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Knowledge gaps in human papillomavirus infection and vaccination among Polish medical students: an item-level cross-sectional analysis with an embedded feasibility evaluation of a multidisciplinary educational webinar

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Research Article

Keywords: Human papillomavirus, HPV vaccination, Medical students, Undergraduate medical education, Knowledge assessment, Item analysis, Curriculum development, Feasibility study, Health equity, Poland

Posted Date: November 16th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11341781/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Poland introduced universal adolescent human papillomavirus (HPV) vaccination only in June 2023, and coverage remains low. Because clinicians' recommendations strongly influence uptake, future physicians' preparedness matters. Polish studies report aggregate scores, which cannot show which facts are missing and so cannot guide curricular change. We mapped fourth-year medical students' baseline HPV knowledge at item level and assessed the feasibility of a multidisciplinary educational module.

Methods

In February 2024, within the Horizon 2020 project RIVER-EU, we conducted a cross-sectional knowledge assessment with an embedded single-arm pre–post feasibility component at the University of Zielona Góra, Poland. All 96 fourth-year students, none of whom had begun the infectious-diseases course, were invited to a voluntary five-hour expert-led webinar. A 20-item single-choice questionnaire was administered immediately before and after. The primary outcome was item difficulty; analyses comprised Wilson 95% confidence intervals, corrected item–total correlations, Kuder–Richardson Formula 20 (KR-20) with KR-20-if-item-deleted, and McNemar's exact test with Bonferroni–Holm correction. Reporting follows TREND.

Results

Fifty-four of 96 invited students (56.2%) provided complete paired data: 37 women, 17 men. Mean baseline score was 13.19/20 (SD 3.76); KR-20 0.79. Performance varied more than fivefold across items (18.5–98.1%), so the mean concealed the educationally relevant pattern. Four items were answered correctly by half the cohort or fewer: cervical cancer as an uncommon individual outcome of infection (18.5%), the cervical cancer burden in Ukraine (20.4%), the vaccines' registered age (35.2%) and adult schedules (50.0%). All four discriminated acceptably (corrected item–total r 0.23–0.44), so none is an artifact of item construction. Natural history and epidemiology was the weakest domain (50.0%), virology and vaccine science the strongest (77.0%); sexes did not differ ($p = 0.27$). All 54 subsequently scored 20/20, but this ceiling, on an immediate unproctored post-test, is uninterpretable as learning.

Conclusions

Deficits concentrated in the applied and epidemiological content of HPV prevention - eligibility, age indications, dose schedules and individual cancer risk after infection not in the biology of the virus or its

vaccines. The module was feasible to deliver and evaluate; controlled studies with proctored, delayed assessment are needed before claiming effectiveness.

Background

Human papillomavirus (HPV) is among the most common sexually transmitted pathogens. Most sexually active people acquire HPV at some point in life; most infections clear spontaneously, but persistent infection with high-risk oncogenic types can progress to malignancy [1]. HPV 16 and 18 account for most cervical cancers [2], and HPV is causally associated with a substantial proportion of anal, penile, vaginal, vulvar, and oropharyngeal cancers, as well as with anogenital warts [1, 2].

Prevention rests on vaccination and screening [3]. Population-level analyses show that vaccination programs markedly reduce HPV infection, high-grade precancerous lesions and, in settings with sufficient follow-up, invasive cervical cancer, with additional herd effects among unvaccinated individuals [1, 4].

Poland launched a universal, publicly funded HPV vaccination program for adolescents in June 2023, targeting girls and boys aged 12 and 13 years, using the bivalent and nonavalent vaccines [5]. This was considerably later than in most European Union countries, and uptake has remained well below the level required for population impact [5, 6]. Public understanding of the program is limited: in a nationwide survey of 1056 adults conducted shortly after the launch, 51.3% had heard of the free vaccination program and only 31.9% correctly identified girls and boys aged 12 and 13 years as the eligible population [6]. Awareness among parents is similarly incomplete [7, 8].

In this context, the physician's recommendation is decisive, since it is among the strongest predictors of a parent's or patient's decision to vaccinate [7, 9]. Adequate knowledge among current and future physicians is therefore a precondition for effective vaccination promotion. Existing Polish studies of medical students describe overall knowledge as moderate and compare students across faculties [10, 11], but they were not designed to identify which specific, teachable facts are missing. This distinction matters practically. An aggregate score of, say, 64% correct is compatible with uniformly partial understanding across the whole topic and with near-complete mastery of the biology alongside near-total ignorance of the vaccination schedule; the two situations call for entirely different curricular responses, and only an item-level analysis can tell them apart.

International work suggests that the deficits are not uniformly distributed. In a multi-institution study of 718 US medical students, 92.8% linked HPV to cervical cancer, but far fewer recognized its role in vaginal or vulvar (67.7%), anal (63.3%) and penile (53.9%) cancers, and only 33.3% correctly identified the age of vaccine eligibility [12]. Comparable patterns have been reported elsewhere [13, 14]. If Polish deficits follow a comparable structure, then general exhortations to teach more about HPV are unlikely to be efficient, whereas targeted curricular changes might be.

An additional consideration applies in the Polish setting. This study was conducted within RIVER-EU, a Horizon 2020 project addressing health-system barriers to measles–mumps–rubella (MMR) and HPV vaccination in underserved communities, whose Polish work stream concerns Ukrainian economic migrants and refugees [15, 16]. Poland hosts a large Ukrainian population, and physicians trained in Poland will counsel patients whose vaccination history, screening experience, and background cervical cancer risk were determined by a different health system. Preparedness for that task is a distinct educational requirement, and one aspect of it - knowledge of the cervical cancer burden in Ukraine - was included in the assessment reported here.

A review of the medical program syllabi at the Collegium Medicum of the University of Zielona Góra, conducted by the authors, indicates that HPV and preventive vaccination are addressed across several subjects rather than within a single coherent module. It also shows that comparatively little attention is given to the practical aspects of assessing vaccine eligibility, communicating with patients, countering vaccine hesitancy, and organizing population-level vaccination programs.

The primary aim of this study was therefore to map, at item level, the baseline knowledge of fourth-year Polish medical students regarding HPV infection and HPV vaccination to identify specific, actionable curricular targets and to characterize the measurement properties of the instrument used. A secondary, exploratory aim was to assess the feasibility of delivering a structured, multidisciplinary, expert-led educational program alongside the existing curriculum and collecting paired knowledge data.

Methods

Study design and reporting

This was a cross-sectional knowledge assessment with an embedded single-arm pre–post feasibility component, conducted within the RIVER-EU project [15]. The primary analysis is cross-sectional and descriptive: it characterizes baseline knowledge at item level. The study had no control group and was neither designed nor powered to estimate the effect of teaching on knowledge; the pre–post component aimed to establish deliverability and data-collection procedures ahead of a future controlled evaluation. The manuscript follows the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) statement [17]; a completed checklist is provided as Additional file 1.

Setting and participants

We conducted the study on 24 February 2024 among fourth-year medical students at Collegium Medicum, University of Zielona Góra, Poland. All 96 fourth-year students were invited. We selected this cohort because, under the curriculum, these students had not yet begun the infectious diseases lecture cycle, so their knowledge reflected earlier teaching in the program rather than immediate prior instruction on the topic. All participants were adults.

Both webinar attendance and study participation were voluntary. The webinar was offered on a Saturday, outside the compulsory timetable, and carried no course credit. Before entering the study, participants were informed about its aim, procedures and rules of participation, and each provided informed consent. We emphasized that participants could withdraw at any time, without giving a reason and without consequences.

Educational intervention

The intervention was a structured five-hour educational webinar delivered online in a single session by six experts in virology, epidemiology, infectious diseases, pediatrics, gynecological oncology, and vaccinology. It was organized into six sequential, expert-led blocks covering the etiology and epidemiology of HPV infection, mechanisms of oncogenesis, the clinical course of infection, HPV vaccines, vaccination schedules across age groups, and the rules governing vaccination eligibility. It also addressed the organization of vaccination in Poland and the role of vaccination in preventing HPV-related cancers. The format was predominantly didactic, with time for questions to the experts. Each of the six blocks was 40 minutes, followed by a 10-minute discussion.

Study instrument

The instrument comprised 20 single-choice items assessing knowledge of HPV infection, HPV-associated diseases, HPV vaccines, vaccination schedules, and preventive strategies, one of which concerned the age of the first MMR dose in the Polish immunization schedule, reflecting that RIVER-EU addresses both MMR and HPV vaccination [15]. The expert teaching team wrote all 20 items de novo, informed by the published literature [3, 10–14]. The item on the cervical cancer burden in Ukraine was based on the Bulletin of the National Cancer Registry of Ukraine (2022) [18]. Each item had four response options and a single keyed answer, and was scored as correct or incorrect, giving a total score from 0 to 20. For analysis and interpretation, the authors assigned the 20 items post hoc, by consensus, to five content domains: natural history and epidemiology of HPV infection; vaccination schedules and eligibility; program organization and the professional and legal framework of vaccination; virology and vaccine science; and effectiveness of primary and secondary prevention. This grouping was descriptive and was not used for any inferential test. The full questionnaire, in the original Polish and in English translation, together with the scoring key and the sources of the factual answers, is provided as Additional file 2.

We conducted a pilot study with 11 graduates of the Faculty of Medicine of the Collegium Medicum, University of Zielona Góra, who were not among the 96 students invited to the main study, to test the clarity and completeness of the items. We incorporated suggestions from the pilot before launching the study.

Data collection

We administered the questionnaire online immediately before and immediately after the webinar. We limited completion time to 20 minutes on each occasion, about one minute per item on average. Neither administration was proctored, and no measures prevented participants from consulting materials, external sources, or one another during the post-test. Only students who completed both administrations contributed data to the analysis. Responses were scored from the recorded answer options against the key reproduced in Additional file 2; the totals so obtained agreed with the automatic score generated by the online form for all 54 respondents. Because every post-intervention total score equaled the maximum, the post-intervention result for each individual item follows from the total scores.

The online form recorded each respondent's name, which was used to link the pre- and post-intervention records at the individual level. We then de-identified the linked dataset and performed all statistical analyses on anonymized data with names removed.

Statistical analysis

All analyses were performed in R version 4.5.0. We included only complete paired datasets; we performed no imputation.

The primary outcome was the item-difficulty index, defined as the proportion of correct responses per item before the intervention. Items were ranked by difficulty and reported with exact numerators and denominators and with 95% Wilson score confidence intervals, which are preferred to the normal approximation at proportions close to 0 or 1 [19]. We calculated descriptive statistics for the total score (mean, standard error of the mean, median, minimum, maximum, standard deviation, range, skewness, and excess kurtosis).

We examined the instrument's measurement properties in three ways. Internal consistency was assessed on the pre-intervention responses using the Kuder–Richardson Formula 20 (KR-20), the form of Cronbach's alpha appropriate for dichotomously scored items [20]. For each item, discrimination was quantified as the corrected item–total correlation (the point-biserial correlation between the item and the total score computed with that item excluded) and as the difference in the proportion correct between the highest- and lowest-scoring 27% of the cohort; values of the corrected item–total correlation below 0.20 were regarded as unsatisfactory, following conventional criteria for post-examination item analysis [21]. KR-20 was additionally recomputed with each item deleted in turn, so that items degrading the internal consistency of the instrument could be identified.

We performed two pre-specified sensitivity analyses: one excluding the MMR item so the total score reflected HPV content only, and one excluding any item found to discriminate unsatisfactorily. We added one post hoc analysis excluding item 1, for the reason set out in the Results.

Secondary outcomes concerned change between the two administrations. We assessed normality of the pre-intervention score distribution with the Shapiro–Wilk and Jarque–Bera tests; neither rejected

normality (Shapiro–Wilk W = 0.966, p = 0.12; Jarque–Bera p = 0.36), so we used the paired Student's t-test for total scores. As set out at the end of this section, the post-intervention variance was zero, so this comparison is degenerate in any formulation and is reported descriptively rather than as an estimate of effect. We used an independent-samples t-test to compare women and men before the intervention. Changes in the proportion of correct answers to individual items were analyzed with McNemar's test using exact two-sided p-values derived from the binomial distribution, with the Bonferroni–Holm correction applied across the 20 items to control the family-wise type I error rate.

Because all participants obtained the maximum score after the intervention, the post-intervention scores had zero variance. Under this condition, the paired t-test is algebraically equivalent to a one-sample t-test of the pre-intervention scores against the constant value of 20; both formulations yield the same test statistic and p-value, which are reported accordingly. No standardized effect size is reported for this comparison because, with zero post-intervention variance, the design determines the estimate rather than the data. The interpretive consequences of this ceiling are addressed in the Discussion.

Results

Participants

Of 96 invited students, 54 attended the webinar and completed the pre-intervention questionnaire (56.2%). All 54 also completed the post-intervention questionnaire, so no participant was lost after enrollment, and all 54 contributed complete paired data to the analysis. The remaining 42 invited students did not attend the voluntary Saturday session and therefore did not enter the study; because participation was anonymous at the point of analysis, no characteristics of these students were available. The analyzed group comprised 37 females (68.5%) and 17 males (31.5%). Age was not recorded; all participants were fourth-year students and therefore within a narrow age band, but the lack of exact ages is a limitation.

Distribution of baseline knowledge

The mean pre-intervention score was 13.19/20 (SEM 0.51; 95% CI 12.16–14.21; median 14; SD 3.76), with a minimum of 4 and a maximum of 20 (range 16). This corresponds to 65.9% correct answers, or an overall baseline error rate of 34.1%: on average, about one answer in three was incorrect before teaching. The distribution of total scores was mildly left-skewed (skewness − 0.43) and slightly platykurtic (excess kurtosis − 0.36), with a standard deviation of approximately 19% of the maximum score. Two of the 54 students (3.7%) answered every item correctly before the intervention. Table 1 summarizes the descriptive statistics.

Table 1
Distribution of total HPV knowledge scores before the educational intervention (Zielona Góra, Poland, February 2024; n = 54).

Statistic	Overall (n = 54)	Women (n = 37)	Men (n = 17)
Mean score (of 20)	13.19	13.57	12.35
Mean, % of maximum	65.9	67.8	61.8
Standard error of the mean	0.51	0.61	0.94
95% confidence interval for the mean	12.16–14.21	12.34–14.80	10.36–14.34
Median	14	14	13
Standard deviation	3.76	3.69	3.87
Minimum/maximum	4 / 20	6 / 20	4 / 18
Range	16	14	14
Skewness	−0.43	−0.42	−0.49
Excess kurtosis	−0.36	−0.32	−0.36
Internal consistency (KR-20)	0.79	—	—

Women vs. men before the intervention: independent-samples t-test, t = 1.11, df = 52, p = 0.274; 95% confidence interval for the difference in means − 0.99 to 3.42. KR-20 excluding the MMR item (19 HPV items) = 0.78. KR-20, Kuder–Richardson Formula 20.

Women scored higher than men on average (13.57 ± 3.69 vs 12.35 ± 3.87), but the difference was small and not statistically significant (independent-samples t-test, t = 1.11, df = 52, p = 0.274; 95% CI for the difference − 0.99 to 3.42).

Item-level knowledge gaps

Baseline knowledge varied widely across the questionnaire. The proportion of correct answers varied by more than fivefold between items, from 18.5% to 98.1% (Fig. 1; Table 2), so the mean total score conceals the educationally relevant pattern.

Table 2

Item-level baseline difficulty and discrimination, ranked from the most to the least difficult item (n = 54).

Item	Content of the item	Domain	Correct before, n (%)	95% CI (%)	Corrected item–total r	D_{27}	KR-20 if deleted
13	Cervical cancer is an uncommon individual outcome of HPV infection	NH	10 (18.5)	10.4–30.8	0.40	0.53	0.774
20	New cervical cancer cases in Ukraine, 2020	NH	11 (20.4)	11.8–32.9	0.35	0.53	0.777
16	Age from which program vaccines are registered (girls and boys)	SE	19 (35.2)	23.8–48.5	0.23	0.47	0.786
7	Adult schedules: 18–26 years versus 27–49 years	SE	27 (50.0)	37.1–62.9	0.44	0.73	0.770
10	Most HPV infections resolve spontaneously	NH	29 (53.7)	40.6–66.3	0.52	0.67	0.764
15	HPV programs across EU countries and Poland's position	PO	31 (57.4)	44.2–69.7	0.45	0.60	0.769
1	Number of oncogenic HPV types currently recognized	VS	33 (61.1)	47.8–73.0	0.44	0.60	0.771
17	Relative risk reduction after vaccination at 12–13 years (~ 87%)	EP	33 (61.1)	47.8–73.0	0.13	0.33	0.793
12	Proportion of cervical cancers associated with HPV (~ 99%)	NH	36 (66.7)	53.4–77.8	0.38	0.53	0.775

Domains: NH, natural history and epidemiology of HPV infection; SE, vaccination schedules and eligibility; PO, program organization and professional framework; VS, virology and vaccine science; EP, effectiveness of prevention. CI, Wilson score confidence interval. Corrected item–total r, point-biserial correlation between the item and the total score computed with that item excluded; values below 0.20 are conventionally regarded as unsatisfactory [21]. D_{27}, difference in the proportion correct between the highest- and lowest-scoring 27% of the cohort (15 students in each group). KR-20 if deleted: internal consistency of the remaining 19 items (whole-instrument KR-20 = 0.79). Item wording is abbreviated; Additional file 2 provides the full questionnaire and scoring key, and Additional file 3 provides the before–after comparison for each item.

Item	Content of the item	Domain	Correct before, n (%)	95% CI (%)	Corrected item–total r	D_{27}	KR-20 if deleted
18	Age of the first MMR dose in the Polish immunization schedule	PO	37 (68.5)	55.3–79.3	0.27	0.53	0.782
4	Why vaccination induces a stronger response than natural infection	VS	39 (72.2)	59.1–82.4	0.17	0.47	0.789
5	Only an appropriately qualified physician may assess eligibility	PO	40 (74.1)	61.1–83.9	0.37	0.53	0.775
14	Cervical cancer is preventable by primary and secondary prevention	EP	41 (75.9)	63.1–85.4	0.32	0.33	0.779
3	The main vaccine antigen is the virus-like particle	VS	42 (77.8)	65.1–86.8	0.51	0.53	0.767
6	Vaccinating without required qualifications has legal consequences	PO	43 (79.6)	67.1–88.2	0.22	0.33	0.785
8	Who is authorized to administer vaccines	PO	45 (83.3)	71.3–91.0	0.24	0.27	0.783
2	E6 and E7 proteins drive the cell cycle and uncontrolled cell division	VS	47 (87.0)	75.6–93.6	0.25	0.27	0.783
19	Cervarix is a bivalent vaccine	VS	47 (87.0)	75.6–93.6	0.60	0.47	0.765

Domains: NH, natural history and epidemiology of HPV infection; SE, vaccination schedules and eligibility; PO, program organization and professional framework; VS, virology and vaccine science; EP, effectiveness of prevention. CI, Wilson score confidence interval. Corrected item–total r, point-biserial correlation between the item and the total score computed with that item excluded; values below 0.20 are conventionally regarded as unsatisfactory [21]. D_{27}, difference in the proportion correct between the highest- and lowest-scoring 27% of the cohort (15 students in each group). KR-20 if deleted: internal consistency of the remaining 19 items (whole-instrument KR-20 = 0.79). Item wording is abbreviated; Additional file 2 provides the full questionnaire and scoring key, and Additional file 3 provides the before–after comparison for each item.

Item	Content of the item	Domain	Correct before, n (%)	95% CI (%)	Corrected item–total r	D_{27}	KR-20 if deleted
9	Most people acquire HPV at some point in their lives	NH	49 (90.7)	80.1–96.0	0.43	0.33	0.774
11	Unvaccinated sexually active adolescents may still be vaccinated	SE	53 (98.1)	90.2–99.7	0.31	0.07	0.783

Domains: NH, natural history and epidemiology of HPV infection; SE, vaccination schedules and eligibility; PO, program organization and professional framework; VS, virology and vaccine science; EP, effectiveness of prevention. CI, Wilson score confidence interval. Corrected item–total r, point-biserial correlation between the item and the total score computed with that item excluded; values below 0.20 are conventionally regarded as unsatisfactory [21]. D_{27}, difference in the proportion correct between the highest- and lowest-scoring 27% of the cohort (15 students in each group). KR-20 if deleted: internal consistency of the remaining 19 items (whole-instrument KR-20 = 0.79). Item wording is abbreviated; Additional file 2 provides the full questionnaire and scoring key, and Additional file 3 provides the before–after comparison for each item.

Four of the 20 items were answered correctly by half the cohort or fewer, and all four had sound measurement properties, so each can be read as a genuine knowledge deficit. The weakest concerned the interpretation of cervical cancer as an uncommon individual outcome of HPV infection (item 13; 10/54, 18.5%, 95% CI 10.4–30.8) and the number of new cervical cancer cases recorded in Ukraine (item 20; 11/54, 20.4%, 95% CI 11.8–32.9). These were followed by the age from which the vaccines used in the national immunization program are registered (item 16; 19/54, 35.2%, 95% CI 23.8–48.5) and the recommended schedules for vaccination in adults, including the distinction between the 18–26 and 27–49 year age bands (item 7; 27/54, 50.0%, 95% CI 37.1–62.9).

A further group of items fell between 50% and 70% correct: spontaneous clearance of HPV infection (item 10; 53.7%), the status of HPV programs across EU countries and Poland's late position among them (item 15; 57.4%), the magnitude of relative risk reduction after vaccination at ages 12–13 (item 17; 61.1%), the number of oncogenic HPV genotypes currently recognized (item 1; 61.1%), the proportion of cervical cancers attributable to HPV (item 12; 66.7%) and the age of the first MMR dose (item 18; 68.5%).

At the opposite end of the range, students performed well on items concerning the mechanisms of HPV oncogenesis, vaccine composition, and the professional framework of vaccination. The possibility of vaccinating unvaccinated but sexually active adolescents (item 11; 98.1%), the lifetime probability of acquiring HPV (item 9; 90.7%), the oncogenic role of the E6 and E7 proteins (item 2; 87.0%), and the bivalent composition of one of the licensed vaccines (item 19; 87.0%) were the four easiest items. Items on who may assess eligibility for and administer vaccination, and on the consequences of doing so without the required qualifications (items 5, 6, and 8), were answered correctly by 74.1%, 79.6%, and 83.3%, respectively.

The domain-level summary (Table 3) shows the same pattern in aggregate. Natural history and epidemiology was the weakest domain (50.0% of responses correct, 95% CI 44.1–55.9), followed by vaccination schedules and eligibility (61.1%, 95% CI 53.4–68.3). Virology and vaccine science was the strongest (77.0%, 95% CI 71.7–81.7), with program organization and the professional framework close behind (72.6%, 95% CI 67.0–77.6). The pattern is therefore one of comparatively secure knowledge of how the virus and the vaccines work, and of the rules governing who may vaccinate, alongside insecure knowledge of the epidemiological context of infection and of the operational content of the vaccination schedule itself.

Table 3
Baseline performance by content domain.

Content domain	Items	Correct responses / total	Correct (%)	95% CI (%)
Natural history and epidemiology	5	135/270	50.0	44.1–55.9
Vaccination schedules and eligibility	3	99/162	61.1	53.4–68.3
Effectiveness of prevention	2	74/108	68.5	59.3–76.5
Program organization and professional framework	5	196/270	72.6	67.0–77.6
Virology and vaccine science	5	208/270	77.0	71.7–81.7

Domains are ordered from weakest to strongest. Each item contributes 54 responses. Authors assigned items to domains post hoc by consensus and did not use this assignment for inferential testing; these figures are for orientation only. CI, Wilson score confidence interval. Item 1 (number of oncogenic HPV types) is included in the virology and vaccine science domain; excluding it, that domain stands at 81.0% (175/216).

Measurement properties of the instrument

Internal consistency was acceptable (KR-20 = 0.79), indicating that the items measured a common underlying construct to a satisfactory degree and supporting the use of the summed score as an overall measure. Excluding the MMR item, so that the score reflected HPV content only, gave a mean of 12.50 of 19 (SD 3.60; 65.8% correct) and KR-20 = 0.78; the difficulty ranking of the remaining items and every conclusion drawn from it were unchanged.

The corrected item–total correlation was positive for every item and had a median of 0.36 across the 20 items (Table 2; Fig. 2). Two items fell below the conventional threshold of 0.20: the magnitude of risk reduction after vaccination at ages 12–13 (item 17; 0.13) and the reason vaccination induces a stronger response than natural infection (item 4; 0.17). Both are among the easier items, so neither bears on the deficits reported above; each of the four items answered correctly by half the cohort or fewer discriminated acceptably (0.23–0.44). No single item degraded the internal consistency of the instrument materially: deleting items one at a time left KR-20 between 0.76 and 0.79, and no deletion

raised it by more than 0.01. Excluding items 4 and 17 together gave a mean of 11.85 of 18 (SD 3.55) and KR-20 = 0.80, without altering the ranking or interpretation of the remaining items.

One item requires comment on its frame of reference rather than on student performance. Item 1 asked how many oncogenic HPV types are currently recognized; the keyed answer was sixteen, and 33 of 54 students (61.1%) selected it. The next most frequent choice was fourteen (12/54, 22.2%), the number of high-risk genotypes targeted by validated clinical assays, followed by eighteen (7/54, 13.0%) and twenty (2/54, 3.7%). Published counts of oncogenic genotypes differ with the classification adopted — the International Agency for Research on Cancer designates twelve genotypes as Group 1 carcinogens, while clinical and applied sources commonly cite wider panels — so the item is answerable only against a stated reference standard. The item discriminated acceptably in this cohort (corrected item–total r = 0.44), and excluding it altered nothing: the mean became 12.57 of 19 (66.2% correct) with KR-20 = 0.77, and the difficulty ranking of the remaining items was unchanged. The item should name the classification it refers to before the instrument is reused.

Immediate post-intervention performance and feasibility

After the webinar, all 54 participants achieved the maximum score, so the post-intervention standard deviation was zero. The paired comparison of total scores — equivalent here to a one-sample test of pre-intervention scores against the maximum of 20 — indicated that post-intervention performance was significantly higher than pre-intervention performance ($t = 13.33$; $df = 53$; $p < 0.0001$). At the item level, the proportion of correct answers rose to 100% for every item, from a baseline range of 18.5% to 98.1% (Fig. 3). After Bonferroni–Holm correction, the improvement was statistically significant for 16 of the 20 items (Additional file 3). The four items that did not reach significance after correction (items 2, 9, 11, and 19) were already answered correctly by 87.0% to 98.1% of students at baseline, leaving little room for measurable change.

No adverse or unintended effects of participation were observed or reported.

These post-intervention results are reported for completeness and as evidence that the program could be delivered and the paired data collected as planned. As set out in the Discussion, the uniform maximum score is a property of the assessment conditions and does not support an inference about how much was learned.

Discussion

Principal findings

Fourth-year Polish medical students entered the study with a moderate mean level of knowledge about HPV, but the mean is the least informative feature of these data. Performance ranged from 18.5% to 98.1% correct across items, and the gaps were not randomly distributed. Students were secure on the mechanisms of oncogenesis, on vaccine composition, and on the professional and legal framework of

who may vaccinate, and insecure on the epidemiology of infection and on the operational content of the vaccination schedule — the age from which the program vaccines are registered, the rules for vaccinating adults, and how the individual risk of cancer following infection should be understood. These are precisely the facts a clinician needs to answer a parent's or a patient's question at the point of care.

The item analysis supports that reading in a way an aggregate score cannot. Each of the four items identified as a deficit correlated acceptably with the rest of the instrument (corrected item–total r 0.23–0.44), so none of them can be set aside as an artifact of ambiguous wording, and the content they identify can be taught against with some confidence. The two items that did discriminate weakly (items 4 and 17) are among the easier ones and carry none of the conclusions. Reporting difficulty without discrimination leaves a curriculum committee unable to make that distinction.

We delivered the intervention as planned and obtained paired data from every participating student, establishing feasibility. However, all 54 participants scored 20/20 on an unproctored post-test administered immediately after teaching, and this result is uninterpretable as a measure of learning.

The deficits in context

The most consequential finding concerns the national program's age indications. Only 35.2% of these fourth-year medical students answered this item correctly, eight months after the program launched nationwide. In a nationwide survey of Polish adults conducted shortly after the launch, 31.9% correctly identified girls and boys aged 12 and 13 years as the population eligible for free vaccination [6]. The two questions are related but not identical — ours addressed the age from which the vaccines used in the program are registered, theirs the age band actually invited — and the instruments, response formats, and populations differ. Hence, the comparison is indicative rather than formal, and no statistical test between them is appropriate. Even so, it is difficult to read the two figures together without concluding that these future physicians were, on the program's operational parameters, no better informed than the public they will advise. Given that the physician's recommendation is among the strongest determinants of vaccination decisions [7, 9], this gap has direct consequences for coverage.

This pattern closely resembles what has been reported internationally. In a multi-institution study of 718 US medical students, only 33.3% correctly identified the age of vaccine eligibility and 48.1% the number of doses required, while 92.8% knew that HPV causes cervical cancer [12]. Our students likewise performed better on the aetiological link than on schedule and eligibility. The convergence between two health systems with very different vaccination histories suggests the deficit is a structural feature of how HPV is taught — as a topic in virology and oncology rather than as a clinical procedure — rather than a peculiarity of any one curriculum. Our syllabus review supports this interpretation: HPV content is spread across several subjects, with limited attention to eligibility assessment, communication, and program organization.

Item 13 — cervical cancer as an uncommon individual consequence of HPV infection — was the single hardest item, with only 18.5% correct, and it discriminated well (corrected item–total r = 0.40), so the low

score is unlikely to be an artifact of ambiguous wording. The two commonest incorrect options were each selected by 20 of 54 students: that HPV 18 is the genotype most often responsible for cervical cancer, and a compound statement whose first clause (infection is usually acquired soon after sexual debut) is correct but whose second clause (infection usually becomes persistent) is not. The most plausible reading is a genuine misconception in which the very high population attributable fraction of HPV in cervical cancer is conflated with a high individual risk of cancer following infection. That conflation matters clinically: it is the distinction a clinician must make when reassuring an anxious patient with a positive HPV test and explaining why screening, rather than alarm, is the appropriate response. The finding that only 53.7% of students knew that most HPV infections resolve spontaneously (item 10) points in the same direction. Even so, the word ‘rare’ in the keyed option may have seemed inconsistent with the strong causal message delivered elsewhere in the curriculum, and the wording should be reconsidered before reusing the instrument.

Awareness of the wider spectrum of HPV-related disease was also uneven: only 66.7% of students knew the proportion of cervical cancers attributable to HPV at baseline, a figure lower than the 92.8% reported for the simpler aetiological link in the US cohort [12] and one that should not be described as high. Incomplete knowledge of HPV-attributable disease limits the quality of preventive counseling, particularly for the male patients now included in the Polish program.

An observation specific to the Polish setting concerns the cervical cancer burden in Ukraine, which only 20.4% of students identified correctly — the second hardest item in the instrument, and one that discriminated acceptably (corrected item–total r = 0.35). Poland hosts a large Ukrainian population, and the RIVER-EU work stream within which this study was conducted addresses precisely the health-system barriers this community faces [15, 16]. In the parent-facing arm of the same work stream, 59.6% of Ukrainian migrant and refugee parents in Poland had a low level of HPV knowledge [16]; the present data indicate that the clinicians who will counsel them are themselves least secure on exactly this content. Physicians who cannot situate a migrant patient's background risk are poorly placed to counsel on screening or catch-up vaccination. We had not anticipated that this item would rank among the hardest, and the result suggests that the equity dimension of HPV prevention is at present largely absent from the curriculum. We note that this is a single item and that inference from it should be correspondingly cautious; it identifies a hypothesis for larger studies rather than a settled finding.

Our baseline findings are broadly consistent with previous Polish work reporting moderate HPV-related knowledge among medical students [10, 11] and incomplete knowledge among the adult population and parents [6–8]. They extend that literature in two ways: by identifying which specific facts are missing rather than reporting an aggregate score, and by reporting the discrimination properties of each item, which allows genuine deficits to be separated from measurement artifacts.

Interpretation of the post-intervention result

All 54 participants scored 20/20 immediately after teaching. We do not interpret this as evidence that the intervention produced complete mastery, and we caution readers against doing so.

Three design features account for the result. The post-test was administered online, immediately after the session, and without proctoring; participants could have consulted webinar materials, external sources, or one another, and the questionnaire content mapped directly onto material just presented. The resulting zero variance eliminates any differentiation among students, so that the magnitude of the measured change is bounded by the design rather than estimated from it; the associated t-test, although formally significant, is degenerate, and no meaningful standardized effect size can be derived from it. Finally, without a control group, even a well-measured change could not be attributed to the intervention rather than to testing effects or maturation.

What the post-intervention data do support is narrower but not trivial: a five-hour multidisciplinary webinar could be organized alongside an existing curriculum, six experts from different disciplines could be coordinated to deliver it, students engaged with the assessment, and complete paired data were obtained with no attrition between the two administrations. These are the questions a feasibility study is designed to answer, and they inform the design of the controlled trial that should follow. Brief expert-led interventions have improved HPV knowledge, attitudes, and readiness to counsel among medical, nursing, and other health-professional students in the United States [22–24] and among university students in Japan [25], and a single educational lecture has improved vaccine confidence in a Polish setting [26]; a Polish trial in medical students, with a harder proctored post-test and delayed follow-up, would be a reasonable next step.

Strengths and limitations

The main strength of this study is the item-level analysis of a psychometrically characterized instrument (KR-20 = 0.79) administered to a defined cohort at a defined point in training, converting a general impression of moderate knowledge into a specific list of teachable deficits. Reporting item discrimination alongside item difficulty is uncommon in studies of this kind and proved material to the interpretation, since it established that each of the four deficits identified lies in the construct the instrument measures rather than in the wording of a single item. The multidisciplinary composition of the teaching team, spanning virology through gynecological oncology, is also unusual among reported interventions.

The limitations are substantial and constrain the conclusions accordingly. First, the post-intervention assessment was unproctored and immediate; the uniform maximum score reflects performance under highly favorable, possibly assisted, conditions and does not establish independent mastery. Second, the invariant post-intervention score produces a complete ceiling effect, precluding any estimate of effect size or of between-student variation after teaching. Third, there was no control group, so no causal claim can be made about the intervention. Fourth, knowledge was not reassessed after any interval, so retention is unknown.

Fifth, and most important for the baseline map, attendance was voluntary, and the webinar was held on a Saturday outside the compulsory timetable. Hence, the 54 participants (56.2% of those invited) were likely positively selected for interest in vaccination and possibly for academic engagement. The direction

of this bias is predictable: it would tend to overestimate baseline knowledge, and therefore to understate the true extent of the deficits identified. The gaps reported here should thus be read as a conservative estimate. No information was available on the students who did not attend, so the magnitude of the bias cannot be quantified.

Sixth, the sample was modest and drawn from a single university, limiting precision and generalizability to other Polish medical schools; the study was not powered for hypothesis testing, and the item-level analysis should be regarded as descriptive and hypothesis-generating. Confidence intervals around the individual item difficulties are correspondingly wide, and the ranking of adjacent items should not be over-interpreted. Seventh, the instrument was assembled for this study and, apart from internal consistency, item analysis, and pilot testing, has not been formally validated; each item was scored dichotomously with a single keyed answer, and the wording of items 1 and 13 in particular requires revision: item 1 should state the classification against which oncogenic genotypes are to be counted, and item 13 should be reworded so that the keyed option does not turn on the word 'rare'. Eighth, responses were not anonymous at the point of collection, since the online form recorded respondents' names before the dataset was de-identified for analysis; socially desirable responding cannot be excluded, although the knowledge items have objectively correct answers and are less susceptible to it than attitudinal items. Ninth, age was not recorded, and sex was the only participant characteristic available, so the cohort cannot be described as fully as would be conventional. Finally, the authors assigned items to content domains post hoc as a descriptive convenience rather than using a validated structure; the domain figures in Table 3 are for orientation and were not used for inferential testing.

Implications for curriculum design

If this pattern holds in larger, multicenter samples, its curricular implications are specific. Additional teaching on HPV virology and oncogenesis is unlikely to be the most efficient use of scarce curricular time, because students already perform well in that domain. The deficits lie in the applied and epidemiological layer: which age groups are eligible under the national program and from what age the vaccines are registered, how vaccination is handled in adults, how the individual risk of cancer following infection should be explained to a patient, and how to advise patients from migrant communities whose prior exposure to screening and vaccination differs from the Polish norm. This content is procedural and epidemiological rather than mechanistic. It lends itself to short, structured, clinically framed teaching, ideally consolidated in a single module rather than distributed across subjects, and assessed under conditions that allow retention to be demonstrated. The item-level map reported here, together with the published instrument in Additional file 2, is offered as a starting point for such a module and for its evaluation elsewhere.

Conclusions

Fourth-year Polish medical students demonstrated moderate overall knowledge of HPV and HPV vaccination, but with marked and systematic variation across topics. The deficits were concentrated in

the applied and epidemiological aspects of vaccination — age indications, adult dose schedules, the natural history of infection and the individual risk of cancer following it, rather than in the biology of the virus or its vaccines. On the operational parameters of the national program, performance was comparable to that reported for the Polish general public on a related question. Knowledge of the cervical cancer burden in the Ukrainian population that Polish physicians increasingly serve was among the weakest areas of all. Because participation was voluntary, these estimates are likely to be conservative. Item discrimination analysis additionally showed that each of these deficits lies in the construct the instrument measures rather than in the wording of a single item, underlining the value of reporting item-level measurement properties rather than aggregate scores alone. These specific gaps constitute an actionable target for curriculum design.

A structured, multidisciplinary, expert-led webinar proved feasible to deliver alongside the existing curriculum, and we obtained complete paired data from every participant. The uniform maximum score on the immediate post-test reflects unproctored assessment conditions and a ceiling effect and does not demonstrate learning or retention. Controlled studies with proctored assessment, a post-test capable of discriminating above the ceiling, and delayed follow-up are needed before establishing the module's educational effectiveness.

Abbreviations

CI
confidence interval
EU
European Union
HPV
human papillomavirus
KR-20
Kuder–Richardson Formula 20
MMR
measles–mumps–rubella
RIVER-EU
Reducing Inequalities in Vaccine uptake in the European Region – Engaging Underserved communities
SD
standard deviation
SEM
standard error of the mean
TREND
Transparent Reporting of Evaluations with Nonrandomized Designs

Declarations

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. The Institutional Ethics Committee of the University of Zielona Góra, Poland, approved it (approval KB-UZ/21/2021, dated 15 September 2021, and Annex KB-UZ.0015.03.2024, dated 31 January 2024), as part of the RIVER-EU project. The latter explicitly covers the educational intervention component described in this study. All participants were adults and provided informed online consent to participate; we obtained consent before participants completed the first questionnaire. Participation was voluntary and could be withdrawn at any time without giving a reason and without consequences.

Consent for publication

Not applicable. The manuscript contains no person's data in any form.

Competing interests

The authors declare no competing interests.

Funding

This study was conducted within the RIVER-EU project (*Reducing Inequalities in Vaccine uptake in the European Region – Engaging Underserved communities*), which received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 964353. The funder had no role in the study design, data collection, analysis, or interpretation, or in writing the manuscript. The views expressed are those of the authors alone.

Author Contribution

MG conceived and designed the study. MG developed the study instrument, and MG and EK delivered the educational program. MG collected the data. AK performed the statistical analysis. MG and ŁDD drafted the manuscript. EK and AK critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

Acknowledgement

The authors thank the students who took part in the study and the experts who delivered the educational program.

Data Availability

Availability of data and materials:The questionnaire and scoring key are provided as Additional file 2, and the item-level before–after comparison as Additional file 3. The de-identified, item-level dataset analyzed during the current study, and any further data, are available from the Polish RIVER-EU coordinator, Maria Ganczak (m.ganczak@inm.uz.zgora.pl), on reasonable request.

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Figures

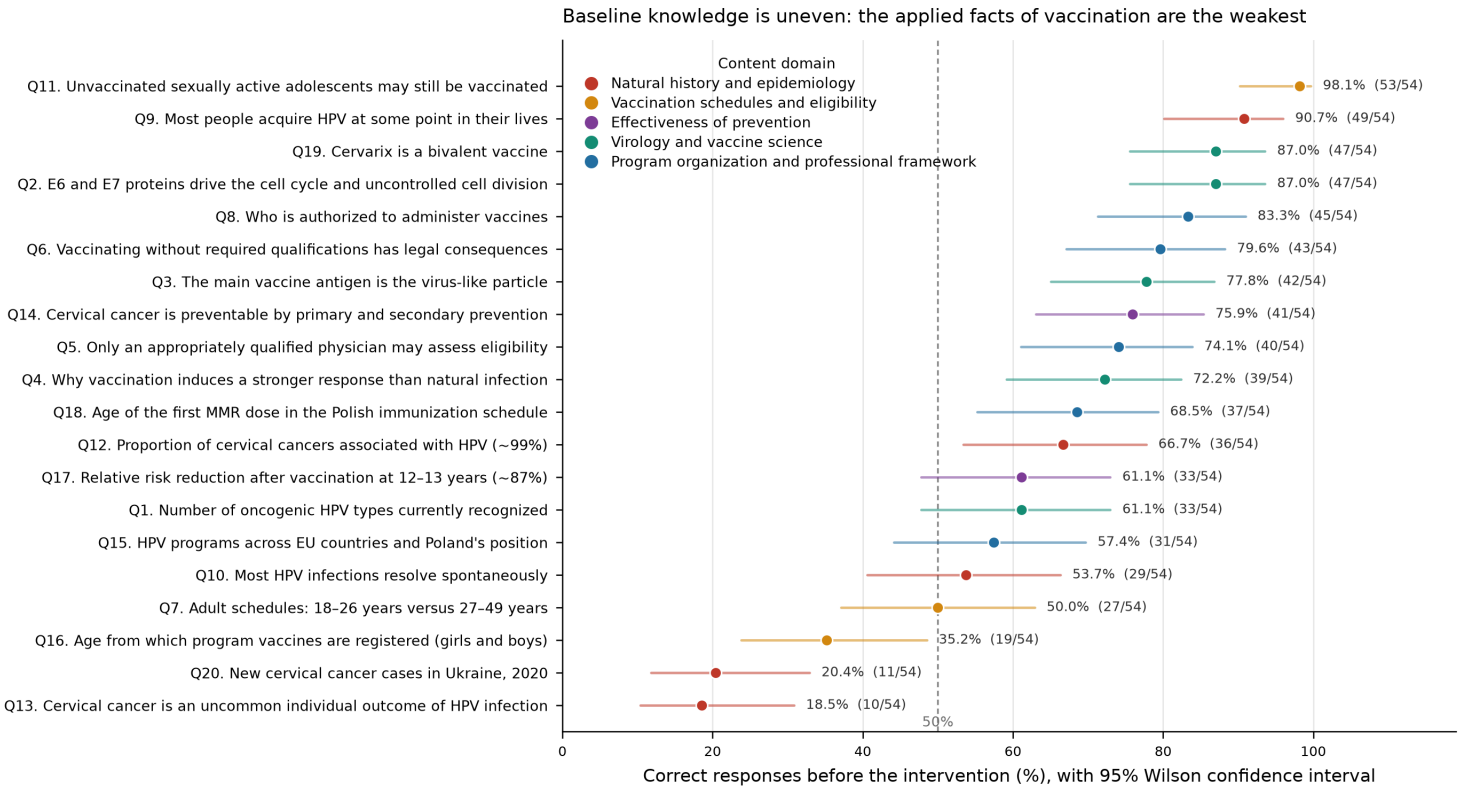


Figure 1

Proportion of correct responses before the educational intervention for each of the 20 questionnaire items, ranked from the least to the most difficult (n = 54). Points are colored by content domain; horizontal lines are 95% Wilson score confidence intervals; absolute numerators are shown alongside each point. The dashed line marks 50% correct. Performance varies more than fivefold across items, with the applied and epidemiological content of HPV prevention concentrated at the lower end of the ranking.

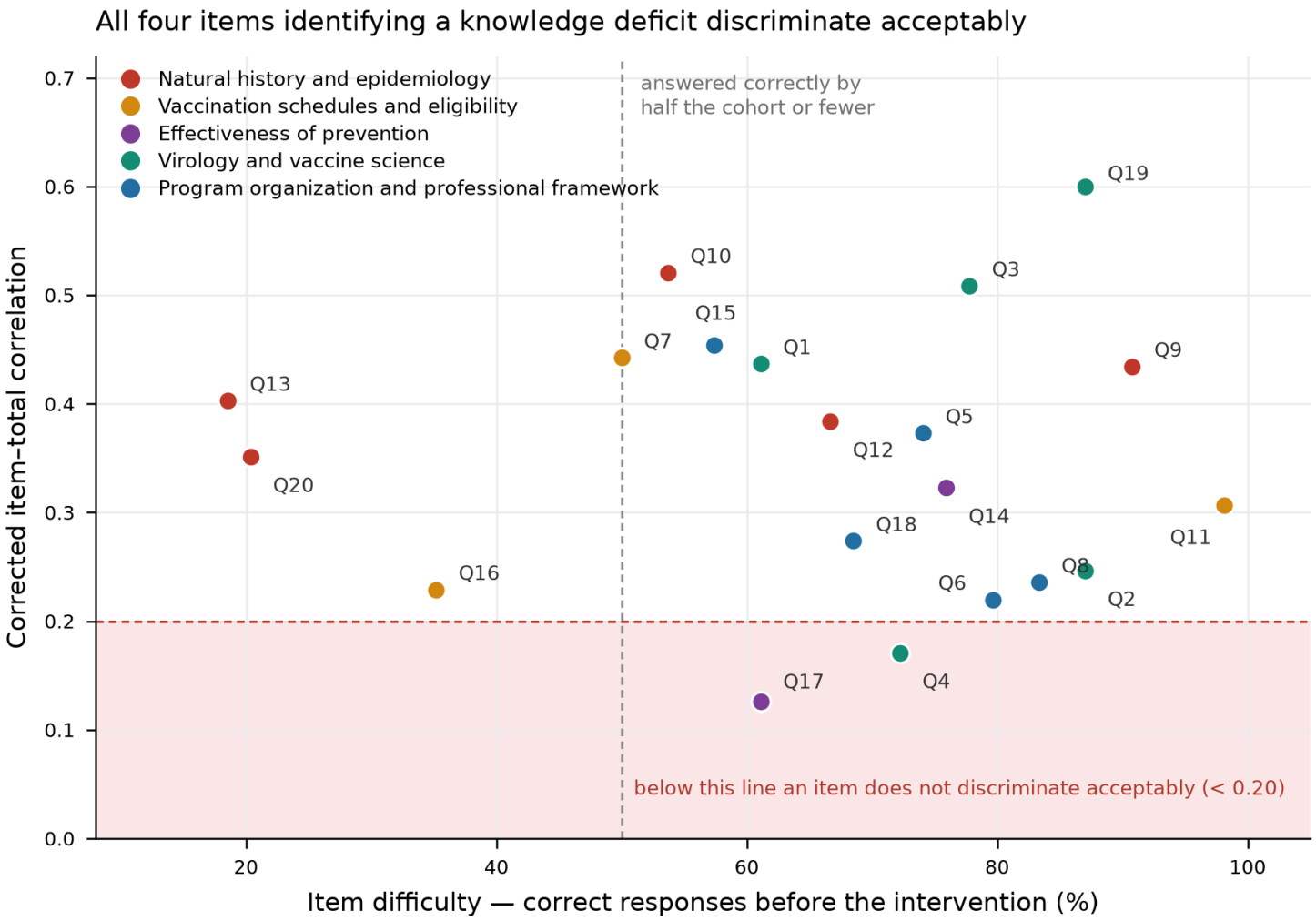


Figure 2

Item difficulty plotted against the corrected item–total correlation for each of the 20 items. The shaded band marks corrected item–total correlations below the conventional acceptability threshold of 0.20 [21]; the vertical dashed line marks 50% correct. Every item correlates positively with the rest of the instrument. The four items answered correctly by half the cohort or fewer all discriminate acceptably (0.23–0.44), so their low scores are interpreted as knowledge deficits rather than as artifacts of item construction. The two items below the threshold (items 4 and 17) are among the easier items and carry none of the conclusions.

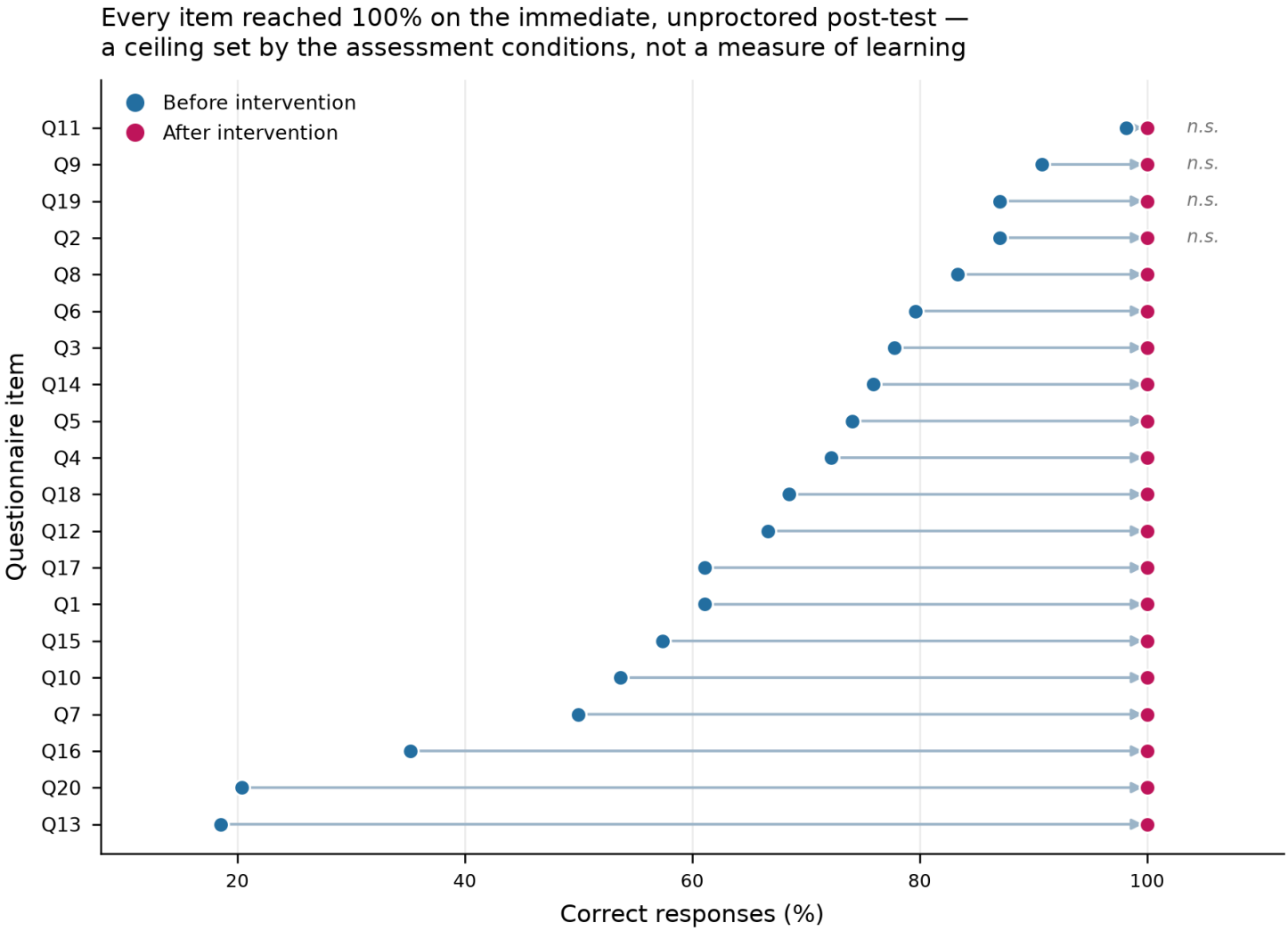


Figure 3

Proportion of correct responses before and after the educational webinar for each questionnaire item, ordered as in Fig. 1. Every item reached 100% correct on the post-intervention questionnaire. Items marked n.s. (2, 9, 11, and 19) did not show a statistically significant improvement after Bonferroni–Holm correction, reflecting a high proportion of correct answers already at baseline. Because the post-test was administered online immediately after teaching and without proctoring, the uniform ceiling reflects the assessment conditions and is not interpreted as a measure of learning.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile2questionnaireandkey1..docx
- Additionalfile3itemanalysis..docx