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Examining Associations Between Knowledge and Vaccine Uptake Using the Human Papillomavirus Knowledge Questionnaire (HPV-KQ)

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Objectives: Understanding the relationship between human papillomavirus (HPV) knowledge and vaccination behavior is important to inform public health interventions, yet few validated HPV knowledge scales exist. This study describes development of the *Human Papillomavirus Knowledge Questionnaire* (HPV-KQ) and its validation with parents residing in the southern United States (US). **Methods:** Drawing on previously published measures, we developed the 13-item HPV-KQ and administered the scale via Web-based survey to parents (N=1105) of adolescents ages 9 to 17 years. Dimensionality, internal consistency, model fit, and predictive validity were assessed. **Results:** The scale was bidimensional. One factor captured general HPV knowledge, and the second factor captured perceptions of gender differences in HPV infection and vaccine recommendations. The 13-item scale and 2-factor solution displayed strong internal consistency and good model fit. Parents of vaccinated adolescents scored higher on the 13-item HPV-KQ (Mean = 8.56) than parents of unvaccinated adolescents (Mean = 6.43) ($p < .001$). In regression models, controlling for key covariates, parents' performance on the HPV-KQ predicted adolescent HPV vaccination ($p < .001$). **Conclusions:** Evaluation indicates the HPV-KQ is a reliable and valid tool for measuring knowledge of HPV and the HPV vaccine among parents residing in the southern US. We recommend further efforts to validate the scale with other populations.

Key words: adolescent; immunization; HPV; vaccine; knowledge; United States; parent
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Human papillomavirus (HPV) is the most common sexually transmitted infection, affecting almost every unvaccinated adult over the course of their life.[1] Currently, an estimated 79 million individuals in the United States (US) have active HPV infection, and 14 million new

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infections occur annually.[1] Whereas over 100 different types of human papillomaviruses are known, 14 types are considered high-risk due to their oncogenic potential.[2] HPV infections are responsible for 44,000 cancer cases every year in the US, including nearly all cases of cervical cancer, as well as cancers of the vulva, vagina, penis, anus, and oropharynx.[3,4] Among HPV-attributable cancers, 43% of cases occur in men.[3]

In 2006, a safe and effective HPV vaccine was approved by the US Food and Drug Administration (FDA) for adolescent girls.[5] Approval for adolescent boys followed in 2011, with the latest vaccine protecting against 9 different HPV types[6] and preventing an estimated 92% of HPV-attributable cancers.[7] Currently, the Advisory Committee on Immunization Practices (ACIP) recommends that immunocompetent adolescents initiate a 2-dose series of HPV vaccination at ages 11 or 12 years; adolescents who initiate at or after 15 years of age require 3 doses, with "catch-up vaccination" recommended through 26 years of age.[8] Most recently, ACIP has endorsed shared clinical decision-making when considering HPV vaccination for unvaccinated individuals ages 27 through 45 years.[8,9]

The National HPV Vaccination Roundtable and Healthy People 2030 have endorsed a national goal of increasing the proportion of adolescents (ie, ages 13 through 15 years) who have received all recommended doses of the HPV vaccine to 80%.[10,11] However, currently 72% of US adolescents have had at least one dose of the HPV vaccine, and only 54% are fully vaccinated against HPV.[12] Existing research suggests that US adolescents and their parents/caregivers continue to have limited knowledge of HPV and the HPV vaccine.[13,14] Increasing knowledge of the risks associated with HPV infection and the safety and efficacy of the HPV vaccine are important first steps to build confidence in vaccination and increase uptake among US adolescents.[15,16]

Several validated scales to assess parental knowledge of HPV have been developed.[17-20] Limitations of existing knowledge scales include the length of the instrument or use of separate scales for general and vaccine-specific HPV knowledge,[18-20] limited inclusion of items addressing male vaccination and male HPV-associated cancers, validation with subpopulations only (eg, Canadian parents of boys; African-American mothers of daughters in the US),[17,18] and small sample sizes in psychometric analyses.[17,19]

Reliable and valid measures for assessing HPV knowledge are important to identify gaps in knowledge, as well as knowledge disparities across groups, so as to understand changes in knowledge over time, and to investigate the role that knowledge plays in vaccination decision-making. Current literature indicates that parental awareness and knowledge of HPV is associated with vaccination decision-making and adolescent vaccination status.[21-25] For instance, Allen et al[22] reported higher levels of HPV and HPV vaccine-related knowledge among parents with vaccinated adolescents or those with the intention to vaccinate, compared to parents who decided against vaccinating their adolescents. Mansfield et al[24] also found that parents with higher HPV knowledge were significantly more likely to report an intention to vaccinate their daughters. Although some studies failed to identify a relationship between parental HPV knowledge and adolescents' vaccination status,[23,26] those studies were notable for small sample size (ie, < 200 parents)[23,26] and the inclusion of parents of male adolescents only.[23] In addition, HPV vaccination promotion campaigns recently have adopted a strong emphasis on 'HPV vaccination as cancer prevention' in advertising and messaging campaigns and now emphasize the importance of on-time initiation of vaccination for boys and girls. Multiple existing HPV knowledge scales reflect outdated vaccine information (eg, 3-dose regimens, initial approval for girls only), and were developed prior to approval of the 9-valent HPV vaccine that prevents HPV infections that cause cervical, anogenital, and head and neck cancers.[27]

Given the limitations of existing scales, we identified the need for an updated, brief HPV knowledge scale and undertook the development of the *Human Papillomavirus – Knowledge Questionnaire* (HPV-KQ), an instrument designed to assess HPV and HPV vaccine-related knowledge. In this study, we describe the development of this scale and present an evaluation of its psychometric properties. Furthermore, we investigate knowledge differences on the HPV-KQ across parents with vaccinated versus unvaccinated adolescents. We also assess the predictive validity of the HPV-KQ by examining associations between parents' performance on the HPV-KQ and the HPV vaccination

status of their adolescents, while controlling for known correlates of HPV vaccination. We hypothesized that parents of vaccinated adolescents would score higher on the HPV-KQ than parents of unvaccinated adolescents and that parents' scores on the HPV-KQ would predict vaccination status of their adolescent.

METHODS

Background

Data were collected as part of a larger study (U01IP001095) funded by the US Centers for Disease Control and Prevention (CDC) that aimed to investigate rural-urban HPV disparities in the US and develop a responsive intervention to increase adolescent HPV vaccination.

Development of the 13-item HPV-KQ

Initially, members of the study team, consisting of experts from a variety of health-related disciplines (eg, pediatrics, public health, health psychology, cancer, and health disparities research) reviewed existing HPV knowledge scales.[17-21,28,29] Team members identified key HPV-related information that was commonly represented in existing scales (eg, causes cervical cancer, sexually transmitted, highly prevalent, can be asymptomatic, affects men and women). They then identified other important HPV-related information that was rarely or never represented (eg, causes other cancers, including head and neck cancers; causes cancers in men; vaccination recommended for boys and girls; vaccination requires more than one dose).

The team then developed a 13-item true/false scale (Box 1) to measure HPV- and HPV vaccine-related knowledge. Final decisions on item selection and wording were made through an iterative consensus building process and prioritized the creation of a scale that was brief, contained items about both HPV and HPV vaccination, and addressed HPV's impact on both males and females. Four items (ie, items 1, 2, 7, 13) were modified from existing scales to improve wording or to enhance the accuracy of the statement. For instance, one item, "HPV can be passed on during sexual intercourse,"[20] was modified to read "HPV is transmitted through sex." This is important because HPV can be transmitted through non-intercourse sexual acts (eg, anal and oral sex), as illustrated by increases HPV-associated anal and oropharyngeal cancers.[30] Replacing "intercourse" with the more general term of "sex" is also important to create a more inclusive scale (ie, recognizing that HPV

Box 1. The 13-item Human Papillomavirus Knowledge Questionnaire (HPV-KQ)

Human Papillomavirus Knowledge Questionnaire (HPV-KQ)

Directions: For each statement below, please select "True", "False", or "Don't know". If you have never heard of HPV, please select "Don't know" for the statements below.

	True	False	Don't Know
1. Only women can gel infected with HPV*	T	F	DK
2. HPV can cause cervical cancer in women	T	F	DK
3. HPV can cause cancer in areas such as the head and neck	T	F	DK
4. HPV causes cancer in women only*	T	F	DK
5. HPV can cause genital warts	T	F	DK
6. A person could have HPV for many years without knowing it	T	F	DK
7. HPV is transmitted through sex	T	F	DK
8. Most people infected with HPV have visible signs or symptoms of the infection*	T	F	DK
9. A person's chances of getting HPV increase with the number of sexual partners they have	T	F	DK
10. Nearly all sexually active people will contract HPV at some point	T	F	DK
11. The HPV vaccine is only recommended for girls*	T	F	DK
12. Full protection against HPV requires more than 1 dose of the vaccine	T	F	DK
13. The HPV vaccine is most effective if given to people who have not yet started having sex	T	F	DK

Note: "Indicated reverse scored item.

transmission also occurs during sex between men and during sex between women).

Five items (ie, items 5, 6, 8, 9, 10) were directly replicated from existing scales. Specifically, item 5 ("HPV can cause genital warts") has been used verbatim in previous scales.[20,21] Item 6 ("A person could have HPV for many years without knowing it") was directly replicated from Waller's scale[20] because the item remains important and aligns with current scientific evidence. Item 8 ("Most people infected with HPV have visible signs or symptoms of the infection"), item 9 ("A person's chances of getting HPV increase with the number of sexual partners they have"), and Item 10 ("Nearly all sexually active people will contract HPV at some point") were directly replicated from Kasymova et al,[28] although similar items have appeared in at least 2 other scales.[18,20]

At least one prior scale[29] includes an item about HPV's causal role in head and neck cancers; the expert team believed a standalone item about head and neck cancers was needed, given the dramatic rise in oropharyngeal cancers due to HPV.[30,31,] Thus a similar item was created for the HPV-KQ (ie, item 3; "HPV can cause cancer in areas such as the head and neck"). The team also created an item to assess whether individuals understood that HPV-caused cancers occur in both men and women (item 4; "HPV causes cancer in women only" [False item]). This information was considered important to include because of the identified knowledge gap concerning HPV-related cancers in men.[31-33]

Similarly, the team identified knowledge about pan-gender recommendations for HPV vaccination to be salient, given previous literature showing that both adolescents and adults in the US often falsely believe that HPV vaccination is recommended only for girls or young women.[32,33] In addition, previous research has shown that healthcare providers are less likely to recommend the HPV vaccine to parents of male adolescents,[34,35] despite recommendations from ACIP and American Academy of Pediatrics (AAP) that routine HPV vaccination be initiated at age 11 or 12 years for males, with vaccination able to be given starting at age 9.[36-38] No existing scales were identified that have items about the 2011 recommendation for HPV vaccination among boys in the US, although Perez et al[21] developed a similar item for a Canadian sample ("The HPV vaccine is approved and recommended by Health Canada for males aged 9-26 years"). The team considered knowledge on the need for and recommendations on adolescent male vaccination to be salient information for an HPV knowledge scale because of the large body of literature that has shown that parents of male adolescents and male adolescents themselves are less likely to be knowledgeable about HPV vaccination or to receive recommendations for vaccination.[32-34] Thus, item 11 was developed ("The HPV vaccine is only recommended for girls" [False item]). Finally, given changing recommendations on required doses of the HPV vaccine (ie, 2 doses if HPV vaccination begins at < 15 years of age; 3 doses if HPV vaccination begins at ≥ 15 years of age), a new item was developed (ie, item 12; "Full protection against HPV requires more than 1 dose of the vaccine").

Thus, the HPV-KQ includes 13 items that address key HPV constructs (ie, transmission, sequelae, prevention) and includes items on male vaccination and male HPV-associated cancers that are not well-represented in existing scales. Following development, the HPV-KQ was tested for readability, yielding a Flesch Reading Ease score of 72.6 (ie, fairly easy to read) and a Flesch-Kincaid Grade Level score of 5.8. The HPV-KQ was programmed for delivery via the Qualtrics^{XM} survey platform and pilot-tested for acceptability and clarity with a convenience sample of 23 parents of children and adolescents. No major concerns were identified by pilot-study participants, and thus, the 13-item scale was finalized and deployed for the current study. Pilot-test respondents were not included in the study sample or data analysis.

Study Design and Sample

From December 2019 to January 2020 we recruited parents and legal guardians of adolescents, ages 9 to 17 years, through the Ipsos KnowledgePanel®, a nationally representative online research panel with members recruited through address-based probability sampling methods. The KnowledgePanel® includes both US residents with Internet access and those without. Internet access and a digital device are provided to participating members without Internet access to reduce the chances of under-sampling in this group. Because the parent study was focused on HPV vaccination in the southern US, the current study included KnowledgePanel® members residing

in southern states, as defined by the US Department of Health and Human Services (HHS) as HHS Region 4 (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee) and HHS Region 6 (Arkansas, Louisiana, New Mexico, Oklahoma, Texas). Other eligibility criteria included: (1) having English proficiency, (2) being ≥ 18 years of age, and (3) being a parent or legal guardian of an adolescent aged 9 to 17 years.

A total of 2262 parents/guardians from the KnowledgePanel® were contacted about the study for recruitment, and 1250 (55.3%) opted into the survey. We excluded 71 ineligible respondents (ie, who did not meet inclusion criteria); an additional 74 respondents failed to complete the survey. This yielded a total sample size of 1105 parents of adolescents and a cooperation rate of 48.9%.

Procedure

We sent eligible members of the KnowledgePanel® information about the study and an electronic link to the survey. Parents and legal guardians (henceforth referred to collectively as 'parents') were able to complete the self-administered Web-based survey on the platform of their choice. The introduction to the survey contained a description of the research study and an implied consent script. In addition to the HPV-KQ, the survey also assessed vaccination-related behaviors and experiences. The survey took a median of 10 minutes to complete. Recruitment of parents continued until the target sample size of 1000 was reached. This target sample size was based on the availability of eligible KnowledgePanel® households in the 13 states and anticipated response rates.

Measures

Socio-demographic characteristics. Parents' socio-demographic data were provided by Ipsos, (ie, measured at recruitment into the KnowledgePanel® and updated annually) including age, race/ethnicity, highest level of education, gender, income level, current employment status, marital status, and household size. Zip codes were used to classify participants as rural or urban based on Rural-Urban Commuting Area (RUCA) codes, with RUCA ≥ 4 categorized as rural.[39] Parents reported on key socio-demographic characteristics of their adolescent, including the adolescent's age, gender, school setting (ie, public, private, online, homeschool), and health insurance coverage (ie, presence and type of insurance).

HPV-KQ. Participants responded to HPV-KQ items by selecting "true," "false," or "I don't know." A total knowledge score (possible range = 0-13) was created for each participant by summing their correct responses across the 13 items. Incorrect responses and responses of "I don't know" were assigned a score of 0.

Adolescent HPV vaccination status and other relevant healthcare variables. To examine the relationship between parental knowledge and adolescent vaccination status (ie, to assess the predictive validity of the HPV-KQ), parents were asked whether their adolescent had received at least one dose of the HPV vaccine ("yes" vs "no/I don't know"). Parents also reported on several other healthcare-related variables that were used as covariates in later analyses (eg, how long it took to travel to the place their adolescent most often received healthcare, whether their adolescent had received a healthcare visit in the past year, and whether a provider had ever recommended the HPV vaccine for their adolescent.)

Data Analysis

We analyzed the data using SAS 9.4 (SAS Institute, Cary, NC). To correct for sampling biases due to nonresponse and/or incomplete coverage of the Web-based panel, we used survey weights provided by Ipsos to calibrate data to be representative of the target population (ie, parents of adolescents ages 9-17 years from 13 southern states).

We generated descriptive statistics for the total sample of parents (N=1105), for parents with vaccinated adolescents (≥ 1 dose of the HPV vaccine; N=363), and for parents with unvaccinated adolescents (N=742). We used chi-square and Student's t-test to examine group differences between parents of vaccinated versus unvaccinated adolescents.

To investigate the structure of the HPV-KQ, we used a randomization procedure to split the total sample (N=1105) into 2 random subsamples. We made no *a priori* hypotheses about underlying factors and conducted exploratory factor analysis (EFA) using principal component analysis with varimax rotation on the HPV-KQ data from the first randomly generated subsample (N=551).[40]

We retained items with loadings larger than 0.45. A confirmatory factor analysis (CFA) with data from the second randomly-generated subsample (N=554) was used to confirm the factor solution that emerged from the EFA. To investigate model fit, indices were compared to recommended thresholds.[41-43] We calculated Cronbach's alpha to measure internal consistency of the full 13-item HPV-KQ and of the derived factor solution; alphas between 0.80 and 0.95 were considered evidence of strong internal consistency.[44]

To explore the predictive validity of the scale, we used Student's t-test to compare the performance of parents of vaccinated versus unvaccinated adolescents on the HPV-KQ. Specifically, we compared parents' responses on each of the 13 individual items and parents' total knowledge scores for the full 13-item scale and the derived factor solution. To assess predictive validity further, we used weighted multivariable logistic regression to determine whether parents' HPV knowledge, as measured by the HPV-KQ, predicted adolescent vaccine uptake (ie, ≥ 1 dose of the HPV vaccine). In other words, we analyzed whether higher parent scores on the 13-item scale and the derived factor solution were associated with increased odds that their adolescent was vaccinated against HPV. Models were adjusted for parental and adolescent demographic factors that were chosen from those independently associated with the outcome variable (ie, adolescent vaccine uptake) using stepwise selection procedures, with inclusion criteria of $p < .05$. Data were clustered at the state level to account for error correlation within states. We used odds ratios and 95% confidence intervals to describe the extent to which variation in parents' knowledge was associated with adolescents' vaccination status. Because provider recommendation is a robust predictor of HPV vaccine uptake,[45-50] we estimated separate models for parents who had received a provider recommendation for HPV vaccination (N=593) and parents who had not received a provider recommendation for HPV vaccination (N=510). In all analyses, p values < .05 were considered to be statistically significant.

RESULTS

Table 1 summarizes key socio-demographic and healthcare-related characteristics of the sample, as well as group differences between parents of vaccinated versus unvaccinated adolescents. Parents' mean age was 42.7 years (SD = 8.1); parents of vaccinated adolescents were significantly older than parents of unvaccinated adolescents ($p < .001$). A total of 42.2% of the sample were fathers. Gender of the parent was associated with adolescent vaccination status, with more mothers reporting HPV vaccination among their adolescents than fathers ($p = .045$). The diverse sample included 25.5% who were Hispanic, 16.7% who were non-Hispanic black or African-American, 51.7% who were non-Hispanic white, and 6.2% who identified as a different non-Hispanic race/ethnicity.

About one out of five (19.4%) participants resided in a rural area. Most parents were married (80.4%), with a mean household size of 4.2 members (SD = 1.4). Most parents (59.0%) did not possess a college degree. There was a statistically significant difference in vaccination status by child's age, with parents of older adolescents more likely to report that their child had been vaccinated against HPV ($p < .001$). There was no statistically significant difference in vaccination status by gender of the adolescent ($p = .49$) or with respect to health insurance coverage ($p = .11$). Parents who reported that a healthcare provider had recommended HPV vaccination were significantly more likely to have a vaccinated adolescent ($p < .001$).

Factor Analysis and Reliability Measures

Initially, dimensionality of the HPV-KQ was examined with data from 551 participants. Tables 2 shows the results of the EFA. The rotated solution yielded 2 factors, with relatively strong item loadings (> .45).[40,41] Factor 1 included 7 items (items 2, 5, 6, 7, 8, 9, 13) and captured 83.8% of total variance. This factor appeared to capture general knowledge of HPV. It included items such as "HPV can cause genital warts," "HPV is transmitted through sex," and "A person could have HPV for many years without knowing it." Factor 2 included 3 items (items 1, 4, 11) and captured 16.2% of the variance. This factor appeared to capture gender-related aspects of HPV knowledge. Items that loaded onto Factor 2 were: "Only women can get infected with HPV" (False), "HPV causes cancer in women only" (False), and "The HPV vaccine is only recommended for girls" (False). Three items (items

Table 1

Socio-demographic and Healthcare-related Characteristics of Total Study Sample (N=1105) and by Child's HPV Vaccination Status

Variable	Level	Total sample (N=1105)	HPV vaccinatedchild (N=363)	HPV un-vaccinated child (N=742)	p-value
CHARACTERISTICS OF PARENT					
Age (M [SD])		42.69 (8.14)	44.03 (7.56)	41.55 (7.74)	< .001
Gender (parent)	Male	466 (42.17)	138 (37.94)	328 (44.28)	.045
	Female	638 (57.73)	225 (62.06)	413 (55.72)	
Race and ethnicity	Non-Hispanic black or African-American	184 (16.65)	59 (16.14)	125 (16.84)	.104
	Non-Hispanic white	571 (51.67)	184 (50.74)	387 (52.11)	
	other, Non-Hispanic	69 (6.24)	24 (6.65)	45 (6.01)	
	Hispanic	282 (25.52)	96 (26.47)	186 (25.04)	
Residence	Urban	891 (80.63)	304 (83.65)	587 (79.07)	.071
	Rural	214 (19.37)	59 (16.35)	155 (20.93)	
Marital status	Married/Living with Partner	888 (80.36)	297 (81.7)	591 (79.64)	.637
	Divorced	91 (8.24)	32 (8.81)	59 (8.02)	
	Separated	26 (2.35)	8 (2.33)	18 (2.38)	
	Never married	88 (7.96)	23 (6.46)	65 (8.75)	
	Other	12 (1.09)	3 (0.7)	9 (1.22)	
Household size (M [SD])		4.17 (1.39)	4.28(1.58)	4.29 (1.31)	.931
Household income	< $25,000	136 (12.31)	43 (11.76)	93 (12.57)	.141
	$25,000-$49,999	215 (19.46)	65 (17.94)	150 (20.22)	
	$50,000-$99,999	361 (32.67)	109 (29.91)	252 (33.93)	
	> $100,000	394 (35.66)	147 (40.4)	247 (33.28)	
Employment status	Working (paid employee or self-employed)	884 (80.0)	281 (77.31)	603 (81.23)	.315
	Not working (temporary layoff OR looking for work)	57 (5.16)	18 (4.9)	39 (5.3)	
	Retired	25 (2.26)	12 (3.31)	13 (1.73)	
	Disabled	36 (3.26)	14 (3.77)	22 (2.94)	
	Not working (other)	104 (9.41)	39 (10.71)	65 (8.8)	
Highest level of education	≤ 12 grade (did not graduate high school)	64 (5.79)	25 (6.95)	39 (5.2)	.120
	High school graduate or GED	341 (30.86)	102 (28.23)	239 (32.22)	
	Some college	247 (22.35)	72 (19.94)	175 (23.64)	
	Associate's degree	98 (8.87)	40 (11)	58 (7.84)	
	Bachelor's degree	200 (18.1)	64 (17.75)	136 (18.28)	
	Master's degree or higher	154 (13.94)	59 (16.12)	95 (12.81)	

Table 1

Socio-demographic and Healthcare-related Characteristics of Total Study Sample (N=1105) and by Child's HPV Vaccination Status

Variable	Level	Total sample (N=1105)	HPV vaccinated child (N=363)	HPV un-vaccinated child (N=742)	p-value
CHARACTERISTICS OF CHILD					
Age (years)	9	135 (12.26)	2 (0.57)	133 (18.03)	< .001
	10	117 (10.63)	1 (0.36)	116 (15.74)	
	11	112 (10.17)	25 (6.86)	87 (11.81)	
	12	119 (10.81)	36 (9.98)	83 (11.19)	
	13	122 (11.08)	63 (17.35)	59 (7.99)	
	14	123 (11.17)	58 (16.06)	65 (8.79)	
	15	99 (8.99)	53 (14.8)	46 (6.27)	
	16	150 (13.62)	69 (18.98)	81 (10.95)	
	17	122 (11.08)	54 (15.04)	68 (9.23)	
Gender	Male	548 (49.59)	174 (48.55)	374 (50.43)	.486
	Female	550 (49.77)	183 (51.15)	367 (49.53)	
	Other	1 (0.09)	1 (0.3)	0 (0.00)	
Health insurance coverage	Public insurance	441 (40.38)	149 (41.66)	292 (39.69)	.110
	Private insurance	592 (54.21)	194 (54.24)	389 (52.92)	
	No insurance	69 (6.32)	15 (4.11)	54 (7.39)	
Received healthcare provider recommendation for the HPV vaccine	Yes (vs all others)	510 (46.2)	343 (94.57)	167 (22.58)	< .001

Note.
Totals may not sum to 1105 for all variables due to missing data.

3, 10, 12) did not load strongly onto either factor; we dropped them from the subsequent CFA.

Both the original 13-item HPV-KQ and the 2-factor solution that emerged from the EFA fit the data well, based on fit indices in the CFA (Table 3).[51] We used the chi-square goodness-of-fit test to examine model fit. The 2-factor solution fit the data better than the original 13-item scale and a constrained one-factor solution consisting of the 10-items with strong factor loadings. Cronbach's alpha indicated that the original 13-item HPV-KQ had high internal consistency (α = 0.87), as did the 2 derived factors (Factor 1 α = 0.84; Factor 2 α = 0.82).

Predictive Validity Analyses

Table 4 displays the number and percentage of parents who correctly answered each HPV-KQ item, as well as differences across individual items and total knowledge scores for parents of vaccinated versus unvaccinated adolescents. Percentages of correct responses varied widely across individual items; only 20.2% of participants answered item 10 correctly ("Nearly all sexually active people will become infected with HPV at some point"), whereas 80.1% of participants answered item 2 correctly ("HPV can cause cervical cancer in women"). In addition to item 10, other 'low-scoring' items included item 3 ("HPV can cause cancer in areas such as the head and neck" 21.2% correct), item 5 ("HPV can cause genital warts" 45.5% correct), and item 13 ("The HPV vaccine is most effective if given to people who have not yet started having sex" 44.4% correct).

Table 2

Results of Exploratory Factor Analysis for the 13-item HPV-KQ

		Factor loadings		Uniqueness/ Unique variances
	Item	**Factor 1**	**Factor 2**	
	1. Only women can get infected with HPV (False)[a]	0.212	**0.782***	0.344
	2. HPV can cause cervical cancer in women (True)	**0.481***	0.421	0.591
	3. HPV can cause cancer in areas such as the head and neck (True)	0.353	0.056	0.872
	4. HPV causes cancer in women only (False) [a]	0.188	**0.688***	0.492
	5. HPV can cause genital warts (True)	**0.591***	0.140	0.632
	6. A person could have HPV for many years without knowing it (True)	**0.618***	0.402	0.457
	7. HPV is transmitted through sex (True)	**0.669***	0.315	0.454
	8. Most people infected with HPV have visible signs or symptoms of the infection (False)[a]	**0.451***	0.417	0.623
	9. A person's chances of getting HPV increase with the number of sexual partners they have (True)	**0.682***	0.264	0.465
	10. Nearly all sexually active people will contract HPV at some point (True)	0.374	0.111	0.848
	11. The HPV vaccine is only recommended for girls (False) [a]	0.189	**0.775***	0.363
	12. Full protection against HPV requires more than 1 dose of the vaccine (True)	0.370	0.337	0.750
	13. The HPV vaccine is most effective if given to people who have not yet started having sex (True)	**0.575***	0.175	0.639
Eigenvalue of factors without rotation	-	4.59	0.89	-
Percentage of variance explained by factors	-	83.8	16.2	-

Note.
[a] **Reverse-coded items**

Parents with vaccinated adolescents displayed significantly greater knowledge across all items when compared to parents of unvaccinated adolescents (range of $p = .04$ to $p < .001$). Parents of vaccinated adolescents displayed high levels of knowledge about HPV causing cervical cancer (88.0% correct), about HPV infecting both men and women (90.4% correct), about the possibility of asymptomatic infection (80.6% correct), and about the recommendation that both girls and boys receive the HPV vaccine (81.2% correct). Parents of vaccinated adolescents scored higher than parents of unvaccinated adolescents on the original 13-item HPV-KQ ($M = 8.6$ vs $M = 6.4$, $p < .001$), on Factor 1 ($M = 4.8$ versus $M = 3.9$, $p < .001$), and on Factor 2 ($M = 2.0$ versus $M = 1.8$, $p < .001$).

The 3 items that did not load onto the 2-factor solution (items 3, 10, 12) were notable in that they

Table 3

Confirmatory Factor Analysis for One-factor and 2-factor Solutions for the HPV-KQ

Factor Solution	N of items	Items	χ^2 p-value	Goodness of Fit Index (GFI)	Adjusted GFI (AGFI)	Standardized root mean square residual (SRMR)	Root mean square error of approximation (RMSEA)
One factor solution (13-item constrained model)	13	1-13	< .0001	0.834	0.768	0.072	0.121
One factor solution (10-item constrained model)a	10	1,2,4,5, 6,7,8,9, 11,13	< .0001	0.835	0.758	0.071	0.123
Two factor solution (Factor 1 + Factor 2)	10	Factor 1 (2,5,6,7, 8,9,13) + Factor 2 (1,4,11)	< .0001	0.916	0.867	0.051	0.087

Note.
Recommended thresholds for acceptable model fit indices: Goodness of Fit Index (GFI): > 0.90;51 Adjusted Goodness-of-Fit Index (AGFI): > 0.85;51 Standardized root mean square residual (SRMR): < 0.08;31,33 Root mean square error of approximation (RMSEA): < 0.0640
[a]Contains all items with strong factor loadings (> 0.45) in the EFA

were highly missed items. Only 21.2% of participants correctly answered item 3 ("HPV can cause cancer in areas such as the head and neck") and only 20.2% correctly answered item 10 ("Nearly all sexually active people will become infected with HPV at some point"). Item 12 yielded the largest difference between parents of vaccinated and unvaccinated adolescents, with 73.9% of parents of vaccinated adolescents correctly reporting that HPV vaccination requires more than one dose, compared to only 38.6% of parents of unvaccinated adolescents (p < .001).

Table 5 shows abbreviated results of the multivariable regression models assessing whether parental HPV knowledge predicted adolescent uptake of HPV vaccination (≥ 1 dose). Complete model data are found in Supplementary Tables 1 and 2. We ran separate models for the full sample (Model 1; N=1105), for parents who had never received a provider recommendation for HPV vaccination (Model 2; N=593), and for parents who had received a provider recommendation (Model 3; N=510). As expected, parental performance on the HPV-KQ predicted adolescent uptake of HPV vaccination, when controlling for key covariates (eg, adolescent race/ethnicity, age, gender, parent employment status, etc). Specifically, parents' scores on the 13-item HPV-KQ and parents' scores on Factor 2 predicted adolescent vaccine uptake in the full sample (p < .001 and p = .008, respectively) and among parents who reported having received a provider recommendation for HPV vaccination (p = .01 and p = .01, respectively). (p < .001, p = .008, respectively). Parental knowledge scores for Factor 1 did not significantly predict adolescent vaccination uptake in any group (p > .05).

DISCUSSION

Evidence from this study supports the use of the HPV-KQ for evaluating knowledge of HPV and HPV vaccination among parents in the US South. The scale has strong internal consistency and also offers other benefits, including accessibility (ie, 5th grade reading level) and brevity. Most importantly, the HPV-KQ captures key information on HPV transmission, sequelae, and prevention. It reflects

Table 4.

Differences among Parents (N=1105) in Individual Item Responses and Total Knowledge Scores by Child's HPV Vaccination Status, for Total Scale and Derived Factors

HPV-KQ Item	Factor	Parents' correct responses N (%)			
		Total sample (N=1105)	Parent of HPV vaccinated child (N=363)	Parent of HPV unvaccinated child (N=742)	p-value
1. Only women can get infected with HPV (False)[a]	2	844 (76.38)	328 (90.43)	516 (69.6)	**< .001**
2. HPV can cause cervical cancer in women (True)	1	885 (80.09)	320 (88.03)	565 (76.12)	**< .001**
3. HPV can cause cancer in areas such as the head and neck (True)	-	234 (21.18)	96 (26.37)	138 (18.61)	**.003**
4. HPV causes cancer in women only (False)[a]	2	677 (61.27)	271 (74.74)	406 (54.76)	**< .001**
5. HPV can cause genital warts (True)	1	503 (45.52)	195 (53.69)	308 (41.48)	**< .001**
6. A person could have HPV for many years without knowing it (True)	1	804 (72.76)	293 (80.63)	511 (68.89)	**< .001**
7. HPV is transmitted through sex (True)	1	677 (61.27)	257 (70.83)	420 (56.67)	**< .001**
8. Most people infected with HPV have visible signs or symptoms of the infection (False)[a]	1	577 (52.22)	236 (64.95)	341 (45.94)	**< .001**
9. A person's chances of getting infected with HPV increase with the number of sexual partners they have (True)	1	706 (63.89)	265 (72.93)	441 (59.48)	**< .001**
10. Nearly all sexually active people will become infected with HPV at some point (True)	-	223 (20.18)	86 (23.74)	137 (18.43)	**.04**
11. The HPV vaccine is only recommended for girls (False)[a]	2	701 (63.44)	295 (81.19)	406 (54.72)	**< .001**
12. Full protection against HPV requires more than 1 dose of the vaccine (True)	-	555 (50.23)	268 (73.88)	287 (38.64)	**< .001**
13. The HPV vaccine is most effective if given to people who have not yet started having sex (True)	1	491 (44.43)	197 (54.2)	294 (39.56)	**<.001**
		Total Knowledge Scores Mean (SD)			**p-value**
13-item HPV-KQ		7.13 (3.16)	8.56 (3.02)	6.43 (3.91)	**< .001**
HPV-KQ Factor 1 (7 items)		4.20 (2.37)	4.85 (2.02)	3.88 (2.47)	**< .001**
HPV-KQ Factor 2 (3 items)		2.01 (1.20)	2.46 (0.92)	1.79 (1.26)	**< .001**

[a] **Reverse-coded items**

up-to-date information on HPV and HPV vaccination such as the need for multiple doses of the vaccine, recommendations that both boys and girls be vaccinated, and evidence that the vaccine is most effective when received early in adolescence (ie, before sexual debut). These are important pieces of knowledge given the large numbers of parents who delay initiation of the HPV vaccine series for their adolescent, fail to complete the series, or fail to initiate entirely. The inclusion of several items focused on boys and men in the HPV-KQ is also important, as males have been underrepresented in

Table 5

Multivariable Logistic Regression Models Examining the Association between Parent Performance on the HPV-KQ and Adolescent HPV Vaccine Uptake, by Provider Recommendation for HPV Vaccination

Outcome variable: Adolescent uptake of ≥ 1 dose of the HPV vaccine						
	Model 1		Model 2		Model 3	
	All parents (N=1105)		Parents reporting no provider recommendation (N=593)		Parents reporting provider recommendation (N=510)	
VARIABLES	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
HPV-KQ (13 items)	1.07 (1.03,1.11)	**< .001**	1.06 (0.98,1.15)	.12	1.08 (1.02,1.14)	**.01**
HPV-KQ Factor 1 (7 items)	0.95 (0.87,1.04)	0 .25	0.84 (0.68,1.04)	.11	0.98 (0.9,1.06)	.58
HPV-KQ Factor 2 (3 items)	1.37 (1.09,1.74)	**.008**	1.67 (0.91,3.07)	.10	1.32 (1.06,1.64)	**.01**

Note.
See Supplementary Tables 1 and 2 for full models. Models for HPV-KQ Factor 1 and HPV-KQ Factor 2 are fitted jointly. Adolescent covariates included in the models: race/ethnicity, gender, age, school type, travel time to healthcare provider, health care visit in past year. Parent covariates included in the models: employment status.

HPV-related research and vaccination campaigns. In addition, the 13-item HPV-KQ includes an item about head and neck cancers, an important new area of emphasis given observed increases in oropharyngeal cancers. Given these strengths, the HPV-KQ likely is useful in capturing information about individuals' knowledge of HPV to develop public health campaigns and programming to combat vaccine misinformation and vaccine hesitancy among US parents.

In a sample of more than 1100 parents from 13 southern states, respondents, on average, answered only 7 of 13 knowledge questions correctly. Several HPV-KQ items were missed by large numbers of participants, signaling potential gaps in parental HPV knowledge. Few parents were familiar with the widespread prevalence of HPV among sexually active unvaccinated adults or the causal role of HPV in head and neck cancers. Fewer than half of parents correctly answered an item about HPV causing genital warts. The need for early initiation of HPV vaccination was not widely understood. Future public health campaigns to target these aspects of HPV-related knowledge may be useful. Understanding that nearly all sexually active unvaccinated individuals will acquire HPV at some point may help convince parents of the importance of timely vaccination and reduce HPV-related stigma.

In our study, parents of vaccinated adolescents demonstrated higher HPV knowledge on the HPV-KQ than parents of unvaccinated adolescents, consistent with prior findings using other HPV knowledge scales.[22] Parents of vaccinated adolescents outperformed parents of unvaccinated adolescents on all items, including items that assessed prevalence, symptoms, HPV-associated cancers, sexual transmission of HPV, potential for dormancy, and vaccination recommendations. Parental HPV knowledge may increase vaccination intentions and use; conversely, the vaccination process also may cause increases in parents' knowledge. Additional research is needed to understand the complex relationship between knowledge, vaccination intentions, and vaccination behaviors. Prospective studies would be especially helpful to understand temporal aspects of these relationships. In addition, findings support the predictive validity of the scale, as parental performance on the HPV-KQ predicted adolescent vaccination status when controlling for key parental and adolescent covariates.

Because scientific understanding and clinical recommendations for HPV vaccination change

over time, updating or creating new knowledge scales periodically is important. In addition, the target audience of a knowledge scale, both in terms of the development process and psychometric validation, is critical. The HPV-KQ was intended for use with parents of adolescents in the US. Its readability level enables it to be administered to adolescents as well, although future validation studies with this age group are needed. With recent changes in vaccination recommendations for adults ages 27 through 45 years (ie, shared clinical decision-making), there is also a need to investigate knowledge among adults who are considering vaccination for themselves. Some knowledge items on the HPV-KQ assess areas that may not be relevant for adults considering HPV vaccination (eg, initiation prior to sexual debut, child vaccination recommendations). Expansion or modification of the scale may be useful for this population.

A final important consideration is whether researchers and clinicians should adopt the full 13-item HPV-KQ or the 2-factor solution that emerged from EFA. Whereas the 2-factor solution demonstrated a superior model fit, the original 13-item scale fit the data relatively well and allows for the inclusion of important items such as HPV's causal role in head and neck cancers and the widespread prevalence of HPV. Importantly, the 3 items that did not load strongly onto either of the 2 factors during EFA were items that were missed frequently by participants. These items may represent gaps in knowledge, and, with appropriate justification, may be beneficial to include in future studies utilizing the HPV-KQ.

Strengths of the current study include that the development of the HPV-KQ was tailored to address gaps in existing scales, and the scale includes multiple items that address the HPV vaccine's role in cancer prevention. In addition, the scale was validated for a large and diverse sample of parents in the southern US, a region disproportionately burdened by HPV-associated cancers.[52] This study also included parents of adolescents across a broad age range (9 to 17 years), including large numbers of both vaccinated and unvaccinated youth.

Limitations to this study include the use of only parents from the southern US. Although the parent sample was large (N=1105), drawn from 13 states, and diverse in terms of gender, race, and ethnicity, future validation efforts may wish to expand to other US regions. In addition, parental report of their children's vaccination status was not confirmed by providers or state registries. Limitations to our study also included how parental HPV knowledge was conceptualized. The HPV-KQ included response options of "true," "false," and "I don't know." For the current study, responses of "false" and "I don't know" were grouped together and considered to represent "lack of knowledge" (ie, scored as 0). Future studies may wish to analyze these responses separately to determine whether there are key differences in lack of knowledge (ie, "I don't know" responses) versus misinformation (ie, "false" responses).

In terms of limitations regarding psychometric findings, it should be noted that whereas Factor 2 appeared to capture gender-relevant knowledge about HPV, all Factor 2 items were "false" items. Thus, there is a possibility that Factor 2 is an artifact of response patterns (eg, failure to read the wording closely, confusion over how to answer false items, etc). This concern is mitigated somewhat by the fact that parents of vaccinated adolescents performed better than parents of unvaccinated adolescents on all items, regardless of whether they were "true" or "false."

In addition, we found differences in the predictive value of the full HPV-KQ, Factor 1, and Factor 2. Specifically, multivariable logistic regression modeling showed that parents' performance on the 13-item scale and on Factor 2 predicted adolescent vaccination for both the full sample and for parents who had received a provider recommendation for HPV vaccination, with higher parental knowledge associated with increased likelihood of vaccination when controlling for important covariates. However, performance on the 7-item Factor 1 did not predict adolescent vaccination status. This may reflect the importance of gender-based HPV knowledge; all Factor 2 items addressed that HPV and HPV vaccination impact all genders. Communication and health messaging that stress the importance of HPV vaccination among males continues to be critical, especially given the barriers to male vaccination that have been identified.[53] Parents with knowledge about the universal recommendations for vaccination for boys and girls also may hold less stigma about HPV vaccination, as they may perceive HPV vaccination as a routine part of well child visits for boys and girls alike.

With initial evidence supporting the use of the HPV-KQ to measure HPV knowledge, a number of future directions exist. An important extension will be to conduct additional validation studies, including comparing parent performance on the HPV-KQ with existing HPV knowledge measures. Additional validation studies that compare parent performance on the HPV-KQ to existing HPV knowledge scales would be useful. In addition, administering the HPV-KQ to adolescents and young adults would be an important extension. Adolescents, particularly early and middle adolescents, often have been excluded from research on vaccine decision-making.[53-55] Investigating what adolescents know about HPV and the HPV vaccine and identifying effective ways to provide developmentally appropriate information would be worthy goals of future research. Use of the scale to explore whether there are socio-demographic differences in knowledge (eg, gender, race, and ethnicity-related differences; differences across geographic areas) also may be useful in efforts to target particular groups or places for HPV information campaigns. In addition, greater understanding is needed of the role that HPV knowledge plays in HPV decision-making. Innovative mobile interventions are under development[56,57] that use technology to increase HPV knowledge and promote positive attitudes toward vaccination. Robust knowledge scales will continue to play an important role in measuring changes in HPV knowledge as part of discrete interventions. Knowledge scales also are critical to measure changes in HPV knowledge over time as we continue to make progress towards high HPV vaccination coverage and the eradication of HPV-associated cancers.

Human Subjects Approval Statement

The study protocol was approved by the Duke University Health System Institutional Review Board (IRB) (Pro00101137) and the University of South Carolina IRB (Authorization agreement for reliance on DUHS IRB; Pro00085811). Because the US Centers for Disease Control and Prevention (CDC) only had access to de-identified data, it was determined that the CDC was not engaged in human subjects research and CDC's IRB approval was not required.

An implied consent script, presented at the beginning of the Web-based survey, communicated the survey purpose and the contact information of the study's principal investigator. Responses to all survey questions beyond an initial eligibility screen were optional.

Conflict of Interest Disclosure Statement

EBW is an investigator for Pfizer and an unfunded investigator for Moderna vaccine studies. All other authors have no conflicts of interests to declare.

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Supplemental Table 1

Full Regression Models Predicting Adolescent Uptake of ≥ 1 Dose of the HPV Vaccine by 13-item HPV-KQ Total Score for Total Sample and by Provider Recommendation Status

Key knowledge variable: 13-item HPV-KQ Outcome variable: Adolescent uptake of > 1 dose of the HPV vaccine							
		Model 1		Model 2		Model 3	
		All parents (N=1105)		Parents reporting no provider recommendation (N=593)		Parents reporting provider recommendation (N=510)	
Predictor Variables		**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**
Parental HPV knowledge	*Total Score on 13-item* HPV-KQ	1.22 (1.17,1.27)	**< .001**	1.06 (0.98,1.15)	.12	1.08 (1.02,1.14)	**.01**
Adolescent's race and ethnicity (*vs white, non-Hispanic*)	*Hispanic*	1.41 (0.67,2.96)	.36	1.01 (0.34,3.01)	.98	1.35 (0.6,3.02)	.47
	Non-Hispanic black or African-American	1.46 (0.74,2.87)	.27	2.25 (1.02,4.96)	**.05**	1.52 (0.55,4.16)	.42
	Non-Hispanic other	0.8 (0.56,1.16)	.24	1.3 (0.27,6.31)	.74	0.55 (0.31,1)	**.05**
Adolescent gender (*female vs male or other*)		1.14 (0.84,1.54)	.41	1.91 (0.73,4.98)	.19	0.64 (0.47,0.86)	.003
Adolescent's age	*In years*	1.45 (1.36,1.53)	**< .001**	1.27 (1.11,1.45)	**< .001**	1.34 (1.27,1.41)	**< .001**
Adolescent's type of school	*Home/Online school vs Public School*	0.22 (0.1,0.49)	**< .001**	0 (<0.001, <0.001)	**< .001**	0.15 (0.06,0.38)	**< .001**
	Other School vs Public School	1.14 (0.6,2.17)	.68	2.13 (0.5,9.16)	.31	1.34 (0.7,2.57)	.37
Parent's employment status	*Working vs Not working or other*	0.44 (0.22,0.87)	**.02**	0.59 (0.18,1.99)	.40	0.29 (0.14,0.61)	**.001**
Travel time to regular healthcare provider	*< 15 minutes vs > 15 minutes*	1.69 (1.33,2.15)	**< .001**	1.83 (0.72,4.63)	.20	2 (1.29,3.09)	**.002**
Healthcare visit for adolescent in past 12 months	*Yes vs No/Other*	2.32 (1.29,4.16)	**.005**	0.53 (0.08,3.5)	.51	1.75 (0.71,4.32)	.23
	Degrees of Freedom	**11**		**11**		**11**	
	-2 Log L	**1099.2**		**153.9**		**560.9**	

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Supplemental Table 2

Full Regression Models Predicting Adolescent Uptake of ≥ 1 dose of the HPV Vaccine by 7-item HPV-KQ Factor 1 Score and 3-item HPV-KQ Factor 2 Score for Total Sample and by Provider Recommendation Status

Key knowledge variable: 13-item HPV-KQ Outcome variable: Adolescent uptake of > 1 dose of the HPV vaccine							
		Model 1		Model 2		Model 3	
		All parents (N=1105)		Parents reporting no provider recommendation (N=593)		Parents reporting provider recommendation (N=510)	
Predictor Variables		**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**	**OR (95% CI)**	**p value**
Parental HPV knowledge factor 1	7-item HPV-KQ Factor 1	1.1 (0.97,1.26)	.15	0.84 (0.68,1.04)	.11	0.98 (0.9,1.06)	.58
Parental HPV knowledge factor 2	3-item HPV-KQ Factor 2	1.63 (1.21,2.18)	**.001**	1.67 (0.91,3.07)	.10	1.32 (1.06,1.64)	**.01**
Adolescent's race and ethnicity (vs white, non-Hispanic)	Hispanic	1.39 (0.68,2.83)	.37	1.1 (0.38,3.16)	.86	1.27 (0.6,2.72)	.53
	Non-Hispanic black or African-American	1.38 (0.7,2.75)	.35	2.16 (0.88,5.28)	.09	1.46 (0.53,4.02)	.46
	Non-Hispanic other	0.9 (0.6,1.34)	.6	1.66 (0.39,7.08)	.49	0.59 (0.34,1.03)	.06
Adolescent gender *(female vs male or other)*		1.23 (0.9,1.68)	.19	2.07 (0.72,5.99)	.18	0.71 (0.53,0.94)	**.02**
Adolescent's age	*In years*	1.44 (1.35,1.54)	**< .001**	1.25 (1.11,1.4)	**< .001**	1.34 (1.27,1.42)	**< .001**
Adolescent's type of school	*Home/Online school vs Public School*	0.22 (0.11,0.47)	**< .001**	0 (<0.001, <0.001)	**< .001**	0.15 (0.06,0.38)	**< .001**
	Other School vs Public School	1.17 (0.62,2.2)	.628	2.08 (0.45,9.54)	.35	1.41 (0.74,2.7)	.3
Parent's employment status	*Working vs Not working or other*	0.45 (0.23,0.87)	**.02**	0.64 (0.19,2.19)	.48	0.29 (0.13,0.62)	**.001**
Travel time to regular healthcare provider	*< 15 minutes vs > 15 minutes*	1.69 (1.36,2.09)	**< .001**	1.73 (0.67,4.49)	.26	2.03 (1.36,3.03)	**.001**
Healthcare visit for adolescent in past 12 months	*Yes vs No/Other*	2.51 (1.54,4.07)	**< .001**	0.56 (0.1,3.24)	.51	1.79 (0.73,4.38)	.20
	Degrees of Freedom	**12**		**12**		**12**	
	-2 Log L	**1101.9**		**150.4**		**560.2**	