BRIEF REPORT

Psoriasis Prevalence and Severity by Expert Elicitation

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ABSTRACT

Introduction: An estimated 2–4% of Western populations are thought to have psoriasis, with a regional incidence ranging from 0.09% to 11.43%. Variance in estimates is a result of differences in study populations, methodology, regional differences, and definitions of disease. Reliable prevalence estimates of plaque psoriasis are challenging to establish. Further, the distribution of psoriasis severity in the population is unknown. This study aims to establish the utility of expert elicitation (EE) as a method for estimating unknown parameters in dermatology by (1) estimating the prevalence of psoriasis in the adult population, and (2) estimating previously unknown disease severity distribution.

Methods: An expert panel of 11 Canadian dermatologists with demonstrated expertise in psoriasis was formed. A proof-of-concept EE

exercise estimated psoriasis prevalence in the general population in Canada, followed by estimation of psoriasis disease severity distribution by body surface area (BSA). Expert estimates were consolidated using Bayesian methods to statistically model the data and represent uncertainty.

Results: The median prevalence of psoriasis in the adult population using the Bayesian estimate was 3.0% (95% credibility interval, 2.7–3.3%), compared with the estimated mean prevalence of 3.4% (95% confidence interval, 2.2–4.9%). By EE, the estimated cumulative distribution of disease severity assessed by BSA suggests that approximately 50% of patients have a BSA of < 3% and 78% of patients have a BSA of < 10%, with only 2% having a BSA of > 50%.

Conclusion: The EE approach resulted in prevalence estimates that had a narrow distribution and were consistent with published literature, supporting its value in dermatology as a complementary method to help guide decision-making in areas where evidence is scarce or uncertain.

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PLAIN LANGUAGE SUMMARY

Psoriasis is a common skin disease that affects 2–4% of the population. Prevalence estimates

vary depending on factors such as study type and population studied. The distribution of disease severity (what proportion of patients have mild, moderate, or severe psoriasis) is not known. In this study, 11 dermatologists with expertise in psoriasis used an approach called expert elicitation to make educated guesses about prevalence and disease severity distribution in the real world. Using a statistical approach called Bayesian estimation, experts can represent the level of certainty in what they know and do not know and make inferences or assumptions about a population. Bayesian estimates are not based on the amount of data; rather, each datum contributes to a statistically meaningful result. The median prevalence of psoriasis in the adult population using the Bayesian estimate was 3.0%, which is in the

expected range based on prior literature and supports the use of this expert elicitation method. This study provides the first expert estimate of disease severity distribution in the population assessed by body surface area affected by psoriasis. Approximately 50% of psoriasis patients have mild disease (< 3% body surface area involved) and 78% of patients have mild or moderate disease (< 10% body surface area involved). Only 2% of patients have more than 50% body surface area involved. This expert elicitation approach can be used to help guide decision-making in areas of dermatology where evidence is lacking or uncertain.

Keywords: Psoriasis; BSA; Expert elicitation; Prevalence; Disease severity; Bayesian

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Key Summary Points

Why carry out this study?

Reliable estimates of plaque psoriasis prevalence and distribution of disease severity have yet to be established.

In Western countries, 2–4% of the population is thought to have psoriasis, with regional incidence ranging from 0.09% to 11.43%. The distribution of psoriasis severity is unknown.

Expert elicitation using Bayesian estimation is an approach to establishing real-world, statistically modeled estimates of unknown values without the need for a large sample size.

What was learned from the study?

The median prevalence of psoriasis in the adult population using a Bayesian consolidation of expert estimates was 3.0%. The cumulative distribution of disease severity, gaged by area of involvement (BSA), suggested that 50% of patients have a BSA of < 3% and 78% of patients have a BSA of < 10%, while 2% of patients have a BSA > 50%.

Expert elicitation resulted in prevalence estimates that had a narrow distribution and were consistent with published literature, supporting its utility in dermatology as a complementary method to help guide decision-making where evidence is scarce or uncertain.

INTRODUCTION

An accurate and consistent estimated prevalence of psoriasis has yet to be established. In Western countries, 2–4% of the population are thought to have psoriasis [1], while global estimates suggest a regional incidence of psoriasis between 0.09% and 11.43% [2]. Large geographical differences in prevalence could be related to genetic susceptibility, possibly related to race [3], or environmental factors influencing disease expression [1]. Other factors influencing prevalence estimates include differences in the definition of prevalence and study methodologies (assessment tools used, unique definitions of clinical presentation, sampling methods, age groups, sex) [1, 4].

Estimates of psoriasis prevalence to date are typically based on observational or cohort studies. Data for these studies come from various sources, including registries, databases (primary care, dermatology clinic, hospital, or insurance), or self-report surveys [4]. Data sources are often utilized without establishing reliability; specifically, misspecified diagnoses contribute to inaccurate prevalence estimates [1]. Point-in-time estimates, lifetime prevalence reports, and studies spanning limited periods of time confound prevalence estimates. For example, studies including children only, adults only, specific age groups, or a variety of ages will often use very different sampling and validation methods [4].

Estimating the real-world prevalence of psoriasis is an area where reliance on indirect evidence may prove useful in ascertaining reliability of previous estimates. Expert elicitation (EE) is a formalized method for quantifying expert judgment, comprising a broad range of methodologies often directed to specific kinds of missing data. Bayesian estimation is one of several approaches used to consolidate expert input and generate parameter estimates based on subjective-probability distributions [5]. Bayes estimates incorporate results as if each expert estimate is an experiment refining the estimate of the truth. The present study uses both averaging of individual results and Bayesian approaches to inferential statistics. EE has

DIGITAL FEATURES

This article is published with digital features, including a summary slide, to facilitate understanding of the article. To view digital features for this article, go to <https://doi.org/10.6084/m9.figshare.14248562>.

utility in instances when confirmatory data are missing or when observational data are available but of insufficient or unknown precision or reliability [6]. In addition to estimating the value of specified parameters, EE allows for examination of the uncertainty in expert estimates by attaching levels of confidence to the estimates, thereby aiding with data interpretation. Our objectives were to establish EE's utility as a method for estimating unknown parameters in dermatology by (1) estimating the prevalence of psoriasis in the adult population, and (2) estimating previously unknown disease severity distribution. These results provide proof-of-concept for EE methods in dermatology as a complementary method where data are uncertain or lacking. These results may assist in patient counseling and give healthcare professionals an accurate understanding of the prevalence and severity distribution of psoriasis using the best available evidence, combined with quantified expert opinion.

METHODS

EE: Study Design and Participants

This study implements EE as a method to estimate unknown or uncertain quantities. Eleven Canadian dermatologists with demonstrated expertise in psoriasis were invited to participate in an online EE exercise to estimate disease prevalence and severity in Canada. Experts had established expertise in psoriasis defined by clinical and academic experience (guideline general committee members, membership to be described elsewhere). The number of experts was based on EE literature that suggests between 3 and 12 experts should be involved in elicitation exercises [7]. A larger survey of dermatologists described below was used to establish a corroborative estimate of disease prevalence. Responses were collected online, and anonymity was maintained. Committee members were blinded to their peers' responses. Ethics committee approval was not required for this study as per section 2.3.b of the Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans, version 2 (TCPS2). Experts

who participated in the EE are published authors on this work with no expectation of privacy.

EE: Estimation Process and Statistical Methods

For this EE process, estimates of disease prevalence and severity distribution were elicited from a group of 11 dermatology experts through an online survey administered in May 2020. Prior to the survey, the expert group met in two online teleconferences in March–April 2020. The teleconferences established the starting point for body surface area (BSA) thresholds that the committee members believed reasonable for estimating proportions across the entire spectrum of disease ($< 3\%$, $< 10\%$, $< 30\%$, $< 75\%$, and $\geq 75\%$ BSA). Using a Delphi methodology, the experts first estimated the proportion of plaque psoriasis (specifically excluding erythrodermic or pustular psoriasis) in the adult population, then estimated rates of plaque psoriasis distributed by BSA. Panel members were asked to provide the most likely, lowest, and maximum estimate of prevalence and of distribution for the predetermined BSA thresholds. The ranges of BSA thresholds could also be adjusted at the expert's discretion in this activity (Supplementary Table 2).

Following primary data analysis of the first EE exercise, a second survey was administered in July 2020. Using a Delphi methodology, the same panel members were asked to refine estimates of the overall prevalence of psoriasis as well as estimate the distribution of disease severity as measured by the area of involvement (BSA). Experts were presented the results of the initial prevalence estimation. Using sliding scales, experts adjusted their estimates of lowest, most likely, and highest possible prevalence of psoriasis in the adult population in Canada. A similar approach refined the distribution of disease by BSA estimates. Defined BSA thresholds for estimating the latter were 0–3%, 3–10%, 10–30%, 30–75%, 75–85%, and $> 85\%$.

Individual estimates of prevalence were fitted to beta distributions assuming the lower,

likely, and upper estimates were 2.5, 50, and 97.5 percentiles, respectively. The estimated beta distributions were combined using averaging and Bayesian analyses to arrive at the estimated prevalence of psoriasis in the adult population. We used the multistate model package [8] for R statistics software [9] to obtain the best-fit beta distribution using the quantile prevalence estimates provided by each expert. Bayesian estimates were derived using one of the determined beta distributions as the prior probability distribution. The averaged distribution parameters were determined by averaging the means and standard deviations of the panel-member beta distributions. For disease severity, the cumulative distribution of BSA was estimated by averaging the interval estimates. Distribution estimates were normalized on the mean estimates ensuring the cumulative value was 100%. Normalized estimates were fit using MyCurveFit (<https://mycurvefit.com>) to generate a best-fit, parametric distribution function and confidence interval for each parameter.

Adjunct Broad Dermatology Community Survey: Study Design and Participants

Prior to the elicitation exercise, national and international dermatologists were invited to complete an online survey to estimate psoriasis prevalence and severity as part of a quality improvement endeavor to inform topics for future clinical guidelines. Ethics committee approval was not required for this study as per sections 2.4 and 2.5 of the TCPS2. Anonymized data was analyzed for the secondary purpose of serving as a point of comparison for the subsequent EE. To minimize bias, members of the guideline panel were blinded to survey results until the completion of the EE process. The survey was administered using the SurveyMonkey platform from 17 January to 18 February 2020, and disseminated through the mailing lists of professional associations ($N = 900$), including the Association des médecins spécialistes dermatologues du Québec ($n = 219$ recipients), the Dermatology Association of Ontario ($n = 222$ recipients), the Dermatologic Society of Manitoba ($n = 14$ recipients), a

Table 1 Disease prevalence and severity survey. Questions were structured to allow for estimations within the respondent's own country

	Lowest possible (%)	Most likely (%)	Highest possible (%)
Prevalence			
What is the prevalence of plaque psoriasis in the adult population?			
Disease severity			
What proportion of the adult plaque psoriasis population is most appropriately treated with topical therapies?			
What proportion of the adult plaque psoriasis population has 10% or more BSA (body surface area) of involvement?			
What proportion of the adult plaque psoriasis population has 30% or more BSA of involvement?			

national dermatology conference delegate email list provided by an author (CWL, $n = 380$ recipients), and a list of international dermatologists from Argentina, Australia, Belgium, Chile, China, Denmark, France, Germany, Italy, Kuwait, Malaysia, Singapore, Spain, Switzerland, and the United States of America ($n = 65$) provided by the guidelines steering committee. The general dermatology survey asked respondents to estimate various parameters related to psoriasis epidemiology and severity, including prevalence in the adult population, as well as the proportion of the population with $\geq 10\%$ and $\geq 30\%$ BSA involvement (Table 1).

RESULTS

Main Results: Disease Prevalence and Severity by Expert Committee Estimation

Overall, 9 of 11 committee members responded to the EE poll in two separate rounds of estimation. Responses were collected anonymously, and reasons for nonresponse were not solicited. In the second round of polling, experts were shown results from the first EE, and asked to adjust estimates on a sliding scale “What are your [lowest possible, most likely, highest possible] estimates for the overall prevalence of psoriasis in the adult population in Canada?”. Given the narrow range of estimated prevalence and the small variances for the distribution of BSA on the second round of polling (Supplementary Table 3), additional estimates were not warranted. Each expert’s quantile estimate was fit to a beta distribution. The curves in Fig. 1a reflect individual experts’ estimates of prevalence based upon values for the prespecified quantiles. One of the beta distributions was used as the prior estimate, with subsequent estimates incorporated as new data. The resulting Bayesian analysis provided a median estimate of 3.0% (95% credibility

interval, 2.7–3.3%) for the prevalence of psoriasis. In comparison, averaging the distributions suggested the mean prevalence is 3.4% (95% confidence interval, 2.2–4.9%) (Fig. 1b and supplementary appendix).

Participants were presented the prevalence estimates from round 1 and asked to estimate the proportion of psoriasis patients with BSA involvement for the following values: < 3%, 3–10%, 10–30%, 30–75%, 75–85%, and > 85% BSA. Estimates were normalized to provide a cumulative value of 100%. An average was made for each of the six points of estimation and the result normalized. The resulting values were then submitted to the panel members, who were asked, “For each of these points, how would you adjust the values—if you would adjust?”. The average for each interval estimate was normalized. The best fitting curve describing the cumulative proportion of patients with a percentage of BSA affected by psoriasis is shown in Fig. 2. From the interval estimates, approximately 50.0% (95% CI 45.5–54.4) of adults with psoriasis have a BSA of < 3%, with 78.2% (95% CI 73.9–82.5) of the population having a BSA of < 10%. Based on the best-fit curve, 50.5% of adults with psoriasis have a BSA of < 3%, 78.3% of the population have a BSA of < 10%, 4% have a BSA of $\geq$ 50%, and 1.5% have a BSA of $\geq$ 75%.

Fig. 1 Beta distributions resulting from **a** individual expert estimated prevalence; and **b** derived mean and Bayesian prevalence. 95% confidence intervals are indicated by the

dashed lines. In total, 9 of 11 experts polled responded anonymously in two separate rounds of polling

Fig. 2 Estimated cumulative distribution of BSA affected by psoriasis

Adjunct Analysis: Disease Prevalence and Severity from Broad Community Dermatology Survey

The survey distributed to the broad community of dermatologists was completed by 99 respondents, including 80 national delegates and 19 international delegates. Respondents were asked to give lowest possible, most likely, and greatest possible estimates for psoriasis prevalence and severity in the adult population (Table 2). The mean estimate of psoriasis prevalence (most likely estimate) in the adult population was 3.56% (SD 1.81%) from national delegates and 2.59% (SD 0.82%) from international delegates. Mean prevalence and disease severity distribution according to BSA are presented in Table 2.

DISCUSSION

In the present study, we applied EE to approximate psoriasis prevalence and the distribution of BSA-based disease severity in the general psoriasis population. There are many instances where disparities in direct evidence or a paucity of data supporting answers to clinical research questions impede disease management. Inferential or indirect information can be used as a complementary method to address observational limitations. EE is a validated approach for collecting indirect evidence from expert opinion and, as demonstrated here, can fill knowledge gaps where direct evidence is unclear [5]. EE utilizes probability distributions instead of point estimates, thereby capturing measures of uncertainty. Averaging and Bayesian methods are used to consolidate EE estimates. Averaging distributions is akin to assuming each estimate is an independent sample producing a consolidated estimate reflecting the mean and variance of the estimates. Bayesian methods take each

Table 2 Mean (SD) plaque psoriasis prevalence and disease severity estimates in adults from the broad dermatology survey and by expert elicitation

	Prevalence and severity estimates, mean (SD)			
	National dermatologists (<i>n</i> = 80)	International dermatologists (<i>n</i> = 19)	Combined (<i>n</i> = 99)	Expert elicitation (<i>n</i> = 9)
Psoriasis prevalence (most likely)	3.56% (1.81)	2.59% (0.82)	3.37% (1.71)	Mean: 3.4% (95% confidence interval, 2.2–4.9%) Bayes: 3.0% (95% credibility interval, 2.7–3.3%)
≥ 10% BSA	24.53% (16.37)	25.42% (15.06)	24.71% (16.13)	21.8% (2.48)*
≥ 30% BSA	11.31% (10.81)	10.26% (9.52)	11.11% (10.59)	8.9% (1.33)*

*Obtained from summation of mean expert estimation of BSA, second round of estimation from Supplementary Table 3

estimate as informative, with each estimate contributing to an approximation of the true value. As seen in our prevalence estimates, the Bayesian consolidation typically has a narrow distribution compared with mean estimates. Although individual expert estimates of prevalence had a wide distribution, consolidation using Bayesian approach provided a narrow distribution with a substantial increase in relative weight of evidence.

To date, one of the most thorough studies examining prevalence of psoriasis in a geographic region was undertaken in the 1950s on the Faroe Islands [10, 11]. This physician-led study in an isolated environment offered a unique opportunity to survey a population for spontaneous and untreated psoriasis (excluding pustular and nail). The primary investigator personally visited 2314 households within a 2-year period to examine the population for evidence of prevalent psoriasis, including patients who were asymptomatic at the time of the census [10, 11]. Psoriasis was found in 2.84% of the population of approximately

11,000 people across all ages, with approximately equal distribution of males and females (158 males, 154 females). A retrospective Canadian database study of over 325,000 patients estimated that chronic psoriasis affects approximately 2.19% of the adult population [12]. Another database study of over 10,000,000 individuals aged 20 years and older estimated prevalence of psoriasis to be 2.54% [13]. The nature of these database studies underestimates the true prevalence of psoriasis because of incomplete and inaccurate capture of diagnosis.

In the present study, the median prevalence using Bayesian analysis was 3.0% (95% credibility interval 2.7–3.3%). This estimate is in the expected range based on other published literature described previously. Bayesian consolidation represents a more powerful estimate than the mean estimate of 3.4% (95% confidence interval 2.2–4.9%), and broad dermatology survey estimate of 3.6% (SD 1.81%). This EE exercise suggests that disease prevalence in Canada may be higher than previously reported. By comparing the Bayesian prevalence

estimate to median estimates and the published literature, we demonstrate the utility of EE as a complementary method for estimating unknown values in dermatology.

The present study provides the first formal assessment of psoriasis disease distribution in the real world. The proportion of patients with mild, moderate, or severe disease reported in registries and databases are inconsistent and not representative of the general population of patients with psoriasis. The grouping of mild-to-moderate, or moderate-to-severe disease, makes comparing results across studies challenging. In addition, the lack of a consistent definition of severity strata precludes the ability to estimate the distribution in a general population, although recent attempts to define psoriasis severity have been made [14]. One previously mentioned retrospective Canadian database study reported only 28% of patients as moderate to severe, with no definition of severity strata provided [12]. A population-based cross-sectional study of patient data from the United Kingdom analyzed the patient electronic medical records of 9034 patients with psoriasis and reported incidence of mild, moderate, and severe psoriasis (as defined by BSA) to be 51.8% ($BSA \leq 2\%$), 35.8% ($BSA 3\text{--}10\%$), and 12.4% ($> 10\%$), respectively [15]. The cumulative distribution by BSA reported here helps to further refine and clarify previous estimates. The power-law distribution demonstrates a natural way of reflecting what is seen in clinic, resulting in a distribution that is a good approximation of the true distribution in the real world. We estimate 50% of patients have a BSA of $< 3\%$, and 78% of patients have a BSA of $< 10\%$, suggesting that a greater proportion of patients have higher disease burden.

This EE exercise has limitations. Although the dermatologists polled in this EE exercise had established expertise in psoriasis as defined by their clinical experience, their perspective may be skewed to more severe cases reflecting their clinical experience. Uncertainty in the prevalence is accentuated by an inability to estimate the proportion of patients, diagnosed or not, in the general community. Nonetheless, given the nature of the question, those having the broadest experience with psoriasis patients are

dermatologists, and the panel was constructed to include those with demonstrable expertise and experience in treating psoriasis patients. Additional sources of bias in this study include exposure to literature, participation in other studies, and recall bias of clinical experience. The methodology used herein allows participants and readers alike to assess the degree to which bias may have influenced the outcomes. Regarding the prevalence of psoriasis, one can see the considerable range of individual estimates, most of which are discordant with the published literature. Based on these individual estimates, it would appear that most respondents were not influenced by published results or do not believe the published data to be accurate. Nonetheless, the consolidated estimates are close to published data on the prevalence of psoriasis in North America.

The true prevalence and severity distribution require ongoing, thoughtful observation. EE ameliorates bias by incorporating broad estimates that provide formal measures of uncertainty. Hence, the present estimates provide a valuable point of comparison of dermatologists' perspectives and support the incorporation of EE into decision-making processes. It is our intention to apply EE to garner insights and direct decisions in developing disease treatment guidelines.

CONCLUSION

We used expert elicitation, complemented with Bayesian consolidation of estimates, to provide real-world estimates of psoriasis prevalence and severity distribution in Canada. The median prevalence of psoriasis in the adult population as per Bayesian analysis of expert estimates was 3.0%, compared with the derived mean prevalence of 3.4%. Bayesian estimates often contain less uncertainty than mean estimates. The cumulative distribution by BSA suggests that approximately 78% of patients have a BSA of $< 10\%$ affected. Based on EE, approximately 22% of the adult population with psoriasis has 10% or more of BSA involved. These estimates can be used to assist in patient counseling and give healthcare professionals an accurate

understanding of the prevalence of psoriasis and distribution of disease severity.

This EE approach can be used to estimate regional prevalence, with the present study presenting a broad estimate of prevalence in the Canadian adult population. EE can also be implemented to assess other elements of disease such as persistence over time, prevalence in special populations, and distribution of disease severity in different populations. A similar elicitation exercise is planned for estimating psoriasis prevalence in other specific populations including the pediatric and elderly. It is our intention to apply EE to garner insights and to direct decisions in developing disease treatment guidelines.

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Compliance with Ethics Guidelines. Ethics committee approval was not required for this study as per section 2.3.b of the TCPS2, since experts who participated in the EE are published authors on this work and therefore have no expectation of privacy. The broad dermatology survey was conducted as part of a quality improvement endeavor to inform topics for

future clinical guidelines, and anonymized data was analyzed for the secondary purpose of research. Ethics committee approval was not required for as per sections 2.4 and 2.5 of the TCPS2.

Data Availability. All data generated or analyzed during this study are included in this published article/as supplementary information files, and any further queries may be made to the corresponding author on reasonable request.

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