



Application of Receiver Operating Characteristic (ROC) Curve to Determine the Diagnostic Ability of A Validated Ten - Item Questionnaire (SS - 10) In Estimating the Prevalence of Sensitive Skin in Hong Kong Population

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Abstract

Sensitive skin is a complex skin condition with patients presented mainly subjective neurological symptoms. Prevalence of sensitive skin across populations vary from 13% in Chinese cities to a three-fold higher in American and European countries. Our study aims to develop a cutoff value using the Receiver Operating Characteristics curve in clinical sample in Hong Kong and examine the prevalence of sensitive skin in a community sample across five districts of Hong Kong. **Method:** The first group of participants consisted of a total of 1,111 new clinic attendees in a local clinic in Kowloon area of Hong Kong. The second group of data was collected from 500 community samples across 5 areas of Hong Kong, with the geographic characteristics ranging from highly to less populated. Participants filled in a questionnaire which contained their demographic information as well as the 10-item version of Sensitive Skin Scale (SS-10). For the clinical sample, a dermatologist diagnosed all the participants for sensitive skin and identified 84 cases (7.56%) of true sensitive skin. **Results and conclusion:** The Area Under the Curve (AUC) of 0.866 of the ROC curve suggested a good diagnostic ability of SS-10 in population of Hong Kong. A cutoff value of 25.5 with a sensitivity of 91.7% and specificity of 75.5% gave rise to 11.4% of prevalence of sensitive skin in the community sample, which is coherent with that in Mainland China. The study may have significant clinical implications for SS-10 to be a standardized and cost-effective screening tool in Asian populations.

Keywords: Sensitive skin, prevalence, 10-items version of the Sensitive Scale, cutoff value, ROC curve, Area Under the Curve

Introduction

Sensitive skin is a skin condition presented mainly with subjective neurological symptoms with minimal signs.^[1,2] It is reported to be a common global skin condition with etiology and pathogenesis still unclear.^[2-6] The absence of a definitive diagnostic test made epidemiological and surveillance study especially its prevalence estimation difficult.^[7] Diagnosis relied on the vigilance of doctors diagnosing the condition during face to face patient consultation in clinic settings. Published prevalence data mostly obtained from clinics, phone surveys or mail out questionnaires.^[8-10] Community surveys carried out based on self-reported four-point scale: very sensitive; moderately sensitive; not very sensitive and not sensitive at all may be subjectively interpreted by individuals depending on the traits of the interviewees, states and severity of the disease

during interviews.^[4,5,11-16] For a subjective neurological disease like sensitive skin, self-reported semi-quantitative questionnaire survey may yield over reporting and inflating prevalence due to false positivity rate. In the documented literatures, sensitive skin was reported to have an average prevalence rate of 36.9% worldwide especially in Europe and United States while an average of 13.0% was reported in the community study in three major metropolitan cities in China.^[17,12] Another study consisting of a smaller sample predominately of female showed a prevalence of 23% in the latter.^[18] A wide discrepancy was seen which has not been fully explained except a different screening method.^[19]

As sensitive skin is defined by abnormal sensations in response to a variety of factors, the best method to diagnose sensitive skin is the use of scales.^[17,19] The 10-items version of the Sensitive Scale (SS - 10) (Appendix 1a) assessing the severity of sensitive skin with

good content validity which captures the core symptoms of sensitive skin was developed by Misery.^[19] The questionnaire has been tested in 11 countries globally and is useful in measuring the severity of sensitive skin. The scale possesses a high internal consistency (Cronbach's alpha = 0.94). It also has a significant and good correlation with Dermatology Life Quality Index (DLQI) ($r = .57, p < 0.0001$) and has been useful in different geographical settings. However, its cutoff level or value in diagnosing sensitive skin has never been reported. Without establishing a cutoff value, the scale could not be standardized and its predictability and diagnostic power dependent on sensitivity and specificity will be compromised. This limit its long - term use as an effective and accurate self -reporting epidemiological diagnostic and surveillance tool of sensitive skin across different populations of the world. In fact, the paper suggested individuals scored from 20 to 60 in SS -10 could be identified as sensitive skin despite no scientific explanation given; albeit; further studies are suggested by the authors.^[19]

In view of this, we attempt to develop a cutoff value in a clinical sample of Hong Kong by plotting a Receiver Operating Characteristic (ROC) curve based on sensitive skin data collected locally to select a cut off value with high sensitivity and predictability and applied it in an epidemiological community study to estimate the prevalence of sensitive skin in the local population of Hong Kong.

Method

The first group of data came from a clinic based prospective study carried out during the period of 1st May 2018 to 30 April 2019 in a private clinic located in the Centre of Kowloon district, Hong Kong. All newly attended patients during this study period were recorded and consulted by a dermatologist. The proportion of clinically diagnosed sensitive skin patients in the private clinic setting, demographic characteristics including age, gender, occupation, marital status, site of involvement, medical history and concomitant skin dermatosis were recorded by a dermatologist. The clinical diagnosis of sensitive skin is based on the definition suggested by International Forum for the Study of Itch (IFSI): sensitive skin is a syndrome defined by the occurrence of unpleasant sensations (stinging, burning, pain, pruritus, and tingling sensations) in response to stimuli that normally should not provoke such sensations. These unpleasant sensations cannot be explained by lesions attributable to any skin disease.^[21] Prior to the consultation, the patients were asked voluntarily to complete the SS-10. Consent was obtained by completing and returning the questionnaire. A translated Chinese version of SS - 10 was used. (Appendix 1b) SS -10 score was recorded and compared with the clinically diagnosis of sensitive skin. The score was also recorded in the subsequent follow up consultation to monitor progress of the disease after management with counselling and emollients only. A total of 1,111 cases were recruited and 84 cases were diagnosed as true sensitive skin and 1,027 were diagnosed as true negative sensitive skin cases. (Table 1)^[20]

Table 1

Clinical diagnosis of sensitive skin in clinic setting made by dermatologist based on the IFSI definition	Number of Patients
True Positive Cases	84
True Negative Cases	1027
Total	1111

The second group of data consisted of epidemiological data from a community study on the prevalence of sensitive skin in Hong Kong using the validated Sensitive Scale -10 (SS-10) Questionnaire.

In January 2018, a total of 500 subjects were recruited using quota sampling method in different geographical areas from more densely populated commercial areas to more spacious sub-urban areas. Having covered a comprehensive geographic feature of Hong Kong at various locations in the sampling increased the representativeness of the studied sample to be generalized to the overall Hong Kong population. Two of the locations were in Kowloon peninsula (Mong Kok, Tsim Sha Tsui), one in Hong Kong island (Causeway Bay), two in the rest of Hong Kong which are less densely populated than the former three (Tsuen Wan and Shatin). Participants were interviewed face-to-face by volunteers, who have no prior knowledge of sensitive skin, on the streets in these geographical locations in Hong Kong. The participation was voluntary. Consent was given to the interviewer when participants agreed to complete the questionnaire and the anonymity of participants was enforced. The questionnaire administered included demographic information (gender, age, ethnicity, marital status, number, gender and age of children, and concomitant skin diseases), following which was the Chinese version of SS-10.

Using the SPSS 22 software, the Receiver Operating Characteristic (ROC) curve analysis was performed to estimate the area under the curve (AUC) and the cut off value with high sensitivity and specificity.

Results

As show in Table 2, a cutoff value of > 25.5 yielded a sensitivity of 91.7% and specificity of 75.5% in the clinical data (N = 1111). An area under the curve of 0.866 suggested that SS-10 had good diagnostic ability (Figure 1). From the second group of data, a prevalence of 11.4 % was documented in the community population with a cut -off value of 25.5 give rise to a prevalence of 11.4 %. (N = 500).

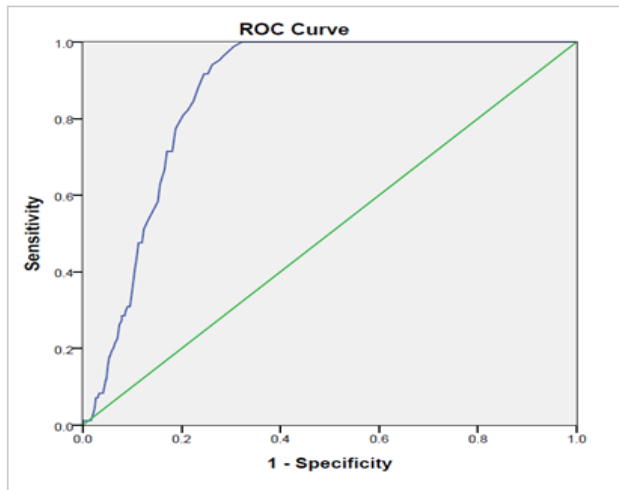
Table 2

Coordinates of curve		
Test Result Variable(s): Ss-total score		
Positive if Greater Than or Equal To ^a	Sensitivity	1-Specificity
-1.00	1.000	1.000
.50	1.000	.793
1.50	1.000	.761
2.50	1.000	.732
3.50	1.000	.701
4.50	1.000	.670
5.50	1.000	.627
6.50	1.000	.602
7.50	1.000	.572
8.50	1.000	.535
9.50	1.000	.510
10.50	1.000	.477
11.50	1.000	.463
12.50	1.000	.440
13.50	1.000	.426
14.50	1.000	.406
15.50	1.000	.381
16.50	1.000	.367
17.50	1.000	.351
18.50	1.000	.337

19.50	1.000	.322
20.50	.988	.306
21.50	.964	.285
22.50	.952	.277
23.50	.940	.262
24.50	.917	.253
25.50	.917	.245
26.50	.881	.234
27.50	.845	.224

Cut off value = 25.5

Figure 1



Area Under the Curve	Standard Error	Asymptotic 95% Confidence Interval	
		Lower Bound	Upper Bound
0.866	0.012	0.843	0.889

Table 3

N = number	Valid	500
	Missing	0

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid .00	443	88.6	88.6	88.6
1.00	57	11.4	11.4	100.0
Total	500	100.0	100.0	

Discussion

Since the development of the SS-10, the total score has been used as a continuum to indicate the severity of skin sensitivity while

diagnostic and screening properties are absent due to a lack in cutoff value. In this paper, the cutoff value of SS-10 is developed through plotting a ROC curve in clinical population in Hong Kong, giving rise to a prevalence of 11.4% that is coherent with the proportion of diagnosis by a dermatologist in the clinical study by Chan.^[20]

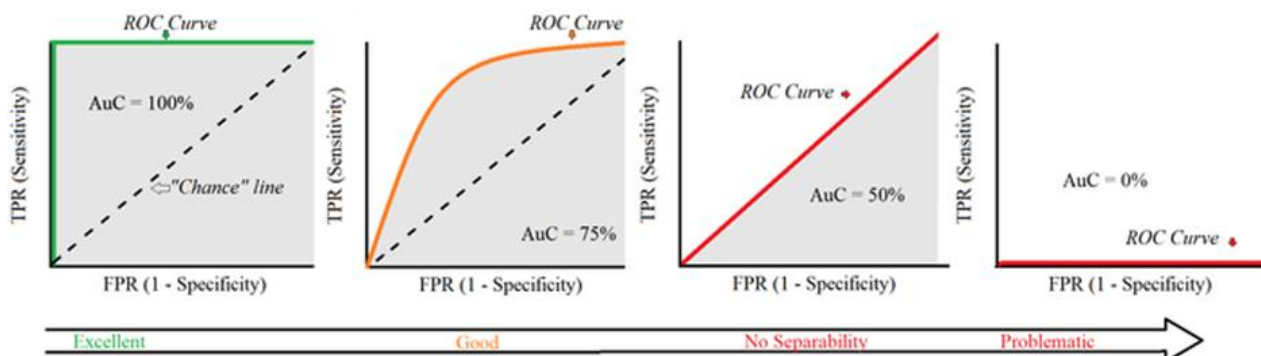
A Receiver Operating Characteristic (ROC) Curve is an established statistical method to compare diagnostic tests. ROC Curve had been shown efficacious and applicable in many areas of science including medicine. It was originally developed during the Second World War by the Allies as part of the radar system to analyse data to differentiate between enemy aircrafts and signal noise produced by flocks of birds. As the sensitivity of the receiver increased, so did the number of false positives. We experiment to compare the dermatologist clinical diagnosis of sensitive skin based on the IFSI definition in a clinic base setting to the validated SS – 10 Questionnaire scores in the community setting in Hong Kong.

The ROC is a plot of the true positive rate against the false positive rate. The ROC curve enabled the researcher ability in the following areas:

1. The relationship between sensitivity and specificity. As illustrated in the ROC curve, an increase in sensitivity will result in a decrease in specificity; the converse is equally true; a decrease in sensitivity results in an increase in specificity.
2. To verify accuracy; the closer the graph to the top and left-hand borders, the more accurate the test is. Similarly, the test is less accurate when the graph is closer to the diagonal. An ideal perfect test; which is unlikely to exist in real world; would go straight from zero up the top-left corner and then straight across the horizontal.
3. To aid researcher manually to select the best cutoff value to yield the maximum sensitivity and specificity which is usually at least 0.8 or greater.

The area under the curve of the ROC curve is important to exemplify statistically whether the test used to compare is a good test of diagnostic value. The greater the area under the curve, the more accurate the test. A perfect test has an area under the ROC curve of 1 and a less useful test will be under 0.5. In our case, the area under the curve of our derived ROC curve = 0.866 (95% Confidence Interval: 0.843 – 0.889) indicate the SS – 10 Questionnaire has a good diagnostic ability in our community setting study of sensitive skin in Hong Kong. (Table 4)

Table 4: The relationship between the area under the curve (AuC) and diagnostic ability of the test



(The green line is the perfect test, the orange line indicated an above 0.5 or 50 % chance of an accurate test; i.e.; good test, the red line is the diagonal below which is less than 0.5 or 50 % chance of having an accurate test; i.e.; a bad test in diagnosis. TPR = true positive rate; FPR = false positive rate = 1 – Specificity)

In the above study; using a validated 10 item sensitive scale comparing with dermatologist diagnosed true positive case of sensitive skin; we were able to estimate a more precise and accurate prevalence of sensitive skin in the community of Hong Kong. The results obtained may be more valid and reliable over time than the previously used four items questionnaire based on asking the subjects to rate their skin as “very sensitive”, “sensitive”, “slightly sensitive” or “not sensitive” which may be subjected to various interpretations in different geographical areas, cultures, languages and context. The ROC curve with a cutoff of at least 0.8 or higher may reduce false positivity rate and avoid over-reporting. Moreover, by adjusting the likelihood ratio or cutoff value; the result may be more flexibly reflecting the prevalence of the condition in the population and to determine whether a test result usefully changes the probability that a condition (such as a disease state) exists.

Our estimated prevalence of 11.4% is much lower than that reported in the literature with an average of 36.9% but comparable to the prevalence of 13% of sensitive skin estimated by the probability cluster sampling methods in the metropolitan cities of China. Our paper is not aiming at investigating the underlying reasons for the difference observed but the high trade off of a high sensitivity rate and specificity rate may well select the “very sensitive” and “rather very sensitive” individuals in the populations who indeed are the one diseased with sensitive skin based on the clinical definition of IFSI. The high prevalence reported in the literature may only select those who have mild or occasional symptoms of sensitive skin under different circumstances but not specific enough to be diagnosed as a disease condition. It would be of interest to apply the ROC curve to determine the diagnostic ability of the validated Ten - Item Questionnaire (SS – 10) in populations in other parts of the world and compare the previously reported sensitive skin prevalence based on the four items questionnaire which is worth further investigation.

There are limitations of ROC curve like the use of dissimilar datasets in one ROC plot is a commonly reported error when ROC is used for comparing multiple classifiers. One ROC curve with several ROC points are drawn in one plot. The comparison between them is valid only when the classifiers are evaluated on either a single dataset or multiple datasets that are almost identical among each other in terms of their data size and positive: negative ratio. The other limitation is that ROC becomes less powerful when used with imbalanced datasets. One effective approach to avoid the potential issues with imbalanced datasets is using the early retrieval area, which is a region with high specificity values in the ROC space. Checking this area is useful to analyse the performance with fewer false positives (or small false positive rate). (Figure 1)

Conclusion

The current study established the cutoff value of SS-10 on a clinical data in Hong Kong. It possessed good diagnostic power and yielded 91.7% of sensitivity and 75.5% of specificity with AUC of 0.866. Using the cutoff value of 25.5 the study reported a

prevalence of 11.4% in community sample in Hong Kong, suggesting its ability to distinguish individuals with and without skin sensitivity. The study has significant clinical implications that points to wider application of SS-10 in Asian populations as a screening tool for sensitive skin.

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Appendix 1a and 1b

Supplementary material to article by L. Miserey et al. "A New Ten-Item Questionnaire For Assessing Sensitive Skin: The Sensitive Scale-10"

DEGREE OF OVERALL SKIN IRRITATION DURING THE PAST 3 DAYS

Using a vertical line, indicate the symptoms felt during the past 3 days on the horizontal line (0 = absence of irritation, 10 = intolerable irritation)

Important To be completed by the patient



SEVERITY OF SKIN CONDITION DURING THE PAST 3 DAYS

Please indicate the intensity of each of the following symptoms during the past 3 days (0 = zero intensity, 10 = intolerable intensity); darken one number between 0 and 10

Important To be completed by the patient

Skin Condition felt

Tingling	0	1	2	3	4	5	6	7	8	9	10
Burning	0	1	2	3	4	5	6	7	8	9	10
Sensations of heart	0	1	2	3	4	5	6	7	8	9	10
Thoughts	0	1	2	3	4	5	6	7	8	9	10
Itching	0	1	2	3	4	5	6	7	8	9	10
Pain	0	1	2	3	4	5	6	7	8	9	10
General discomfort	0	1	2	3	4	5	6	7	8	9	10
Hot flashes	0	1	2	3	4	5	6	7	8	9	10

Visible Skin Condition

Redness

0	1	2	3	4	5	6	7	8	9	10
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Fig. S2 English version of Sensitive Scale-10

皮膚病問卷調查表

詢問地區	詢問日期	Code
詢問醫院	醫生姓名	年齡 01
問卷編號	結束時間	性別 02
本人同意此問卷與皮膚病問卷公司所有資料不與他人進行討論，並且不能向任何人士透露有關本問卷研究的詳情，請在內線，結果及治療進行中的資料。		
詢問醫院名	詢問醫生名	Code
此問卷由「小區」/「次」，與「區」一個作連續性的問卷調查，請在進行一項皮膚病問卷研究，如能合意者，請在放心，將此問卷問卷資料與皮膚病問卷公司使用，並感謝研究。		
請填寫		
S1 您的居住地址(不用填寫郵政編碼)(單選)	Code	
	男性 01	
	女性 02	
S2 年齡性別(單選)	Code	
	12歲以下 00	
	13至19歲 01	
	20至29歲 02	
	30至39歲 03	
	40至49歲 04	
	50至59歲 05	
	60歲或以上 06	
S3 請問你現在從事什麼行業？(單選)	Code	
	學生 01	
	公務 02	
	醫務 03	
	專業技術 04	
	專業或退休人士 05	
S4 請問你本人及家人是否患過以下皮膚病？(可多選)		
濕疹或皮膚炎	皮膚研究/治療/諮詢/ 醫學諮詢服務公司	紅斑/凍瘡/皸裂/ 癬/疥瘡/皮膚病
01	02	03
		04
		05
		06
S5 請問你的婚姻狀況？(單選)	Code	
	未婚 01	
	已婚 02	
	離婚 03	
	Code	
S6 你以前是否已患過濕疹，請問你的年齡？(單選)	Code	
	00	
S7 如S6回答「是」或以上，請問你的子女是否患過濕疹？(請以表格中的一表格填寫)		
	年齡	性別
	01 第一孩子	
	02 第二孩子	
	03 第三孩子	
	04 第四孩子	
	05 第五孩子	
【請以表格中的一表格填寫】		
01	12歲以下	
02	13至19歲	
03	20至29歲	
04	30至39歲	
05	40歲或以上	
標準資料		
S8 請問你以前是否患過以下皮膚病？(單選)		
	是 1	否 2
	3	4
S9 請問你以前是否患過以下皮膚病？(單選)		
	否 1	是 2
	3	4

皮膚敏感量表-10

過去3天的整體皮膚刺激程度

1. 請在水平線上畫上垂直線，以表示過去3天感覺到皮膚受刺激的嚴重程度



過去3天皮膚狀況的嚴重程度

(請以過去3天的皮膚狀況回答以下問題; 0=沒有, 10=難以忍受的程度)

感覺的皮膚狀況

- 2. 感到麻痺 ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩
- 3. 感到火燒 ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩
- 4. 感到灼熱 ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩
- 5. 感到繃緊 ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩
- 6. 感到瘙癢 ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩
- 7. 感到痛楚 ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩
- 8. 感到不舒服 ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩
- 9. 感到潮熱 ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩

看見的皮膚狀況

- 10. 泛紅 ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩

多謝你寶貴意見，
再次多謝被訪者並結束訪問！

Appendix 2: Combination of sensitivity and 1-specificity according to various cut off values

Positive if Greater Than or Equal To ^a	Sensitivity	1 - Specificity
-1.00	1.000	1.000
.50	1.000	.793
1.50	1.000	.761
2.50	1.000	.732
3.50	1.000	.701
4.50	1.000	.670
5.50	1.000	.627
6.50	1.000	.602
7.50	1.000	.572
8.50	1.000	.535
9.50	1.000	.510
10.50	1.000	.477
11.50	1.000	.463
12.50	1.000	.440
13.50	1.000	.426
14.50	1.000	.406
15.50	1.000	.381
16.50	1.000	.367
17.50	1.000	.351
18.50	1.000	.337
19.50	1.000	.322
20.50	.988	.306
21.50	.964	.285

22.50	.952	.277
23.50	.940	.262
24.50	.917	.253
25.50	.917	.245
26.50	.881	.234
27.50	.845	.224
28.50	.821	.212
29.50	.810	.204
30.50	.774	.188
31.50	.714	.181
32.50	.714	.170
33.50	.667	.166
34.50	.631	.157
35.50	.583	.152
36.50	.560	.142
37.50	.536	.132
38.50	.512	.124
39.50	.476	.120
40.50	.476	.113
41.50	.429	.108
42.50	.405	.105
43.50	.345	.099
44.50	.310	.095
45.50	.310	.091
46.50	.298	.087
47.50	.286	.085
48.50	.286	.079
49.50	.274	.079
50.50	.262	.074
51.50	.226	.070
52.50	.214	.065
53.50	.202	.062
54.50	.190	.057
55.50	.179	.055
56.50	.179	.054
57.50	.155	.051
58.50	.131	.049
59.50	.119	.048
60.50	.119	.047
61.50	.083	.041
62.50	.083	.039
63.50	.083	.037
64.50	.083	.035
65.50	.083	.034
66.50	.083	.033
67.50	.071	.030
69.00	.071	.027
70.50	.071	.026
71.50	.048	.024
72.50	.036	.022
74.00	.024	.019
76.00	.012	.017
77.50	.012	.016
78.50	.012	.014
79.50	.012	.012
80.50	.012	.011
81.50	.012	.010
82.50	.012	.009
83.50	.012	.008
84.50	.012	.006
86.50	.012	.005

89.50	.012	.003
93.00	.012	.002
97.00	.012	.001
99.50	.000	.001
101.00	.000	.000