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Review

Self-collected compared with professional-collected swabbing in the diagnosis of influenza in symptomatic individuals: A meta-analysis and assessment of validity

Christopher P. Seaman[a,1], Luong Thi Tuyet Tran[a], Benjamin J. Cowling[b], Sheena G. Sullivan[a,c,d,*]

[a] School of Population and Global Health, University of Melbourne, Melbourne, Australia
[b] WHO Collaborating Centre for Infectious Disease Epidemiology and Control, School of Public Health, The University of Hong Kong, Hong Kong Special Administrative Region
[c] WHO Collaborating Centre for Reference and Research on Influenza, Royal Melbourne Hospital, and the Doherty Department, University of Melbourne, at the Peter Doherty Institute for Infection and Immunity, Melbourne, Australia
[d] Department of Epidemiology, Fielding School of Public Health, University of California, Los Angeles, USA

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ABSTRACT

Self-collected nasal swabs offer a cheaper alternative to professional-collected swabs for influenza testing. However, the diagnostic accuracy of self-collection has not been quantitatively reviewed. We identified 14 studies that compared diagnostic accuracy of self-collected to professional-collected swabs in influenza symptomatic individuals. Self-collected swabs were found to be highly acceptable, simple and comfortable to use. Data from nine studies were meta-analyzed.

Pooled sensitivity was 87% (95% CI: 80%, 92%) and specificity was 99% (95% CI: 98%, 100%), compared to professional-collected swabs in the diagnosis of influenza. Pooled sensitivity and specificity estimates were used to assess the potential bias that would be introduced in studies had self-collected rather than professional-collected samples been used. While self-collected swabbing should not replace the role of clinical testing, our findings support the use of self-collected swabs for influenza research and surveillance. This method will be an important tool for evaluating novel influenza vaccines and vaccination strategies.

1. Introduction

Influenza is an acute respiratory virus, estimated to infect between 5–15% of individuals each year and is subsequently responsible for between 291,243 and 645,832 deaths annually [1]. A laboratory-confirmed diagnosis of influenza is usually made using molecular diagnostic techniques such as reverse transcriptase polymerase chain reaction (RT-PCR) on samples taken from the nose, throat or nasopharynx [2,3]. Within clinical settings, sample collection is routinely performed by trained staff [3]. In community-based research studies and surveillance, however, where participants are followed for signs and symptoms and tested for influenza outside clinical settings, sample collection can be challenging. Requiring presentation to clinics for sample collection can limit the locations in which a study can be conducted, potentially reducing population generalizability [4], while home visits can substantially increase the costs associated with sample collection [5,6]. In both cases, there may be several days' delay between symptoms onset and sample collection.

As efforts to improve influenza vaccines intensify [7] opportunities for improving the economy of community-based trials and observational studies without harming internal validity need to be identified. Self-collected nasal swabs offer an alternative means of sample collection that can potentially reduce the costs associated with diagnosis and allow sampling sooner after illness onset. Indeed, self-sampling has previously been demonstrated to be a cost-effective means of detection for sexually transmitted infections and bacterial upper respiratory tract infections [8,9].

Currently-recommended sampling techniques are not conducive to self-collection. Although nasopharyngeal/nasal wash aspirates and nasopharyngeal (NP) swabs are considered the optimal sampling technique for the confirmation of influenza [3,10,11], neither is reliably self-collected; they cause discomfort and usually require formal

* Corresponding author at: WHO Collaborating Centre for Reference and Research on Influenza, Peter Doherty Institute for Infection and Immunity, 792 Elizabeth St, Melbourne 3000, Australia.
E-mail address: sheena.sullivan@influenzacentre.org (S.G. Sullivan).
[1] Present address: Burnet Institute, Melbourne 3004 Australia; School of Public Health and Preventative Medicine, Monash University, Melbourne 3004, Australia.

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training. Nasal swabs, for example mid-turbinate swabs, are far simpler to collect and sample quality is non-inferior to both nasal wash aspirates [12–14] and NP swabs [11,15]. Self-collected nasal swabs can provide viable specimens for viral detection [14–16] and this has been the sole specimen collection method used in some studies [17,18]. Nevertheless, the diagnostic accuracy of the methodology has only been qualitatively assessed [5]. The objective of this study was to provide a quantitative assessment of the diagnostic accuracy of self-collected versus professional-collected swabs in symptomatic individuals. Further, we aimed to estimate the impact of measurement error associated with self-collection on study findings by applying our pooled estimates of sensitivity and specificity to surveillance-derived prevalence estimates, and measures of association using publicly-available data from an influenza vaccine efficacy trial [19].

2. Methods

2.1. Search strategy

Medline, Embase and Scopus (Web of Science) were searched up to the 30th of January 2018, and updated on 6th of August 2018. A search strategy was developed in consultation with a biomedical librarian, using the following search terms:

1 self* OR person* OR individual* OR parent*
2 swab* OR sample* OR collect* OR take*
3 nose* OR nasal* OR respira*
4 influenza* OR vir*
5 1 adj 2 AND 3 AND 4

In accordance with Cochrane recommendations for conducting reviews of diagnostic accuracy studies [20], no restrictions were set on the search. The search was duplicated by two authors (CPS and LTTT), results independently abstracted and titles screened for subsequent full-text screening. Further combing of references from articles identified for full-text screening was completed by a single author (CPS).

2.2. Review definitions

For this review, a self-swab was defined as a sample taken by an individual who had no formalised training in collecting a swab. The term “self” was extended to include a sample taken from a child or dependant individual by a parent or guardian. Professional-swabs were defined as samples taken by those medically trained to take a swab, such as health care workers or trained researchers. Symptomatic individuals had to fall within the World Health Organization (WHO) definition of an influenza-like illness (ILI) or acute respiratory illness (ARI), with a reported sudden onset fever of greater than 38 °C and a sore throat and/or cough [21].

2.3. Eligibility criteria

Studies eligible for review compared self-collected swabbing to professional-collected swabbing for the diagnosis of influenza virus infection. This definition was extended to include studies using separate cohorts where one cohort self-collected, while the other used professional-collected swabs with results compared post-hoc.

Studies were ineligible if they only assessed self-collection or professional-collection as this did not allow direct comparison of the two techniques. We also excluded studies that used aspiration as the reference standard.

2.4. Quality assessment and publication bias

The quality of each article was assessed using the Quality Assessment for Diagnostic Accuracy Studies (QUADAS-2) tool [22] and completed independently by two authors (CPS and LTTT), with conflicts resolved by a third (SGS). A Deeks’ test was used to assess for publication bias on the diagnostic odds ratio scale [23].

2.5. Data extraction

Data was extracted independently by two authors (CPS and LTTT) using a data collection form. The information extracted included type and location (e.g. nose) of both self- and professional-collected swabs, age and sex demographics of participants, molecular diagnostic method, type(s) of influenza virus analysed (A and/or B) and information on acceptability and accuracy (validity) of self-testing methods. Authors were contacted if the above information was not provided.

2.6. Meta-analysis

Eligibility for meta-analysis required information on concordant samples from the same individual during the same illness episode. Discordant pairs were defined as false-negative if a self-collected specimen was influenza-negative and a professional-collected specimen influenza-positive, and false-positive if vice versa.

Sensitivity and specificity were the effect measures of interest. Values were used as reported or manually calculated if not reported, but sufficient information was provided. Between-study heterogeneity was visually assessed by comparing the relative areas of the 95% prediction interval and 95% confidence interval in the HSROC plot [20] and overlap in the forest plot. Heterogeneity was also assessed using Higgins’ I^2.

A bivariate random-effects model was used for meta-analysis, which allowed for the estimation of pooled sensitivity and specificity measurements [24]. Analysis was conducted in Stata 14.2 I/C (Statacorp, USA) using the -metandi- [25] and –midas- [26] packages. Both packages were designed for meta-analysis of diagnostic accuracy studies, and both use a bivariate-random effects model as default. In sensitivity analyses we removed studies assessed at high risk of bias, the highest weighted study, studies free of false positives or false negatives (zero cell studies) and studies where visual/verbal guidance was provided for self-collection (as this may constitute some form of training), and recalculated the pooled estimates. Differences were assessed qualitatively.

2.7. Sensitivity analysis of outcome misclassification bias

To estimate the potential performance of self-collection within actual studies, we applied simple (non-probabilistic) bias correction methods [27,28]. The range of potential misclassification errors explored was based on the 95%CI of the pooled sensitivity and specificity estimates from the meta-analysis. Misclassification was assumed to be non-differential by disease status when estimating prevalence [29] and by vaccination status when estimating vaccine efficacy [30]. Exposure misclassification was not assessed as this was not the topic of review. Mathematical explanations of these adjustments and R scripts are provided in the Supplementary Materials.

2.8. Sensitivity analysis of outcome misclassification bias in prevalence studies

To adjust for disease misclassification associated with self-collection for influenza surveillance, results from a synthesised study (Elliot et al. [29]) were used. 6043 self-collected swabs were assessed for the presence of A(H1N1)pdm09, during the 2009 influenza pandemic in the UK. Specimens were collected by individuals over the age of 16 years, who had self-reported ILI symptoms to a nursing hotline. Nasal swab kits were mailed out, collected a median of four days post-symptom onset, and return-posted for laboratory confirmation via RT-PCR.

Community prevalence from self-collection was estimated at 19.3% during the study period, compared to 25.9% from clinician sampling. We examined the extent to which self-collected sampling may have distorted the true prevalence within those who took self-collected swabs.

2.9. Sensitivity analysis of outcome misclassification bias in estimating vaccine efficacy

To estimate the potential performance of self-collection *in lieu* of professional-collection in an actual study, we utilised publicly available influenza vaccine efficacy data from a trial in Hong Kong [19]. Briefly, 796 children aged between 6 and 17 years were randomly assigned to vaccination (seasonal trivalent influenza vaccine) or a saline placebo and followed for 16-months [19,30]. Upon report of ILI from a child's parent or guardian, a member of the study team conducted a home visit to collect nose/throat swabs and repeated collection every three days until symptoms resolved. RT-PCR was used to detect the type and subtype of influenza. Overall vaccine efficacy was calculated as (1-OR)*100%, with cases defined as children with a subtyped influenza diagnosis. The crude vaccine efficacy estimate was 45% (95% CI: 6%, 68%). We assessed the degree to which this estimate might have differed had self- or parent-swabbing been used instead of professional swabbing.

3. Results

3.1. Systematic review

Findings of our search are presented in Fig. 1. From 283 retrieved articles, 13 met eligibility criteria, including 12 published articles and one conference poster. One further article [29] was identified from reference lists of full-text screened studies (Table 1). All were published between 2009 [31] and 2017 [32], and conducted in three continents: North America [31,33–38], Europe [29,39–42], and Asia [32,43]. Sample sizes varied from 28 [37] to 7189 [29]. The overall quality of articles reviewed was high (Supplementary material). Deeks' test suggested minimal evidence ($p = 0.07$) of publication bias (Supplementary Material).

Most reviewed studies provided flocked swabs for self-collection. In studies that did not use flocked swabs, two did not specify the swab type used [29,42] and two used foam swabs [32,37]. All studies provided written instructions to participants describing how to self-collect a swab; however, extra assistance was also provided in several studies. Professional observation during self-collection of swabs was done in two studies [35,40]. One study allowed questioning of the supervising professional during self-collection [38], and a further six included professional demonstration or verbal instruction [32,34,37,41–43]. Within seven studies parents took pediatric swabs [31,33,34,36,37,40,42,43], of which four were included in subsequent meta-analysis [31,34,36,40].

All reviewed articles endorsed the use of self-collection as a diagnostic tool. Four studies did not contain sufficient information to conclude this for influenza specifically, due to insufficient cases [37–39,42], but reported high diagnostic accuracy for other, more prevalent, upper respiratory viruses leading authors to this conclusion.

Comfort and acceptability of self-collected swabbing was assessed in six studies. Three assessed flocked mid-turbinate [35,40,41], two assessed foam nasal swabs [32,37] and one did not specify [42]. Questionnaires were used to assess comfort and acceptability in four studies [35,37,41,42] and face-to-face interviews in two studies [32,40]. Self-collection was found to be more comfortable than professional-collection among 71% [37] to 79% [35] of participants. Additionally, between 90% [35] and 96% [37] of participants found self-collection to be simple to conduct. Further qualitative analysis undertaken from face-to-face interviews identified that children significantly preferred

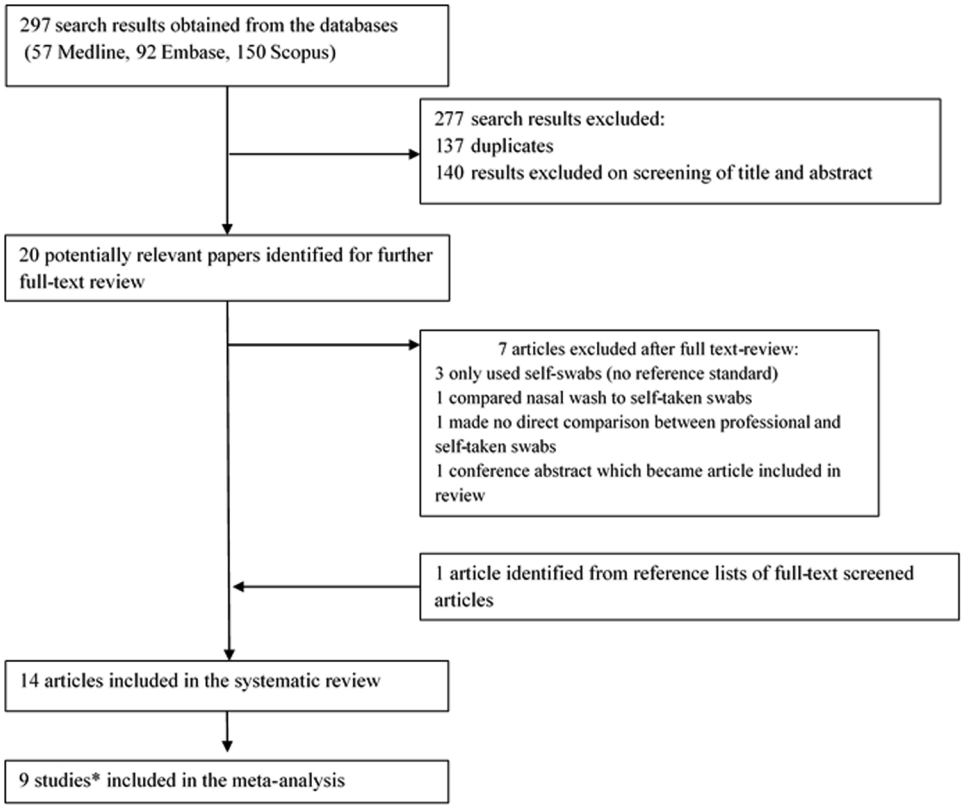

Fig. 1. PRISMA flowchart of search strategy and selection of studies for inclusion in the systematic review and meta-analysis.
*- Goyal et al. 2017 included two meta-analysed studies.

Table 1
Characteristics and summary of all studies included in systematic review and meta-analysis.

Study ID	Study Location	Sample Size	Age Details	Sex, % male	Influenza types analysed	Self-Swab	Professional-Swab	Detection Method	Primary Outcome
Akmatov et al. 2012 [41] ^	Braunschweig, Germany	56	28-46 years	14%	Influenza A and B	Anterior Nasal Flocked[#]	Anterior Nasal Flocked[#]	RT-PCR	Self-swabbing was not inferior in acceptability, viral detection or sample quality as compared to professional-swabbing.
Dhiman et al. 2012 [35] ^	Rochester, Minnesota	58	18-92 years	46%	Influenza A and B	MT Flocked	MT Flocked	RT-PCR	Self-taken and professional-taken MT swabs were comparable for influenza detection by RT-PCR.
Elliot et al. 2015 [29]	England, UK	7189 (6043 self, 1146 professional)	Not given, but adjusted for	Not Given	Influenza A and B	Nasal swab, no further specification	Nose and Throat Swabs	RT-PCR	Cumulative incidence of influenza in self-swabbing group was 19.3%, compared to clinician swabs where cumulative incidence was 25.9%
Emerson et al. 2013 [+] [37]	Seattle, USA	28	6-18 years	43%	Influenza A	Foam nasal swab, with and without saline	Foam nasal swab taken with saline and nasopharyngeal swab taken without saline	RT-PCR	Self-swabbing is a feasible diagnostic method in Cystic Fibrosis children. All disease sensitivity 82% for self-swabbing.
Esposito et al. 2010 *^ [40]	Milan, Italy	203	Mean: 1.99 years, SD (2.96 years)	Not Given	Influenza A and B	MT Flocked	MT Flocked	RT-PCR	MT swabs can be used by parents on children and not decrease influenza virus detection rates as compared to professionally taken MT swabs.
Goyal et al. 2017^ [32]	Nakhon Phanom Province, Thailand	127	65-91 years	Not Given	Influenza A and B	Foam Nasal Swab	Foam Nasal Swab and NP Flocked	RT-PCR	Self-collected swabs in elderly individuals were an acceptable and accurate means of influenza detection, as compared to clinician taken samples.
Granados et al. 2016 [+^] [36]	Peterborough, Ontario, Canada	96	5-19 years	44%	Influenza A	MT Flocked	MT Flocked	RT-PCR	Self-collected and professional-collected MT swabs were highly comparable in both detection and quantification of influenza.
Ip et al. 2012 [+] [43]	Hong Kong	170	2-85 years	47%	Influenza A and B	Nose-Throat, both flocked	Nose-Throat, both flocked	RT-PCR	Self-swabbing for influenza was 90% sensitive for influenza A and 89% sensitive for influenza B
Larios et al. 2011 ^ [38]	Toronto, Ontario	76	23-59 years	Not Given	Influenza A and B	MT Flocked	NP Flocked	RT-PCR	Self-taken MT swabs may be a viable alternative to professional NP swabs for RT-PCR detection of ARI's in adults.
McGolrick et al. 2016+ [33]	Ontario, Canada	664 adequate samples analysed	> 2 years of age	Not Given	Influenza A and B	MT Flocked	Any clinically taken swab	RT-PCR	Self-taken swabs were able to accurately capture the timing of seasonal influenza epidemic peaks for both influenza A and B, when compared to national surveillance data from clinical sampling.
Plymoth et al. 2012 [39]	Eskilstuna and Stockholm, Sweden	3359 (1843 self, 1516 professional)	Median age: 46, IQR (39-56)	41%	Influenza A and B	Nylon flocked swab	Any clinically taken swab	RT-PCR	No direct comparison to a gold standard, but evidence suggested that self-swabbing for influenza is a feasible surveillance method
Smeija et al. 2009 [+^] [31]	Alberta, USA	400	13 adults and 47 children with influenza	Not Given	Influenza A and B	MT Flocked	NP Flocked	RT-PCR	Serial MT self-swabs have equivalent sensitivity to professional NP swabs in the diagnosis of influenza.
		29		17%	Influenza A	MT Flocked	MT Flocked	RT-PCR	

(*continued on next page*)

Table 1 (*continued*)

Study ID	Study Location	Sample Size	Age Details	Sex, % male	Influenza types analysed	Self-Swab	Professional-Swab	Detection Method	Primary Outcome
Vargas et al. 2016 +^ [34]	Northern Manhattan, New York, USA		20% under 5 years, 49% over 18 years						MT self-swabbing was a feasible surveillance method for influenza in a low-income, urban population
Zoch et al. 2015* [42]	Braunschweig, Germany	75 children in cohort, 230 swabs self, 1326 swabs professional	Median 25 months (IQR: 18-30 months)	45%	Influenza A and B	Nasal Swab	Throat Swab	RT-PCR	Use of a symptom diary and parentally taken samples provide accurate data to investigate patterns of infection and immunity in longitudinal early childhood studies, including for influenza.

MT Flocked = Mid-turbinate Flocked Swab, NP Flocked = Nasopharyngeal Flocked Swab, RT-PCR = Reverse Transcriptase-PCR.
Sample size is reflective of paired swabs, not participants, except where specified.
Anterior Nasal Flocked swab is what is described in the study, however these are identical to a mid-turbinate swab.
* Study only used parentally taken swab.
+ Studies included both parentally taken and self-taken swabs.
^ Study included in both systematic review and meta-analysis.

parent-collected swabs compared with clinician-collected ($p < 0.0001$) [40]. One barrier to self-collection identified from interviews was difficulty collecting when feeling unwell [32].

Viral loads from self- and professional-collected swabs were compared in six studies. No differences were identified in four studies [29,36,40,43]. In the two studies where a differential viral load was reported, one found a slightly increased viral load in professional-collected swabs ($p = 0.02$) [35] while the other observed a 10-fold higher viral load in self-collected swabs [37].

3.2. Meta-analysis

Pooled sensitivity and specificity were calculated by bivariate random-effects meta-analysis (Fig. 2). Self-collected swabs correctly identified an influenza-positive individual 87% of the time (95% CI: 80%, 92%) and correctly identified an influenza-negative individual 99% of the time (95% CI: 98%, 100%).

Visual assessment of both forest plots (Fig. 2) and the HSROC plot (Supplementary Material) indicated no between-study heterogeneity in sensitivity estimates and minimal between-study heterogeneity in specificity estimates. This was confirmed by the I^2 values of 0% and 27% for sensitivity and specificity, respectively.

Sensitivity analysis (Supplementary Material) indicated that our findings were robust, with all three sensitivity analyses qualitatively demonstrating negligible change to overall pooled estimates of sensitivity and specificity.

3.3. Outcome misclassification adjustment

Adjusted estimates of A(H1N1)pdm09 influenza prevalence from self-collected swabbing, as reported in Elliot et al. [29] are shown in Table 2. When adjusted for potential disease misclassification, prevalence lay between 19.2% and 24.1%. Based on our point estimates of sensitivity and specificity (Fig. 2), adjusted prevalence was 21.3%, representing a decrease to the published estimate which was 19.3%.

Adjusted vaccine efficacy estimates from Cowling et al. [30] are provided in Table 3. The crude vaccine efficacy estimate from professional-collected swabs was 44.9% (95% CI: 6%, 68%). When adjusted for measurement error associated with self-collected swabbing, vaccine efficacy lay between 35.9% and 44.7%. Based on our point estimates of sensitivity and specificity (Fig. 2) the estimated vaccine efficacy was 40.2%, a small decrease on the original 44.9%.

4. Discussion

To the best of our knowledge, this is the first study to have systematically reviewed and quantitatively assessed self-collection of respiratory samples for influenza testing, extending our understanding of this technique beyond the previous qualitative review [5]. Our findings suggest that self-collection is highly comparable to professional-collection for diagnosis of influenza in symptomatic individuals, and we have demonstrated that findings from studies using self-collection are probably only minimally affected by measurement error.

Our pooled specificity estimate for self-collection of 99% (95% CI: 98%, 100%) is in line with expected near perfect specificity of RT-PCR for the diagnosis of influenza [44]. Apparent false positives may have arisen because discomfort during professional-collected swabs [32,35,37,40,41] may have hindered sample quality. In studies where professional-collected swabs were collected many days after self-collected swabs [36,37], false-positives were probably associated with reduced viral shedding by the time the second (professional) swab was collected [45,46], and were probably not false-positive at all. However, our reported imperfect specificity suggests as prevalence of influenza decreases, the predictive accuracy of self-collected swabbing will too.

Our study was limited by a small number of studies (n = 9 in the meta-analysis), small sample sizes in the identified studies (n = 1170

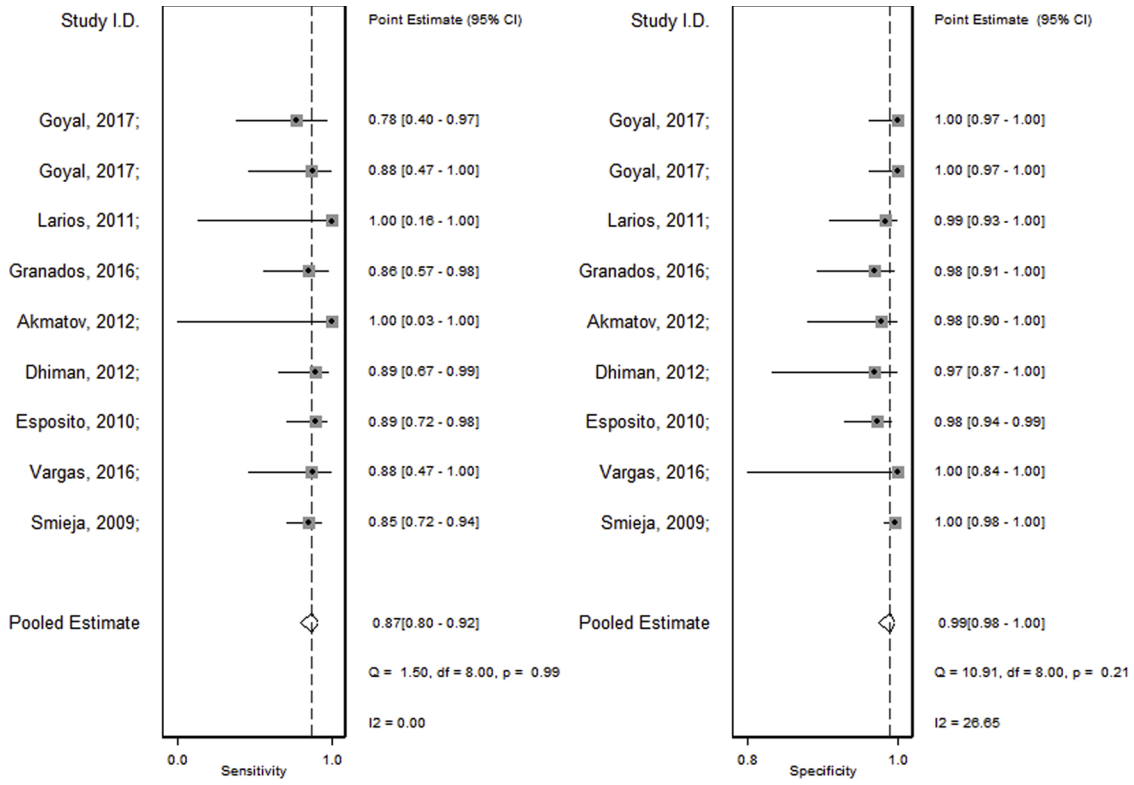

Fig. 2. Bivariate Random-Effects pooled estimate of sensitivity (n = 136 paired swabs, 87%, 95%CI: 80%, 92%) and specificity (n = 1066 paired swabs, 99%, 95%CI: 98%, 100%) of self-collected nasal swabs compared to professional-collected swabs in the diagnosis of symptomatic influenza.

Table 2
Prevalence estimates from self-collected nasal swabs, from Elliot et al. [29], adjusted for potential disease misclassification. Published estimate of A/H1N1 influenza prevalence was 19.3%, compared to 25.9% from clinician-collected samples.

		Sensitivity			
Specificity		80%	84%	87%	92%
	98%	22.2%	21.1%	20.3%	19.2%
	99%	23.2%	22.0%	21.3%	20.1%
	100%	24.1%	23.0%	22.2%	21.0%

Table 3
Vaccine efficacy estimates from 2009 to 2010 study in Hong Kong [19,30], adjusted for potential disease misclassification attributable self-collected swabbing. Vaccine efficacy from professional-collected swabs was estimated at 44.9% (95% CI: 6%, 68%).

		Sensitivity			
Specificity		80%	84%	87%	92%
	98%	35.9%	36.3%	36.6%	37.1%
	99%	39.7%	40.0%	40.2%	40.6%
	100%	44.4%	44.5%	44.5%	44.7%

paired swabs) and a small, overall number of influenza-positive cases (n = 136). The dearth of data may have hidden any true heterogeneity in reported results (Fig. 2). However, sensitivity analyses (Supplementary Material) demonstrated that our findings were consistent and robust to change.

The small number of included studies also limited the potential for subgroup analyses or meta-regression. As more studies become available, it will be important to assess whether diagnostic accuracy varies by influenza subtype or lineage, age of the patient and the type of swab used. Influenza was reported as a pooled outcome, and not stratified by type, in most analysed studies. Viral shedding has previously been shown to be higher for influenza A [45], suggesting that accurate diagnosis of influenza B may be more difficult than influenza A. Only two of the included studies were designed to report results by influenza type [35,40], but were insufficiently powered to report disaggregated results. One synthesized study found no difference in sensitivity by influenza type, but was not designed to assess specificity [43]. Viral shedding has been reported to be higher for children [45], suggesting that earlier, self-collection of swabs may be more valuable in older age groups.

For both influenza surveillance and research, our results suggest that self-collected swabs provide a reliable alternative to professional-collection. When we revised prevalence and vaccine efficacy estimates using our pooled sensitivity and specificity estimates, prevalence changed from 19.3% to 21.3% [29] and vaccine efficacy from 44.9% to 40.2% [30], suggesting that use of self-collected swabs would only minimally harm study validity. While prevalence estimates are vulnerable to deviations in sensitivity and specificity (Table 2), estimates varied minimally across the assessed range. This supports the use of self-collected swabs at a population level for measuring disease prevalence. Furthermore, we observed that the largest impact on estimates in a research setting was due to decreasing specificity (Table 3), which is unsurprising [28]. However, given that RT-PCR is ˜100% specific as a diagnostic method [44], false positives are largely attributable to sample collection errors. Therefore, using a well-considered study design, specificity should approach ˜100%, and at this level, adjusted vaccine efficacy estimates would be expected to hardly deviate, even in the presence of low sensitivity.

The largest application of self-collection for influenza diagnosis exists within future influenza research. Two studies have estimated that self-collection of swabs may be up to five times cheaper than relying upon professional collection [5,35], depending on the disease, by avoiding professional payment (clinician or nurse) [9]. Whilst that study focused on bacterial illnesses, the savings for influenza diagnosis

are expected to be similar. Savings from self-collection may permit additional swabbing of asymptomatic individuals, for example within household transmission studies, as large proportions of influenza virus infections are asymptomatic [47]. Increased sampling could generate more reliable estimates of disease prevalence and may elicit enhanced details on the virulence of circulating influenza strains.

More speculatively, self-swabbing may be useful for routine influenza surveillance. Current population-level estimates of influenza incidence are largely derived from clinical testing, and are biased towards sub-populations with health-seeking behaviours [4]. Self-collection of swabs among patients not presenting for care could mitigate this bias. Whilst further study would be required to assess the appropriateness and cost of this approach, some evidence suggests that self-swabbing is highly accepted within underrepresented populations [34]. In a pandemic, self-collected swabs that are mailed to a diagnostic laboratory may provide a safer method of diagnosis that is aligned with social distancing strategies to reduce transmission [29].

Notwithstanding the advantages, we also note two caveats. First, a self-collected swab would need to be sent to a laboratory for testing, either by mail or by courier. In some locations, postal services may refuse to accept biological samples, while couriers can be costly. Second, environmental conditions between collection and laboratory testing may hinder virus isolation in culture.

In conclusion, we have shown that self-swabbing is a reliable method of specimen collection for the diagnosis of influenza. Further, we have shown that any measurement error due to self-swabbing is likely to have minimal impact on estimates in vaccine efficacy/effectiveness studies. The implications of this finding are most applicable to influenza research and may also have future clinical- and population-level applications. Clinicians play an important role in the diagnosis of influenza and provide important interventions that self-swabbing could not meet, such as prescription of antivirals or prophylactic antibiotics and detection of secondary infections, particularly for high-risk populations. Nevertheless, our findings support the use of self-collected swabs for influenza testing in research and surveillance, including studies that evaluate novel influenza vaccines and vaccination strategies.

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CRediT authorship contribution statement

Christopher P. Seaman: Methodology, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Luong Thi Tuyet Tran:** Validation, Writing - original draft, Writing - review & editing. **Benjamin J. Cowling:** Validation, Writing - review & editing, Supervision. **Sheena G. Sullivan:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Visualization, Supervision.

Declaration of Competing Interest

BJC has received honoraria from Sanofi and Roche. All other authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jcv.2019.07.010.

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