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The vaccine hesitancy scale: Psychometric properties and validation

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ABSTRACT

Introduction: The SAGE Working Group on Vaccine Hesitancy developed a vaccine hesitancy measure, the Vaccine Hesitancy Scale (VHS). This scale has the potential to aid in the advancement of research and immunization policy but has not yet been psychometrically evaluated.
Methods: Using a cross-sectional design, we collected self-reported survey data from a large national sample of Canadian parents from August to September 2016. An online questionnaire was completed in English or French. We used exploratory and confirmatory factor analysis to identify latent constructs underlying parents' responses to 10 VHS items (response scale 1–5, with higher scores indicating greater hesitancy). In addition to the VHS, measures included socio-demographics items, vaccine attitudes, parents' human papillomavirus (HPV) vaccine decision-making stage, and vaccine refusal.
Results: A total of 3779 Canadian parents completed the survey in English (74.1%) or French (25.9%). Exploratory and confirmatory factor analysis revealed a two-factor structure best explained the data, consisting of 'lack of confidence' (M = 1.98, SD = 0.72) and 'risks' (M = 3.07, SD = 0.95). Significant Pearson correlations were found between the scales and related vaccine attitudes. ANOVA analyses found significant differences in the VHS sub-scales by parents' vaccine decision-making stages ($p < .001$). Independent samples t-tests found that the VHS sub-scales were associated with HPV vaccine refusal and refusing another vaccine ($p < .001$). Socio-demographic differences in the VHS were found; however, effect sizes were small ($\eta^2 < 0.02$).
Conclusions: The VHS was found to have two factors that have construct and criterion validity in identifying vaccine hesitant parents. A limitation of the VHS was few items that loaded on the 'risks' component and a lack of positively and negatively worded items for both components. Based on these results, we suggest modifying the wording of some items and adding items on risk perceptions.

1. Introduction

Since inoculation was first introduced in Europe in the 18th century to prevent smallpox there have been people who have been hesitant about receiving vaccinations [1–4]. The term 'vaccine hesitancy' refers to the delay in acceptance or refusal of vaccination despite the availability of services [5]. The factors contributing to vaccine hesitancy likely varies depending on the specific vaccine, individual and social influences, and one's environment [6–8]. Vaccine hesitancy has been described as an attitude (concerns or doubts) as well as a behaviour [9]. Vaccine hesitancy has been used to refer to a heterogeneous group representing divergent attitudes including issues of confidence (e.g. not trusting in vaccines or health care providers), complacency (e.g. not perceiving a need for vaccination or not valuing vaccination), and convenience (e.g. access) [6,10,11]. Vaccine hesitancy is complex and multilayered as "individuals may refuse some vaccines, but agree to others, delay vaccination or accept vaccination although doubtful about doing so" (p. 6649) [5]. Peretti-Watel et al. (2015) have criticized the ambiguity of the available definitions for vaccine hesitancy, and has theorized vaccine hesitancy as a decision-making process that depends on one's level of commitment to health (or risk) culture as well as one's confidence in health authorities and mainstream medicine [12].

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There is concern that public confidence in vaccines is decreasing and anti-vaccine movements are becoming stronger [4,9,10,13–16]. For example, a recent study of Canadian vaccine experts and front-line providers showed that they considered vaccine hesitancy to be a significant problem that is contributing to suboptimal vaccination coverage [9]. Recent outbreaks of largely eradicated diseases such as measles, mumps, and diphtheria have been attributed to vaccine hesitancy [2,3,14,17]. This reduces herd immunity, making individuals who are not yet vaccinated and those with compromised immune systems vulnerable to infection [18].

The development and standardization of a measure of vaccine hesitancy is crucial in order to improve the measurement, evaluation, and ability to compare across jurisdiction and over time. Some measures have begun examining vaccination issues related to vaccine hesitancy. These include (1) the eight-item Vaccine Confidence Scale that has three factors [19,20]; (2) the 18-item Parental Attitudes about Childhood Vaccines that was developed using qualitative methodology [21] and found to have two [7] or three [22] factors upon further validation; (3) the one-dimensional, 7-item Vaccine Conspiracy Belief Scale [23]; (4) the one-dimensional, nine-item Knowledge of Vaccination Scale [24]; (5) the four-factor, 12-item Vaccination Attitudes Examination Scale [25]; and (6) the five-item Vaccine Attitude Scale [26]. Furthermore, there are additional measures that examine general attitudes related to specific vaccines such as Measles, Mumps, and Rubella (MMR) [27], human papillomavirus (HPV) [28–31], or human immunodeficiency virus (HIV) [32]. Though related to vaccine hesitancy, these measures are more general than vaccine hesitancy (e.g. as theorized by Peretti-Watel and colleagues) [12].

In 2015, Larson and colleagues from the SAGE Working Group on Vaccine Hesitancy sought to standardize the measurement of vaccine hesitancy [33]. This research group developed a measure to quantify vaccine hesitancy by conducting a systematic review of existent research, examining questions used by the WHO-UNICEF Joint Reporting Form, and through expert consultation [33]. Although Larson et al. (2015) constructed the scale and encouraged the future validation of this measure, to our knowledge, this measure has not yet been psychometrically validated.

A standardized, validated measurement tool of vaccine hesitancy beliefs would aid in the advancement of research and immunization policy. This tool has the potential to be used widely to understand the correlates of vaccine hesitancy, the association of vaccine hesitancy with vaccine coverage, compare vaccine hesitancy between countries, and evaluate changes in vaccine hesitancy over time. The objective of this paper is to therefore test the psychometric properties of Larson et al.'s (2015) scale questions. Accordingly, this study examines the scale's structure and internal consistency, construct validity, criterion validity, and socio-demographic differences in parents' vaccine hesitancy.

2. Methods

2.1. Participants and study design

We used a cross-sectional design to collect self-reported survey data through an online questionnaire from a national sample of Canadian parents. Data collection was facilitated by Canada's largest market research and polling firm, Leger—The Research Intelligence Group. The online survey was offered in English and French (i.e. Canada's two official languages). Data presented in this study were collected in the first of a two-wave study undertaken in August to September 2016. Parents and/or guardians (hereafter referred to as parents) of a 9- to 16-year-old child were eligible to participate. To recruit participants, Leger sent email invitations and survey links to panellists; a maximum of three reminder emails were sent. A detailed explanation of the survey methodology is presented elsewhere [34].

2.2. Scale description

We validated a vaccine hesitancy measure developed by the SAGE Working Group on Vaccine Hesitancy, which has not been psychometrically evaluated (see Larson et al., 2015) [33]. The Working Group developed survey items based on: (1) conducting a systematic review of peer reviewed and grey literature of existing vaccine hesitancy surveys; (2) completing expert consultations (within the SAGE Working Group on Vaccine Hesitancy and with SAGE members); and, (3) examining vaccine hesitancy questions on immunization that are completed annually by national immunization program managers [33]. The Working Group developed three groups of survey questions: core closed questions, Likert-type scale questions, and open-ended questions. This study sought to validate the 10 VHS Likert-type scale questions because Likert scales are more feasible for health providers and researchers to administer, quantify and evaluate nuance. Accordingly, the open-ended vaccine hesitancy questions and core closed questions of vaccine hesitancy at the community level are not included in this study's validation.

In this study, we used the 10 items of the Vaccine Hesitancy Scale (VHS) that are measured on a five-point Likert-type rating scale ranging from 'strongly disagree' to 'strongly agree' (Supplemental File, Section 1, Tables A1 and A2). No changes were made to the wording of the 10 VHS items. We administered questions in a random order to ameliorate any order effect. We reversed seven items in the scoring of the scale so that higher scores indicated more hesitancy on all items.

2.3. Measures

All participants completed socio-demographics items. The 10 VHS items on a five-point Likert-type rating scale (as described above) were included. The survey assessed additional vaccine attitudes (measured on seven-point Likert-type rating scales ranging from '1-strongly disagree' to '7-strongly agree'). To validate the VHS, the following four vaccine attitude scales were used: (a) *Vaccine-related conspiracy beliefs* were measured using a seven-item psychometrically developed scale, the Vaccine Conspiracy Belief Scale (VCBS; Cronbach's $\alpha = 0.94$) [23]; (b) *Harms of HPV vaccination* were measured using six items that comprise a sub-scale of the HPV Attitudes and Beliefs Scale (HABS; Cronbach's $\alpha = 0.90$ and 0.91; sample item: 'I feel that the HPV vaccine may lead to long-term health problems') [31]; (c) *Benefits of HPV vaccination* were measured using 10 items that comprise a sub-scale of the HABS (Cronbach's $\alpha = 0.95$ and 0.95; sample item: 'I feel that the HPV vaccine works well') [31]; (d) *Trust* was measured using four items constructed for this questionnaire (sample item: 'I trust the information I receive about vaccines').

The *Precaution Adoption Process Model (PAPM),* a stage-based theoretical model, was used to assess parents' HPV vaccine decision-making stage [35]. The PAPM elucidates all the stages involved in adopting health-protective behaviours (e.g. vaccination), and is helpful in highlighting qualitative differences among people in different stages. Parents were asked: 'which of the following best described your thoughts about the HPV vaccine for [CHILD] before today?' Six response options were provided to classify parents according to distinct categorical stages of HPV vaccine decision-making: (1) unaware, (2) unengaged, (3) undecided, (4) decided not to vaccinate, (5) decided to vaccinate, and (6) vaccinated.

To assess vaccine outcomes, participants were asked: (1) 'have you ever refused vaccinating [CHILD] with the human papillomavirus (HPV) vaccine?'; and (2) 'have you ever refused vaccinating [CHILD] with any childhood vaccine other than the human papillomavirus (HPV) vaccine?'

2.4. Statistical analysis

Inattentive or unmotivated responders were detected and removed using two bogus items and statistical psychometric synonyms (i.e. participants who respond inconsistently across similar items in the questionnaire) [36,37].

To explore the structure of the VHS, an Exploratory Factor Analysis (EFA) was conducted on half the sample (n = 1887; selected randomly) using Principal Axis Factoring with orthogonal rotation (varimax).[1] In order to examine model fit, a Confirmatory Factor Analysis (CFA) was used on the second half of the sample (n = 1892; selected randomly). To determine internal consistency, Cronbach's α and the inter-item correlations were calculated.

To examine construct (convergent) validity, Pearson correlations were conducted between the VHS with related attitudes. Construct validity was also investigated using an ANOVA (and post hoc independent samples t-tests) to evaluate differences in vaccine hesitancy scores by PAPM stage. We expect vaccine hesitant parents' (PAPM stages 2–4, 'hesitant') scores to be higher than scores of parents who are not aware (i.e. stage 1, 'unaware') or those who have accepted vaccination (i.e. PAPM stages 5–6, 'acceptors'). To examine criterion validity of the scale, independent samples t-tests (based on results from Levene's tests) were used to evaluate differences in vaccine hesitancy on two vaccine outcomes (i.e. HPV vaccine refusal and refusal of another vaccine).

To examine the distribution of the scale, the central tendencies of the scale and the diversity in responses were explored. ANOVA analyses were used to detect significant associations between socio-demographic characteristics and vaccine hesitancy. Statistical analyses were performed using IBM SPSS V.23, SPSS AMOS V.24, and R 3.3.2.

3. Results

3.1. Sample characteristics

A total of 4606 parents completed the online questionnaire. The response rate, calculated based on completion by participants who initiated the questionnaire (n = 6789), was 67.85%. Based on our data cleaning criteria to detect inattentive or unmotivated respondents, 827 (17.95%) participants were excluded from the sample. Sample socio-demographics for the final sample are presented in Table 1. The final sample consisted of 3779 parents between the ages of 18 and 81 (M = 43.51, SD = 6.86). The majority of respondents were women (65.31%), White (85.31%), married or common law (79.89%), working full-time (68.11%), completed the survey in English (74.12%), and had a university education (45.51%). Measures of central tendency and dispersion for the VHS items can be found in the Supplemental File (Section 2, Table A3).

Table 1
Sample sociodemographics (N = 3779).

Participant characteristics	N (%)
Gender	
Man	1311 (34.69)
Woman	2468 (65.31)
Age	
Range	18–81
Mean (SD)	43.51 (6.86)
Language answered questionnaire	
English	2801 (74.12)
French	978 (25.88)
Language first learned	
English	2488 (65.84)
French	1049 (27.76)
Other	242 (6.40)
Marital status	
Single/Separated/divorced/widowed	760 (20.11)
Married/common law	3019 (79.89)
Education	
Elementary or high school	659 (17.44)
Trade technical or vocational	1400 (37.05)
University bachelor or graduate	1720 (45.51)
Employment status	
Working more than 30 h/week	2574 (68.11)
Working less than 30 h/week	483 (12.78)
Not employed	722 (19.11)
Born in Canada	
Yes	3214 (85.05)
No	565 (14.95)
Ethnicity	
White	3224 (85.31)
Other	555 (14.69)
Religion	
Christian	2190 (57.95)
No religious affiliation	1286 (34.03)
Other	303 (8.02)
Income	
<39 K	407 (10.77)
40–79 K	1005 (26.59)
80–119 K	1020 (26.99)
>120 K	950 (25.14)
Prefer not to answer	397 (10.51)
Child's gender	
Boy	1826 (48.32)
Girl	1953 (51.68)

3.2. Structure, model fit and internal consistency

EFA identified two factors with Eigenvalues greater than one; parallel analysis also suggested a two-factor solution (Tables 2 and 3). Two factors explained 66.73% of the common variance of the 10 items scale. Nevertheless, one factor was predominant as it explained 54.81% of the common variance of the 10 items scale and has an Eigenvalue higher than four times the Eigenvalue of the other factor (Table 3). One item (i.e. "my child/children does or do not need vaccines for diseases that are not common anymore", item 10) was flagged as unreliable as it loaded similarly on both factors (0.450 and 0.328).

A CFA was conducted for the nine and 10 items scales for one and two factors solutions on the combined, English and French sub-samples respectively (Table 4). In CFA, on all samples, the item that had been flagged as unreliable in EFA (i.e. item 10) loaded poorly (i.e. standardized regression weight <0.60) on the first factor. The one factor solution of the 10 and nine items scale produced a poor fit on all three samples. Model fit of the two-factor solution for both 10 and nine items scales was superior to the one factor solution. Albeit similar model fit indices, for the two-factor solution, the nine-item scale performed better than the 10-item scale (Table 4).

Based on the EFA and CFA, a two-factor structure best explained the data. Item 10 was removed, resulting in a nine item VHS that was divided into two sub-scales consisting of seven and two items

[1] The Kaiser–Meyer–Olkin measure verified the sampling adequacy (N = 1887) for the analysis, KMO = 0.93. Bartlett's test of sphericity ($\chi^2(45) = 10936.9$, $p < .001$) indicated that correlations between items were sufficiently large to conduct an EFA.

Table 2
EFA loadings and CFA standardized regression weights of the final 9-item scale.

Vaccine hesitancy scale items	EFA loadings (n = 1887)		CFA Standardized regression weights (n = 1892)	
	VHS Factor 1: Lack of Confidence	VHS Factor 2: Risks	VHS Factor 1: Lack of Confidence	VHS Factor 2: Risks
Childhood vaccines are important for my child's health (R)	0.864	0.195	0.868	–
Getting vaccines is a good way to protect my child/children from disease (R)	0.853	0.197	0.861	–
Childhood vaccines are effective (R)	0.818	0.224	0.851	–
Having my child vaccinated is important for the health of others in my community (R)	0.764	0.195	0.809	–
All childhood vaccines offered by the government program in my community are beneficial (R)	0.719	0.358	0.780	–
The information I receive about vaccines from the vaccine program is reliable and trustworthy (R)	0.624	0.446	0.733	–
Generally I do what my doctor or health care provider recommends about vaccines for my child/children (R)	0.610	0.216	0.671	–
New vaccines carry more risks than older vaccines	0.170	0.685	–	0.661
I am concerned about serious adverse effects of vaccines	0.193	0.655	–	0.682

Note: EFA = Exploratory Factor Analysis. CFA = Confirmatory Factor Analysis. (R) Indicates items that were reverse coded. Extraction Method: Principal Axis Factoring (PAF); Rotation Method: Varimax with Kaiser Normalization. EFA was also conducted using Principle Component Analysis, and no important differences were found.

Table 3
EFA analysis.

	PAF EV >1	EV1 >4x EV2	PA (Number of Factors)	One Factor % Common Variance	Load >0.33 on Forced One-Factor Solution
Entire sample (n = 1887)					
All 10 Items	2	Yes	2	54.81	All do
9 items (without hesitancy item 10)	2	Yes	2	57.35	All do
English sample (n = 1432)					
All 10 Items	2	Yes	2	54.65	All do
9 items (without hesitancy item 10)	2	Yes	2	57.25	All do
French sample (n = 455)					
All 10 Items	2	Yes	1	55.97	All do
9 items (without hesitancy item 10)	2	Yes	1	58.27	All do

Note: PAF = Principal Axis Factoring, EV = Eigenvalue, PA = parallel analysis. Dimensionality was assessed based on following criteria recommended by Slocum-Gori (2011) [41]: (a) number of Eigenvalues greater-than-one, (b) ratio-of- first-to-second-Eigenvalues is greater than four suggesting one dimension, (c) number of factors based on parallel analysis [42]. For EFA, we also reported the percentage of common variance explained by one factor and explored if items load greater than 0.33 on a forced one-factor solution that is expected for a scale to be considered unidimensional.

Table 4
CFA model fit for one and two factor models.

	χ^2/df	CFI	RMSEA	SRMR	NNFI-TLI
Entire sample (n = 1892)					
All 10 Items-one factor	22.7	0.93	0.11	0.06	0.91
All 10 Items-two factors*	16.2	0.95	0.09	0.04	0.94
9 items (without hesitancy item 10)-one factor	24.3	0.94	0.11	0.06	0.92
9 items (without hesitancy item 10)-two factors	15.6	0.96	0.09	0.04	0.95
English sample (n = 1369)					
All 10 Items-one factor	20.0	0.92	0.12	0.07	0.90
All 10 Items-two factors**	12.8	0.95	0.09	0.05	0.94
9 items (without hesitancy item 10)-one factor	21.5	0.93	0.12	0.07	0.91
9 items (without hesitancy item 10)-two factors	11.8	0.97	0.09	0.04	0.95
French sample (n = 523)					
All 10 Items-one factor	6.8	0.92	0.11	0.06	0.90
All 10 Items-two factors***	5.5	0.94	0.09	0.05	0.92
9 items (without hesitancy item 10)-one factor	7.6	0.92	0.11	0.06	0.90
9 items (without hesitancy item 10)-two factors	5.9	0.95	0.10	0.04	0.92
Suggested value for good fit	*2–5*	*≥0.95*	*≤0.06*	*<0.05*	*≥0.95*

Note: CFA indices selected to report the model fit are: (a) Wheaton et al.'s relative/normed chi-square (χ^2/df), (b) the standardized root mean square residual (SRMR), (c) the root mean square error approximation (RMSEA), (d) the comparative fit index (CFI), and (e) the non-normed-fit index (NNFI) also known as Tucker-Lewis index [29,43]. The following cutoff criteria were used: (a) χ^2/df between 2 and 5, (b) SRMR less than 0.08, (c) RMSEA of 0.06 or less, (d) CFI of 0.95 or greater, and (e) NNFI-TLI of 0.95 or greater [43].

* Item 10 was tested as part of Factor 1 (8 items) based on a higher EFA loading on Factor 1 (0.45) compared to Factor 2 (0.38).

** Item 10 was tested as part of Factor 1 (8 items) based on a slightly higher EFA loading on Factor 1 (0.43) compared to Factor 2 (0.40).

*** Item 10 was tested as part of Factor 1 (8 items) based on a higher EFA loading on Factor 1 (0.54) compared to Factor 2 (0.23).

respectively (Table 2).[2] The first component (consisting of seven items) represented 'lack of confidence' and the second component (consisting of two items) represented "risks". For total sample (N = 3779) 'lack of confidence', Cronbach's α was 0.92 and inter-item correlations ranged between 0.52 and 0.79. For total sample (N = 3779) 'risks', Cronbach's α was 0.64 and the inter-item correlation was 0.47.[3]

3.3. Construct validity

3.3.1. Relationship between the VHS and associated vaccine attitudes

Table 5 contains the Pearson correlations between the VHS sub-scales (i.e. 'lack of confidence' and 'risks') and associated vaccine attitudes such as VCBS, harms, trust, and benefits. The VHS sub-scales were positively correlated with the VCBS and harms, and negatively with benefits and trust. The pattern of results was similar for English and French subsamples (Supplemental File, Section 3, Tables A4 and A5).

3.3.2. Relationship between the VHS and PAPM stage

There was a significant effect of VHS sub-scale 'lack of confidence' on PAPM stage [$F(2, 3776) = 287.56$, $p < .001$, $\eta^2 = 0.13$]. Post hoc comparisons of VHS sub-scale 'lack of confidence' using independent sample t-tests revealed that all groups (unaware, hesitant, and acceptor) significantly differed (Supplemental File, Section 4). There was a significant effect of VHS sub-scale 'risks' on PAPM stage [$F(2, 3776) = 246.54$, $p < .001$, $\eta^2 = 0.12$]. Post hoc comparisons of VHS sub-scale 'risks' using independent sample t-tests revealed that all groups (unaware, hesitant, and acceptor) significantly differed from each other (Supplemental File, Section 4).

The pattern of results was similar for English and French subsamples (Supplemental File, Section 4, Tables A6 and A7).

3.4. Criterion validity

Participants who refused the HPV vaccine reported greater vaccine hesitancy 'lack of confidence' (M = 2.64, SD = 0.85) than participants who did not refuse the HPV vaccine (M = 1.92, SD = 0.67). This difference was significant, $t(3\,9\,4) = -15.41$, $p < .001$, and represented a large effect (Cohen's d = 1.05). Participants who refused the HPV vaccine reported greater vaccine hesitancy 'risks' (M = 3.83, SD = 0.86) than participants who did not refuse the HPV vaccine (M = 3.00, SD = 0.92). This difference was significant, $t(3777) = -16.20$, $p < .001$, and represented a large effect (Cohen's d = 0.91).

Participants who refused any other vaccine reported greater vaccine hesitancy 'lack of confidence' (M = 2.82, SD = 0.96) than participants who had not refused any vaccine (M = 1.91, SD = 0.64). This difference was significant, $t(347) = -16.75$, $p < .001$, and represented a large effect (Cohen's d = 1.37). Participants who refused any other vaccine reported greater vaccine hesitancy 'risks' (M = 3.72, SD = 0.83) than participants who had not refused any vaccine (M = 3.01, SD = 0.93). This difference was significant, $t(398) = -14.35$, $p < .001$, and represented a medium effect (Cohen's d = 0.76).

The pattern of results was similar for English and French subsamples (Supplemental File, Section 5, Tables A8 and A9).

3.5. Performance of the VHS in the sample

There was greater endorsement of the 'risks' sub-scale (M = 3.07, SD = 0.95) compared to the 'lack of confidence' sub-scale (M = 1.98, SD = 0.72). Please see the Supplemental File (Section 6, Tables A10–A12) for dispersion and percentiles for both sub-scales.

ANOVA analyses were conducted to evaluate socio-demographic differences in reported vaccine hesitancy (Table 6). There were significant group-level differences in vaccine hesitancy for gender, marital status, education, being born in Canada, language, and income level; however, the effect sizes for these differences were small ($\eta^2 < 0.02$). The largest effect was found in income (small effect size). Further post hoc analyses of group-level differences as well as differences for different subgroups can be found in the Supplemental File (Section 6, Tables A13–A15).

4. Discussion

Understanding vaccine hesitancy has become an international priority. The Global Vaccine Action Plan, endorsed by 194 Member States of the World Health Assembly, outlined goals for the 'decade of vaccines (2011–2020)' in order to increase vaccine coverage [38]. In addition, the World Health Organization Strategic Advisory Group of Experts on Immunization established a working group to specifically address vaccine hesitancy [6,11].

In this study, we conducted a psychometric evaluation of a scale that was designed to measure vaccine hesitancy [33]. Although this measure has face validity, in their final report on the work, the SAGE Working Group on Vaccine Hesitancy "encouraged validation of the developed compendium of survey questions on vaccine hesitancy…" [33]. We have responded to this call and surveyed a large national sample of Canadian parents to examine the VHS's structure and internal consistency, construct validity, criterion validity, and test socio-demographic differences of the VHS.

Analyses revealed a two-factor structure with VHS sub-scales characterized by 'lack of confidence' and 'risks'. Although the definition of vaccine hesitancy has been debated, the VHS sub-scales fits within Peretti-Wattel et al.'s (2015) two proposed dimensions of vaccine hesitancy: "level of confidence in the health authorities and mainstream medicine" and "healthism/ risk culture" [12]. The VHS sub-scales were only moderately associated (r = 0.44), which further suggests that they represent two different constructs. Interestingly, though parents overall were not very vaccine hesitant, more parents endorsed vaccine 'risks' associated with new vaccines and adverse reactions (M = 3.07) compared to 'lack of confidence' (M = 1.98). This result corresponds to findings from a Canadian survey (N = 1000) that found few parents did not trust vaccine-related information provided by doctors (7%) and public health officials (12%), whereas a larger number of parents believed or were uncertain about a link between vaccines and autism (28%) [39].

The construct validity of the VHS sub-scales was emphasized through a medium to large relationship with related vaccine attitudes including a negative relationship with trust in vaccines and a positive relationship with vaccine conspiracy beliefs. This indicates that the VHS is appropriately measuring the construct of interest. Furthermore, a medium to large relationship between the VHS sub-scales and vaccine refusal indicates that the VHS has criterion validity.

Previous research has found that vaccine beliefs are clustered by race, education, and socioeconomic background [10]. This study therefore evaluated whether there were socio-demographic differences in VHS scores. Although some differences on the VHS were found (e.g. by income), which merit further investigation, the overall size of these effects was small.

[2] The EFA and CFA were retested with nine items to ensure that the factor structure held (after deleting the flagged item).

[3] The inter-item correlation between the two items that loaded on Factor 2 correlated positively, r = 0.47. Both these items correlated negatively and less strongly with all items that loaded on Factor 1.

Table 5
Pearson correlations between VHS sub-scales and VCBS, harms, trust, and benefits.

	VHS Factor 1: Lack of Confidence	VHS Factor 2: Risks	VCBS	Harms	Trust	Benefits
VHS Factor 1: Lack of Confidence	X					
VHS Factor 2: Risks	0.44*	X				
VCBS	0.64*	0.63*	X			
Harms	0.58*	0.65*	0.69*	X		
Trust	−0.69*	−0.49*	−0.61*	−0.67*	X	
Benefits	−0.62*	−0.43*	−0.52*	−0.65*	0.69*	X

* Significant at $p < .001$ (2-tailed). $N = 3779$. 'VCBS' Cronbach's $\alpha = 0.95$; 'Harms' Cronbach's $\alpha = 0.93$; 'Trust' Cronbach's $\alpha = 0.85$; 'Benefits' Cronbach's $\alpha = 0.94$.

Table 6
ANOVA analyses of vaccine hesitancy in a Canadian sample ($N = 3779$).

Participant characteristics	*N* (%)	VHS Factor 1: Lack of Confidence M (SD)	ANOVA	VHS Factor 2: Risks M (SD)	ANOVA
Whole sample	**3779 (100)**	**1.98 (0.72)**		**3.07 (0.95)**	
Gender					
Men	1311 (34.7)	2.05 (0.70)	F = 17.279	3.03 (0.94)	F = 4.835
Women	2468 (65.3)	1.95 (0.72)	$p < .001$	3.10 (0.95)	$p = .028$
			$\eta^2 = 0.005$		$\eta^2 = 0.001$
Age categorical					
18–34	345 (9.1)	2.02 (0.79)	F = 1.134	3.10 (0.98)	F = 0.553
35–44	1761 (46.6)	1.99 (0.71)	$p = .322$	3.08 (0.93)	$p = .575$
45 and over	1673 (44.3)	1.96 (0.71)		3.06 (0.96)	
Language answered questionnaire					
English	2801 (74.1)	1.97 (0.72)	F = 4.953	3.06 (0.96)	F = 2.816
French	978 (25.9)	2.03 (0.72)	$p = .026$	3.12 (0.89)	$p = .093$
			$\eta^2 = 0.001$		
Language first learned					
English	2488 (65.8)	1.95 (0.71)	F = 6.294	3.04 (0.97)	F = 7.543
French	1049 (27.8)	2.03 (0.73)	$p = .002$	3.12 (0.89)	$p = .001$
Other	242 (6.4)	2.08 (0.76)	$\eta^2 = 0.003$	3.25 (0.86)	$\eta^2 = 0.004$
Marital status					
Single/Separated/divorced/widowed	760 (20.1)	2.10 (0.78)	F = 23.870	3.16 (0.95)	F = 7.377
Married/common law	3019 (79.9)	1.95 (0.97)	$p < .001$	3.05 (0.94)	$p = .007$
			$\eta^2 = 0.006$		$\eta^2 = 0.002$
Education					
Elementary or high school	659 (17.4)	2.08 (0.74)	F = 25.003	3.12 (0.90)	F = 13.318
Trade technical or vocational	1400 (37.0)	2.05 (0.73)	$p < .001$	3.16 (0.91)	$p < .001$
University bachelor or graduate	1720 (45.5)	1.89 (0.69)	$\eta^2 = 0.013$	2.99 (0.99)	$\eta^2 = 0.007$
Employment status					
Working more than 30 h/week	2574 (68.1)	1.99 (0.69)	F = 0.164	3.06 (0.93)	F = 1.596
Working less than 30 h/week	483 (12.8)	1.97 (0.74)	$p = .849$	3.09 (0.97)	$p = .203$
Not employed	722 (19.1)	1.98 (0.79)		3.13 (0.96)	
Born in Canada					
Yes	3214 (85.0)	1.97 (0.71)	F = 12.814	3.04 (0.95)	F = 23.211
No	565 (15.0)	2.08 (0.76)	$p < .001$	3.25 (0.91)	$p < .001$
			$\eta^2 = 0.003$		$\eta^2 = 0.006$
Ethnicity					
White	3224 (85.3)	1.97 (0.72)	F = 3.033	3.05 (0.95)	F = 18.083
Other	555 (14.7)	2.03 (0.67)	$p = .082$	3.23 (0.89)	$p < .001$
					$\eta^2 = 0.005$
Religion					
Christian	2190 (58.0)	1.97 (0.70)	F = 1.554	3.11 (0.91)	F = 6.849
No religious affiliation	1286 (34.0)	1.99 (0.73)	$p = .212$	3.00 (1.00)	$p = .001$
Other	303 (8.0)	2.05 (0.80)		3.16 (0.98)	$\eta^2 = 0.004$
Income					
<39 K	407 (10.8)	2.12 (0.81)	F = 13.950	3.21 (0.91)	F = 17.051
40–79 K	1005 (26.6)	2.03 (0.73)	$p < .001$	3.14 (0.92)	$p < .001$
80–119 K	1020 (27.0)	1.98 (0.70)	$\eta^2 = 0.015$	3.11 (0.93)	$\eta^2 = 0.018$
>120 K	950 (25.1)	1.85 (0.66)		2.86 (0.99)	
Prefer not to answer	397 (10.5)	2.04 (0.72)		3.17 (0.91)	
Child's gender					
Boy	1826 (48.3)	2.01 (0.71)	F = 4.040	3.10 (0.93)	F = 2.289
Girl	1953 (51.7)	1.96 (0.72)	$p = .045$	3.05 (0.96)	$p = .13$
			$\eta^2 = 0.001$		

Note: Where results differed significantly ($p < .05$), effect sizes were explored (using eta squared, η^2).

4.1. Strengths and limitations

Strengths of this study include a large, national sample (N = 3779). This study's sample included parents of 9–16 year old children; however, the VHS may perform differently in a sample of parents with younger children. This study's sample is slightly more homogeneous than the Canadian population. Accordingly, additional examinations of vaccine hesitancy in a more diverse population would be beneficial. Furthermore, it is possible that participants may report less vaccine hesitancy face-to-face than through an anonymous online survey, which promotes self-disclosure on sensitive items [40,41]. It would be useful for future research to evaluate differences of the VHS using online surveys, telephone surveys, and face-to-face assessments

There were several limitations to the VHS validated in this study. All 'lack of confidence' items (Factor 1) were worded positively and all 'risks' items (Factor 2) were worded negatively. Accordingly, the content and direction of the items were conflated. Tellingly, the item that was eliminated for not loading on either factor could have been a result of this conflation as this item was similar in content to the first factor and similar in expressed direction to the second factor. In addition, only two items loaded on the second factor assessing 'risks'. Although other authors have published scales with factors that were composed of only two items [19], generally less than three items are considered unstable [28] and calculating Cronbach's α for a two-item sub-scale has limitations [42]. Future development of this scale should address these limitations by increasing the number of items of the 'risks' component and ensuring that both dimensions have positively and negatively worded items. Larson et al. (2015) acknowledged a limitation of the VHS was that the identified questions do not address all determinants of vaccine hesitancy and they therefore recommended additional questions be developed and validated. This study's results will help guide future development of the VHS. It would also be helpful for future research to compare the psychometric properties of the VHS to other vaccine attitude scales.

5. Conclusion

The WHO estimates that vaccination prevents approximately 2.5 million deaths annually [38]. Ensuring vaccine coverage and minimizing vaccine hesitancy is therefore an international priority [6,11,38]. To understand the psychometric properties of Larson et al.'s (2015) VHS measure, we evaluated the scale's structure and internal consistency, construct and criterion validity, and socio-demographic differences in vaccine hesitancy among Canadian parents. We found that the VHS comprises two underlying factors: 'lack of confidence' and 'risks'. As expected, the subscales were associated with vaccine attitudes, and important differences were found in vaccine hesitancy by parents' HPV vaccine stage of decision-making. The vaccine hesitancy scales were associated with vaccine refusal. Furthermore, this study found significant, albeit small, socio-demographic differences in vaccine hesitancy (e.g. between gender and income).

A standardized, validated measurement tool of vaccine hesitancy beliefs would aid in the advancement of research and immunization policy. Further research is warranted to modify this measure, assess its predictive validity and test-retest reliability, and conduct evaluations in other populations.

Author contributions

GS conceived and designed the study, conducted data collection, performed statistical analysis, interpreted the data, and wrote the manuscript. OT conducted data collection, performed statistical analyses, interpreted the data, and assisted in writing the results of the manuscript. All authors have read, provided critical feedback on drafts, and approved the final manuscript.

Conflict of interest

ZR reports personal fees from Merck for a lecture and workshop consultation in 2015, outside the submitted work.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.vaccine.2017.12.043.

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