polysymptomatic and inflammatory dysfunction (many symptoms with well-identified inflammatory diseases such as allergic rhinitis or nasal polyposis), and 3) polysymptomatic and noninflammatory dysfunction (many symptoms without a clear underlying inflammatory disease).

DyNaChron shortening

The Original DyNaChron questionnaire was shortened by first, Rasch analysis involving a partial credit model and second qualitative content analysis. Because unidimensionality is required for Rasch analysis, we performed separate analyses for each symptoms domain subscale (organic functions and psychosocial consequences). For each item, we determined the proportion of respondents with floor/ceiling responses. Item fit was examined by standardized residuals. Local dependency between items of the same subscale was studied by correlation among pairs of items residual. According to person-free item measurement in the Rasch model, item calibration must be the same in different subgroups of respondents (lack of item bias). Invariance in the subscales was assessed by searching for uniform and non-uniform differential item functioning (DIF) across several factors: gender, age (18-35, 36-65, and ≥65 years), CND classification

(monosymptomatic/polysymptomatic) and CND inflammatory status (inflammatory/non-inflammatory).

The following criteria were used to flag items that performed poorly:

1. A floor effect or ceiling effect (minimum or maximum response >50% of patients, respectively),
2. Inter-item residual correlation >0.70; highly locally dependent items indicate that 2 items share more than half their "random" variance, so only one of the two items is needed for measurement,
3. Misfit to the Rasch model; item and person-fit residuals between ± 2.5 units are acceptable. A high negative (<2.5) residual number suggests an overfit item (i.e., the information provided by the item does not add any new information to the measurement). A high positive (>2.5) residual number suggests an underfit item (i.e., has poor fit to the model and the response categories are underdiscriminating or not discriminating differences in severity),
4. Important DIF assessed by ANOVA.

An expert committee including the original DyNaChron questionnaire developers, statisticians, and methodologists met for item analysis. The members jointly decided whether to retain or delete an item by the clinical importance of the content and the Rasch analysis. The content analysis was the main determinant.

Validation of the optimized version

The original DyNaChron version demonstrated robust psychometrics properties by CTT [9]. We performed Rasch analysis for both the original and optimized DyNaChron versions and CTT analysis for the optimized DyNaChron version only.

To test the good overall model fit, fit residuals (item–person interaction), with expected mean 0 and standard deviation 1 were examined for each symptom domain subscale. Item–trait interaction was examined by chi-square test for each subscale and was expected to be non-significant. Estimates of the internal consistency reliability of the subscale were based on the Person Separation Index (PSI), a reliability index ranging from 0 to 1. A minimum value of 0.85 is required for individual use [13].

To ensure that for a given item, respondents could differentiate between response options, we analyzed category probability curves and proposed to aggregate response categories into fewer options where disordered thresholds were found [16]. Such re-coding was used to test for overall model fit and fit residuals and for calculating PSI.

Assuming that the dimensional structure of the original DyNaChron version was preserved, this was evaluated by confirmatory factor analysis with maximum likelihood estimation and robust standard errors (Huber-White). The root mean square error of approximation (RMSEA), comparative fit index (CFI) and Tucker-Lewis index (TLI) were used to assess the model's fit.

Table 1. Characteristics of patients included in the optimization of the DyNaChron questionnaire.

	All patients (N=640)	
	N	Median (Range)/ %
Age	640	45 (18-81)
Sex		
Male	330	51.6
Female	310	48.4
Dysfunction classification		
Monosymptomatic dysfunction	96	15.1
Polysymptomatic and inflammatory dysfunction	440	68.8
Polysymptomatic and noninflammatory dysfunction	104	16.3
Symptoms evaluated by Doctor		
Nasal obstruction	515	80.5
Anterior rhinorrhea	415	64.8
Posterior rhinorrhea	412	64.4
Sense of smell difficulty	352	55.0
Facial pain or headache	298	46.6
Number of symptoms (5 max)	640	3 (0-5)
0	3	0.5
1	93	14.5
2	122	19.1
3	150	23.4
4	155	24.2
5	117	18.3

RMSEA < 0.08 and CFI and TLI > 0.90 indicated good fit [16].

For each symptom domain subscale of the optimized DyNaChron, reliability was assessed by the Cronbach alpha coefficient; values > 0.70 were acceptable [17]. Sensitivity to change was assessed by the standardized response mean (SRM; change difference divided by standard deviation of change difference, for patients reporting improved health (score ≥ 5) or and deteriorated health (score ≤ 3) in health status question) with estimated 95% confidence intervals (95% CI) by bootstrap method (1000 samples). An SRM of 0.2, 0.5 and 0.8 was considered small, moderate and large change, respectively [18]. Reproducibility was assessed in patients considering their health as stable (i.e. among patients reporting no change (score=4) in health status question) by the intraclass correlation coefficient (ICC) derived from a mixed ANOVA model. A value 0.6 to 0.8 was considered good and > 0.8 excellent [18].

Rasch analyses involved use of RUMM2020 software and inferential statistics SAS v9.3. All p-values were adjusted according to the Bonferroni method. P<0.05 was considered statistically significant.

Results

The median age of 640 patients included in optimizing the DyNaChron was 45 years, 51.6% were male and 68.8% had poly-

Table 2. Decisions for DyNaChron optimized by Rasch and content analyses

Symptom domain/ subscales	No. of items	Underfit	Residual correlation (r)> 0.7	DIF†	Extreme scores >50%	Content analysis	Expert committee decision	No. items remaining
Nasal obstruction								
Organic	8	Q5 (4.3, p=0.001)	Q9 (r=0.71 with Q8)	Q5 (for CND inflammatory status), Q7 (for age)		Redundancy between Q6 and Q7 and between Q9 and Q8	Q6 and Q7 merged; Q5 and Q9 rejected	5
Psycho-social	4			Q13 (for CND Inflammatory status)			Q13 rejected	3
Anterior rhinorrhea								
Organic	4			Q18 (for age)		Q18 retained for clinical relevance (when eating)	No change	4
Psychosocial	4						No change	4
Posterior rhinorrhea								
Organic	6						No change	6
Psychosocial	4						No change	4
Sense of smell difficulty								
Organic	8	Q45 (4.1, p<0.001) Q40 (8.6, p<0.001)		Q42 (for age); Q44 (for CND inflammatory status)	Q45 (63%)	Q42 retained for clinical relevance (detect unpleasant smells) Q40 and Q45 rejected ‡: sense of taste	Q45, Q40 and Q44 rejected	5
Psychosocial	4						No change	4
Facial pain								
Organic	13	Q65 (4.3, p<0.001)		Q59, Q60, Q62, Q63, Q66, Q67 (for age) Q57, Q63, Q64 (for sex)	Q55 (60%), Q62 and 63 (57%)	Q64 and Q65 rejected ‡: nasal obstruction Q59 to Q63 rejected ‡: eye embarrassment Q56 and Q57 rejected ‡: neurologic disease	Q58, Q66 and Q67 only retained	3
Psychosocial	4						No change	4
Cough								
Organic	6			Q77 (for sex)	Q77 (70%) and Q75 (68%)		Q75 and Q77 rejected	4
Psychosocial	4			Q72 (for age)		Q72 retained for clinical relevance (ability to concentrate)	No change	4

† All differential item functioning (DIF) items identified were uniform; ‡ Another concept was measured

Table 3. Summary fit statistics from Rasch analysis for the original and optimized DyNaChron.

Symptom domain/ subscales	Original DyNaChron					Optimized DyNaChron				
	No. of Items	Fit residual summaries		PSI	P-value†	No. of Items	Fit residual summaries		PSI	p-value†
		Items	Persons				Items	Persons		
Nasal obstruction										
Organic	8	0.12 (2.24)	-0.33 (1.22)	0.89	**<0.001**	5	0.14 (1.53)	-0.37 (1.04)	0.83	0.36
Psychosocial	4	-0.41 (0.50)	-0.54 (1.17)	0.90	0.06	3	0.43 (1.66)	-0.69 (1.33)	0.84	0.09
Anterior rhinorrhea										
Organic	4	-0.21 (1.18)	-0.45 (1.14)	0.88	**<0.001**	4	0.32 (1.62)	-0.50 (1.26)	0.84	**0.01**
Psychosocial	4	-0.57 (0.59)	-0.68 (1.28)	0.94	**0.03**	4	-0.08 (0.59)	-0.79 (1.36)	0.91	0.08
Posterior rhinorrhea										
Organic	6	0.22 (1.42)	-0.47 (1.41)	0.89	**<0.001**	6	0.27 (1.34)	-0.59 (1.49)	0.86	0.27
Psychosocial	4	-0.23 (0.61)	-0.79 (1.39)	0.93	0.12	4	0.15 (0.71)	-0.70 (1.37)	0.92	0.25
Sense of smell difficulty										
Organic	8	-1.15 (4.30)	-0.49 (1.36)	0.95	**<0.001**	5	-0.04 (2.19)	-0.90 (1.76)	0.97	0.110
Psychosocial	4	-0.37 (1.67)	-0.48 (1.05)	0.93	**0.01**	4	0.07 (1.71)	-0.41 (1.05)	0.91	**0.04**
Facial pain										
Organic	13	0.04 (1.62)	-0.29 (1.32)	0.89	**<0.001**	3	0.49 (1.21)	-0.48 (1.08)	0.77	0.120
Psychosocial	4	-0.38 (2.05)	-0.88 (1.37)	0.96	0.40	4	0.05 (1.73)	-0.88 (1.35)	0.95	0.66
Cough										
Organic	6	-0.69 (1.44)	-0.31 (0.84)	0.82	**<0.001**	4	0.04 (1.89)	-0.40 (1.10)	0.76	**0.004**
Psychosocial	4	-0.28 (1.33)	-1.03 (1.56)	0.95	0.32	4	0.38 (1.02)	-1.01 (1.79)	0.94	0.52

PSI: person separation index; † item–trait interaction.

symptomatic and inflammatory dysfunction (Table 1).

For nasal obstruction, organic subscales (Table 2), 5 of the 8 items were retained. Two items were rejected: Q5 "Does your stuffy nose cause discomfort because *it affects your sense of smell*?" presented underfit (4.3, p=0.001) and significant uniform DIF with CND inflammatory status (p<0.0001), and Q9 "… *when you do a sport*?" showed a high local dependency with Q8 "… *when you make a physical effort*?" (r=0.71). From content analysis, the expert committee merged Q6 "…*it prevents you from falling asleep*?" and Q7 "…*it wakes you up during the night*?" into Q5 "… *it prevents you from sleeping*?". For the psychosocial subscales, Q13, "*To what extent does your stuffy nose affect your everyday life*?", was discarded because of significant uniform DIF with CND inflammatory status (p=0.002). With equal ability, this item seemed to be easier for patients with CND non-inflammatory status.

For anterior rhinorrhea, organic and psychosocial subscales, all items were retained. The item Q18, "Does (…) an excessively moist or runny nose (…) cause discomfort *when you are eating*?", presented significant uniform DIF for age groups (p=0.002), younger patients more likely to endorse this item than older patients even with the same level of latent trait. Nevertheless, after content analysis, the item was retained.

For posterior rhinorrhea, organic and psychosocial subscales, all items were retained.

For the sense of smell difficulty item, organic subscales, 3 of 8 items were discarded: Q45 "Are you bothered because your ability to recognise the *sweet or salty taste* of foods is impaired?" presented underfit (4.1, p<0.001) and a floor effect (63% of the sample); Q40 "… *ability to recognise the taste of foods* is impaired?" showed underfit (8.6, p<0.001); and Q44 showed significant uniform DIF with CND inflammatory status (p=0.004). Q42 "… *ability to smell hygiene products* (…) is impaired?" presented significant uniform DIF for age groups (p=0.0004) but was retained after content analysis.

For posterior rhinorrhea, psychosocial subscale, all items were retained and no "misfit" item was found.

For facial pain, organic subscales, only 3 of the 13 items were retained. One item presented underfit, 6 items showed significant DIF for age groups and 3 items for sex, and 3 items showed a floor effect. On content analysis, several items measured concepts other than facial pain [nasal obstruction (Q64 and Q65), eye embarrassment (Q59 to Q63), or neurologic disease (Q56 and Q57)]. The psychosocial subscale was not modified after

Table 4. Summary of classical test theory validation analysis of the optimized DyNaChron.

Symptom domain/ subscales		Cronbach alpha	Reproducibility		Sensitivity to change			
					Deterioration		Improvement	
	No. of items		N	ICC (95% CI)	N	SRM (95% CI)	N	SRM (95% CI)
Nasal obstruction								
Organic	5	0.85	224	0.82 (0.78–0.86)	27	0.42 (0.03–0.85)	62	-0.94 (-1.16–-0.71)
Psychosocial	3	0.84	222	0.78 (0.73–0.83)	27	0.60 (0.18–1.06)	61	-0.73 (-0.93–-0.50)
Anterior rhinorrhea								
Organic	4	0.84	250	0.82 (0.77–0.85)	22	0.31 (-0.07–0.60)	51	-1.23 (-1.51–-0.97)
Psychosocial	4	0.91	243	0.81 (0.76–0.85)	22	0.22 (-0.17–0.81)	50	-0.92 (-1.21–-0.64)
Posterior rhinorrhea								
Organic	6	0.86	251	0.82 (0.77–0.86)	23	0.44 (0.02–0.85)	43	-0.74 (-1.03–-0.48)
Psychosocial	4	0.92	246	0.82 (0.77–0.85)	22	0.49 (0.09–0.90)	43	-0.54 (-0.75–-0.33)
Sense of smell difficulty								
Organic	5	0.97	308	0.92 (0.9–0.94)	19	0.37 (-0.05–0.68)	33	-0.82 (-1.11–-0.54)
Psychosocial	4	0.90	272	0.88 (0.85–0.9)	19	0.42 (-0.03–0.84)	27	-0.58 (-0.84–-0.33)
Facial pain								
Organic	3	0.77	272	0.83 (0.79–0.86)	22	0.53 (0.13–0.95)	45	-0.60 (-0.84–-0.34)
Psychosocial	4	0.95	273	0.81 (0.76–0.85)	20	0.12 (-0.33–0.53)	46	-0.65 (-0.85–-0.41)
Cough								
Organic	4	0.80	287	0.77 (0.71–0.81)	10	0.42 (0.03–0.85)	46	-0.69 (-0.95–-0.44)
Psychosocial	4	0.93	287	0.75 (0.7–0.8)	10	0.08 (-0.62–0.76)	46	-0.57 (-0.76–-0.39)

Sensitivity to change was assessed by the standardized response mean (SRM; change difference divided by standard deviation of change difference, for patients reporting moderate or important change) with estimated 95% confidence intervals (95% CIs) by the corrected bias percentile bootstrap method (1000 samples). Reproducibility was assessed by the intraclass correlation coefficient (ICC) derived from a mixed ANOVA model.

Rasch analysis.

For the cough domain, organic subscales, 2 of 6 items were removed because they showed a floor effect (70% of the sample for Q77 and 68% for Q75) and Q77 presented significant DIF for sex groups ($p<0.0001$). The psychosocial subscale showed no change. On content analysis, Q72 item (ability to concentrate), which presented significant DIF for age groups ($p=0.005$), was retained. In total, 19 of 69 items were removed, for a 27.5% decrease in number of items.

Validation of the optimized DyNaChron

Table 3 shows the results of fit statistics from Rasch analyses of the original and optimized DyNaChron. Item threshold maps showed that all items were reversed. So, items of all subscales were assigned response scales with 5 modalities, except for facial pain, psychosocial subscales, which were assigned response scales with 8 modalities.

Items and person-fit of the original DyNaChron version did not present misfit, except for the domain sense of smell difficulty, organic subscales (mean residual items -1.15±4.3). For all subscales, item–trait interaction was significant ($p<0.001$), which indicates overall misfit. Overall, 25 items (32%) of the original DyNaChron had disordered thresholds.

Fit to the Rasch model for the optimized version was reevaluated after the shortening process and re-scoring thresholds. Results for the optimized domains were satisfactory; residual mean values for items and person-fit showed adequate fit to the model. Item–trait interaction was no longer significant for all organic and psychosocial subscales of the 6 domains except for the cough domain, organic subscale ($p=0.004$). PSI was excellent, except for the facial pain domain, organic subscales (PSI=0.77), and cough domain, organic subscales (PSI=0.76). Factorial analysis confirmed that the initial structure of the optimized scale was preserved (RMSEA=0.060 [90% CI 0.058-0.062]; CFI=0.90 and TLI=0.89). With CTT analysis (Table 4), internal consistency was excellent for all symptom subscales of the optimized DyNaChron, except for the facial pain domain, organic subscales, and cough domain, organic subscales, but with

acceptable values (Cronbach alpha 0.77 and 0.80, respectively). For the two versions, reproducibility was good for the cough domain, organic and psychosocial subscales (ICC 0.75–0.79), and excellent for the subscales for the other 5 domains. The SRM magnitude was the same between the original and optimized version. For patients who perceived their health improved, all subscales of the optimized DyNaChron seemed responsive, with SRM values > 0.5, reflecting moderate to high ability to detect improvement in health state. Analysis of responsiveness in all symptom domains for patients who perceived their health as deteriorated showed fair ability to detect change (SRM <0.50) except for the sense of smell difficulty and facial pain domains, organic subscales, for the original DyNaChron version (SRM=0.56 and 0.65, respectively) and for the nasal obstruction, psychosocial subscale and facial pain, organic subscale, for the optimized version (SRM=0.60 and 0.53, respectively).

Discussion

Various strategies are available for shortening questionnaires [10,11]. As recommended, we used content analysis and a modern psychometrics approach with a Rasch model to shorten the DyNaChron for easier clinical use. We aimed to maintain the content validity within the identified 6-domain structure and preserve the psychometrics properties. Items with lack of expected fit were removed by the expert committee after validation. After the shortening process, 19 of the 69 symptom-related items were removed; nasal obstruction (decrease from 12 to 8 items), facial pain or headache (from 17 to 7 items), sense of smell difficulty (from 12 to 9 items) and cough (from 10 to 8 items) and 5 items presenting some DIF for age (Q18, Q42, Q66, Q67 and Q72) were retained after content analysis.

The original DyNaChron questionnaire presented excellent properties [9]. The structure of the optimized version was preserved and its psychometrics properties were the same as or better than the original version. Indeed, Rasch analysis of the original DyNaChron showed an overall misfit of all domain organic subscales to the model and disordered thresholds for 32% of items. After the shortening process and collapsing categories showing disordered thresholds, overall fit to the model was improved. Disordered thresholds may result from too many categories or unclear label options. They can also appear with no low frequency in any category, in which case there are structural problems in the responses [19]. Most are related to the increase in measurement precision as compared to the same number of dichotomous items. Re-coding disordered thresholds remains problematic for existing scales, and changes to the response format should not be based on statistical evidence alone.

One strength of the study is the use of the combination of content and statistical processes. According to a review on guidelines for shortening questionnaires, only 40% of the 91 shortening processes identified used the combination of the 2 approaches [11]. The large sample size is another strength. Finally, DyNaChron was developed by an expert-based process with a well-defined concept, a condition suggested by Rudmik et al. [4]. The systematic review showed that current tools validated for adults with CND do not satisfy this condition. Yet, this condition is required to keep the measure focused on the latent trait during the shortening process [10,11].

Our study has two main limitations. First, the same patient sample was used for the statistical analysis leading to the optimized instrument and for evaluating its psychometrics properties. We did not include a cross-validation in an independent sample, which is recommended to not overfit the optimized form to the development sample [10]. However, a strength of the Rasch modelling is that resulting scales depend solely on respondent ability and item difficulty [13]. The second limitation is the low proportion of items removed. The original DyNaChron questionnaire includes a large number of items, and only 27% were removed during the shortening process. According to Goetz et al., this proportion can vary widely (21-88%) and does not depend on the length of the original scale [11]. However, the questionnaire is divided into 6 symptom domains and patients rarely have all symptoms at the same time. So, few patients really respond to all items because they complete only domains items where the symptom is present. According to frequency of reported symptoms, patients had to fill in an average of 4.4 domains of the questionnaire, and rarely all items (28.8%). Mean completion time was not exceeding 15 min.

Conclusion

In conclusion, we developed an optimized form of the validated DyNaChron questionnaire by using Rasch analysis supported by content analysis. This new version optimizes the quality of the assessment by deleting redundant items and reduces the burden on respondents while improving the psychometrics properties and preserving the structure.

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Authorship contribution

CR interpreted the results and drafted the manuscript, MS performed the statistical analysis and interpretation, JE contributed to the interpretation of the data, CG contributed to statistical analysis, interpretation and reduction of the questionnaire, RJ conceived the study, contributed to supervision of the data collection and interpretation of the data, FG conceived the study, supervised the data collection, statistical analysis and interpretation. All authors have read, edited, and approved the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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This paper contains supplementary materials online: at www.rhinologyjournal.org

SUPPLEMENTARY MATERIAL

Service d'Epidémiologie et Evaluation Cliniques

Centre d'Epidémiologie Clinique

Société Française d'ORL

Etude DYsfonctionnement **NA**sal **CHRON**ique

QUESTIONNAIRE

Identity of the patient:

Identity number Family Name

Date when questionnaire was filled in. ……/……/……

You have consulted your doctor because your nose or your sinuses are causing you discomfort.

Please answer all of the questions on both sides of each page describing your feelings as precisely as possible There are no right or wrong answers. It is important for us to know how you feel about your symptoms.

According to S. Kacha et al. Development and validity of the DyNaChron questionnaire for chronic nasal dysfunction. Eur Arch Otorhinolaryngol. 2012 Jan;269(1):143-53.

Please tick one of the boxes between 0 and 10 according to the degree of discomfort you feel (0 = no discomfort; 10 = unbearable discomfort). If you feel no discomfort, don't forget to tick the 0 box. If you wish to modify your choice, circle the ticked box containing your new choice.

1. Do you feel discomfort because of a **stuffy nose**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

If you have ticked box 0 (not at all) for question 1, go to question 10.

2. Does your stuffy nose cause discomfort because you have the feeling that your voice is nasal?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

3. Does your stuffy nose cause discomfort because it makes you **breathe through your mouth**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

4. Does your stuffy nose cause discomfort when you **chew or swallow food**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

5. Does your stuffy nose cause discomfort because it prevents you from **sleeping**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

6. Does your stuffy nose cause discomfort when you make a **physical effort** (climbing the stairs, walking fast,…)

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

7. To what extent does your stuffy nose affect your **moods**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

8. To what extent does your stuffy nose affect your ability to **concentrate** (reading, activities that require close attention, making decisions,…)?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

9. To what extent does your stuffy nose affect your **relationships with others**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

10. Do you feel discomfort because your **nose** is excessively **moist or runny**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

11. Does the need to **blow your nose** cause discomfort?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

12. Does the need to **sniff** cause discomfort?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

If you have ticked box 0 (not at all) for questions 10, 11 and 12, go to question 21.

13. Does the feeling of an excessively moist or runny nose (or the consequences: blowing your nose, sniffing, picking your nose) cause discomfort **when you are eating**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

14. Does the feeling of an excessively moist or runny nose (or the consequences: blowing your nose, sniffing, picking your nose) cause discomfort **when you are speaking**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

15. Does the feeling that you have an excessively moist or runny nose cause discomfort because you need to **blow your nose during the night**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

16. Does the feeling that you have an excessively moist or runny nose cause discomfort because you need to **blow your nose as soon as you wake up and during the morning?**

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

17. Does the feeling that you have an excessively moist or runny nose (or the consequences: blowing your nose, sniffing, picking your nose) affect your **moods**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

18. Does the feeling that you have an excessively moist or runny nose (or the consequences: blowing your nose, sniffing, picking your nose) affect your ability to **concentrate** (reading, activities that require close attention, making decisions,...)?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

19. Does the feeling that you have an excessively moist or runny nose (or the consequences: blowing your nose, sniffing, picking your nose) affect your **relationships with others**?

Not at all ☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10 Unbearable

20. Does the feeling that you have an excessively moist or runny nose (or the consequences: blowing your nose, sniffing, picking your nose) affect **your everyday life**?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

21. Does a feeling of **something trickling down the back of your nose or your throat** cause discomfort?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

If you have ticked box 0 (not at all) for question 21, go to question 32.

22. Does the trickling at the back of your nose or throat cause discomfort because you need to **clear your throat**?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

23. Does the mucus cause discomfort because it remains **stuck in your throat**?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

24. Does the trickling down the back of your nose or throat causes discomfort because you need to **cough**?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

25. Does the trickling down the back of your nose or throat causes discomfort because you need to **spit**?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

26. Does the trickling down the back of your nose or throat causes discomfort because it affects your **voice** (hoarseness)?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

27. Does the trickling down the back of your nose or throat causes discomfort because it disturbs your **sleep** (by preventing you from falling asleep or by waking you up during the night)?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

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28. Does the trickling down the back of your nose or throat causes discomfort because it affects your **moods?**

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

29. To what extent does the trickling down the back of your nose or throat affect your ability to **concentrate** (reading, activities that require close attention, making decisions,...)?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

30. To what extent does the trickling down the back of your nose or throat affect your **relationships with others**?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

31. To what extent does the trickling down the back of your nose or throat affect **your everyday life**?

Not at all Unbearable
0 1 2 3 4 5 6 7 8 9 10

32. Are you bothered because your **sense of smell is impaired**?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

If you have ticked box 0 (not at all) for question 32, go to question 42.

33. Are you bothered because your ability to **detect "dangerous" smells** (gas, petrol, smoke, burning, etc) is impaired?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

34. Are you bothered because your ability to **detect cooking smells** (coffee, hot bread/toast, a dish that is simmering or being reheated…) is impaired?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

35. Are you bothered because your ability to **smell hygiene products** (soap, toilet water, perfume, household cleaning products…) is impaired?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

36. Are you bothered because your ability to **detect "unpleasant" smells** (WC, rotting substances, certain cheeses, sweat,…) is impaired?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

37. Are you bothered because your ability to smell **your personal bodily odours** (sweat, WC,…) is impaired?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

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38. To what extent does this impairment of your sense of smell affect your **moods**?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

39. To what extent does this impairment of your sense of smell lower **your sex-drive?**

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

40. To what extent does this impairment of your sense of smell affect your **relationships with others?**

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

41. To what extent does this impairment of your sense of smell affect **your everyday life**?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

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42. Do you feel any discomfort due to a **stuffy head** or **facial tension**, or **facial pain**, or **headaches?**

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

If you have ticked box 0 (not at all) for question 42, go to question 50.

43. To what extent do these feelings of a stuffy head or facial tension, or facial pain or headaches affect your **moods**?

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Unbearable
0 1 2 3 4 5 6 7 8 9 10

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44. To what extent do these feelings of a stuffy head or facial tension, or facial pain or headaches affect your ability to **concentrate** (reading, activities requiring close attention, taking decisions …)

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

45. To what extent do these feelings of a stuffy head or facial tension, or facial pain or headaches affect your **relationships with others?**

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

46. To what extent do these feelings of a stuffy head or facial tension, or facial pain or headaches affect **your everyday life**?

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

When you have these feelings of a stuffy head or facial tension, or facial pain or headaches, are you also:

47. less able to carry out your **everyday physical activities** (walking, climbing the stairs,…)

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

48. bothered by **pain in the eyes** when you move them?

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

49. bothered when you **lean your head forward**?

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

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50. Are you bothered by a **cough**?

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

If you have ticked box 0 (not at all) for question 50, go to question 59.

51. To what extent does this cough disturb your **relationships with others**?

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

52. To what extent does this cough affect your **moods**?

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

53. To what extent does this cough affect your ability to **concentrate** (reading, activities requiring close attention, taking decisions …)

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

54. To what extent does this cough affect your **everyday life**?

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

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55. To what extent does this cough disturb your **sleep?**

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

56. Do you feel discomfort because the cough causes you to **spit**?

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

57. To what extent does this cough make you feel **tired**?

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

58. Do you feel discomfort because the cough sometimes causes a **headache**?

Not at all — Unbearable

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
0 1 2 3 4 5 6 7 8 9 10

59. Please make sure that you have answered at least the following questions:

1
10, 11, 12
21
32
42 and 50

Thank you for answering the questions carefully

According to S. Kacha et al. Development and validity of the DyNaChron questionnaire for chronic nasal dysfunction. Eur Arch Otorhinolaryngol. 2012 Jan;269(1):143-53.