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Attitudes towards immunization and the state of knowledge about vaccines among Polish students

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ABSTRACT

Introduction: Although vaccines are said to be one of the most significant discoveries in contemporary medicine, the problem of vaccine hesitancy is becoming an increasingly important public health issue. Such a state of affairs poses a significant risk of rare disease outbreaks. Moreover, the recent COVID-19 pandemic was brought under control, among other things, by mass vaccinations – yet still, many people are reluctant to use them. This research assesses possible reasons behind the problem and its magnitude in a group of Polish students from various universities.

Material and methods: A cross-sectional study was conducted in April-June 2021 with a self-administered questionnaire among 301 undergraduate students from Polish universities.

Results: Students' trust in the vaccines' effectiveness mainly depended on the field of studies, the kind of sources of knowledge about vaccines they used, their knowledge levels about them, and the experience of developing an illness that a vaccine should protect them against. The kind of sources of knowledge and the levels of knowledge affected students' decisions about whether they wanted to vaccinate their future children or not. Respondents' levels of knowledge about vaccines correlated with their subject of studies and were the highest among those who used mostly scientific sources of knowledge about the vaccines.

Conclusions: This research demonstrates that education improvement regarding the process of immunization is a crucial step towards the solution to the problem of vaccine hesitancy. It is also very significant to promote the use of verified scientific sources of information about vaccines.

KEY WORDS: knowledge, attitudes, public health, young adults, immunization, vaccines.

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INTRODUCTION

Undoubtedly, vaccines may be perceived as one of the most important discoveries in the history of contemporary medicine [1]. Though every invention has its assets and flaws, the latter are relatively infrequent in the case of vaccines. According to the statistics from the Health Resources and Services Administration's report on the matter of the National Vaccine Injury Compensation Program, in the years 2006-2019, over 4 billion doses of vaccines were administered in the USA, which were implicated in compensation (due to severe injury) in less than 6000 cases [2]. In conclusion, the prevalence of severe injuries due to vaccination was approximately 1.5 cases per 1 million doses.

On the other hand, vaccines are said to save millions of lives every year [3]. For example, before the year 1942 – in which mass immunization against diphtheria was introduced in the UK – the average number of cases was about 60 thousand [4]. Between 2009 and 2017, these numbers decreased to 1-7 cases per year [5]. Even more remarkable is that due to the vaccination program, humanity managed to eradicate smallpox [6] – as this single disease is said to have been the cause of 300-500 million deaths in the 20th century alone [7].

Regrettably, recent years have seen a decrease in the percentage of vaccinated children [8, 9] and the spread of anti-vaccination movements' propaganda [10]. Several studies show that undervaccination may result in sudden outbreaks of infectious disease epidemics [11, 12]. Thus, it is crucial to identify the underlying causes of vaccine hesitancy and start reacting against them.

Still, there is not enough research among young people concerning this problem. Students are an essential group to analyze, as, in the near future, they will probably become parents and will be presented with a choice whether to vaccinate their children or not. Moreover, the assumption that their knowledge levels should be significant may be made in their case.

Considering the issues mentioned above, the aims of this research were:

- to measure the scale of vaccine hesitancy among Polish students;
- to investigate the reasons for negative attitudes toward vaccinations;
- to analyze possible relatedness between the level of knowledge about vaccines and the students' trust in their effectiveness.

MATERIAL AND METHODS

A non-representative cross-sectional survey was conducted during April-June 2021 with a self-administered questionnaire among 301 undergraduate students (229 female, 71 male, and 1 non-binary) from Polish universities. The online questionnaire with 28 questions (see Webappendix 1) was prepared using MS Forms (Microsoft, USA) and disseminated to potential participants via social networks and institutional e-mail addresses. Participation in the research was voluntary, and the purpose of the study was explained at the beginning of the questionnaire. The collected data were anonymous. It required about 5-7 minutes to answer all the questions. In order to avoid the impact of the questionnaire structure on the results of the survey, it was carefully analyzed to suggest answers as little as possible (especially in knowledge questions). Additionally, the order of distractors in individual questions was randomly generated for each respondent. The study did not need the approval of the bioethical committee because it was not a medical experiment in accordance with Polish law. Filling in the questionnaire and sending a reply was considered unambiguously as giving informed consent to participate in the study.

Statistical analysis was performed using Statistica 13 software (TIBCO Software, USA). The values of all variables were presented as proportions (percentage). The distribution of data was checked using the Shapiro-Wilk test. The Mann-Whitney U test was used to measure the significance of the difference in comparison of two groups and the one-way analysis of variance (ANOVA) was used in comparison of three or more groups. The $p = 0.05$ was considered the limit of statistical significance.

Main comparisons between groups were pre-specified before data collection and made based on gender, field of study, university level, sources of knowledge about vaccines, and the respondents' knowledge about vaccinations. Additional comparisons were made by dividing students into the groups regarding given answers (after the data collection) – whether mercury is a component of vaccines, based on their attitude towards vaccines against SARS-CoV-2 and the experience of developing an illness that a vaccine should protect them against.

Students were divided into groups by the field of study using the Organisation for Economic Co-operation and Development (OECD) classification [13]:

- natural sciences (NAT),
- engineering & technology (ENG),
- medical & health sciences (MED),
- agricultural sciences (AGR),
- social sciences (SOC),
- humanities (HUM).

Considering university level, respondents were categorized into two groups: years 1-3 (bachelor's degree level) and 4-6 (master's degree level). This division corresponds to the construct of higher education in the Bologna Declaration, to which Poland is a signatory [14].

The division according to the sources of knowledge about vaccines was done as follows. Out of 6 possible answer options about the sources, half were scientific ("scientific articles and textbooks", "experts or doctors", "popular science blogs"), and the other half were unscientific ("information portals, TV, radio", "social media", "friends or family"). Based on respondents' answers, they were divided into five groups:

- those who chose only scientific sources (SCI),
- those who chose more scientific than unscientific ones (MSCI),
- those who chose equal numbers of scientific and unscientific ones (EQL),
- those who chose more unscientific than scientific ones (MUCI),
- those who chose only unscientific sources (UCI).

The division according to the students' knowledge about vaccines was done as follows, using the results from answers given to 8 questions (No. 9, 10, 11, 12, 13, 26, 27, 28 – see Webappendix 1). Six were a single choice, and the respondents were given 1 point for every correct answer. One question had two correct answers – students were given 0.5 points for each. One question had four correct answers – students were given 0.25 points for each. Gained points were summed up. Based on the score, respondents were divided into four categories of knowledge:

- very poor – 2 points or less,
- poor – more than 2, up to 4 points,
- good – more than 4, up to 6 points,
- very good – more than 6 points.

RESULTS

The general characteristics of the study group are presented in Table 1. The distribution of given answers in the questionnaire is presented in Table 2.

TABLE 1. General characteristics of the study group, *N* = 301

Characteristic	%
Gender	
Female	76.08
Male	23.26
Non-binary	0.66
Field of study	
Natural sciences (NAT) – 14.29%	14.29
Engineering & technology (ENG) – 15.95%	15.95
Medical & health sciences (MED) – 19.60%	19.60
Agricultural sciences (AGR) – 10.96%	10.96
Social sciences (SOC) – 27.24%	27.24
Humanities (HUM) – 11.96%	11.96
University level	
Years 1-3	77.74
Years 4-6	22.26
Sources of knowledge about vaccines	
Those who chose only scientific sources (SCI)	35.88
Those who chose more scientific than unscientific ones (MSCI)	25.91
Those who chose equal numbers of scientific and unscientific ones (EQL)	18.94
Those who chose more unscientific than scientific ones (MUCI)	8.64
Those who chose only unscientific sources (UCI)	10.63
Level of knowledge about vaccines	
Very poor	1.66
Poor	9.63
Good	44.52
Very good	44.19

FEMALES VS. MALES

Significant differences in women's and men's answers were infrequent. According to respondents' statements, men were more likely to gain knowledge about vaccines from popular science blogs than women (47.14% and 31.44%, respectively, $p = 0.016$). Furthermore, a higher percentage of men than women claimed that their level of knowledge in this matter was sufficient (57.14% and 42.79%, respectively, $p = 0.035$). Their knowledge testing results did not support this – mean points scored for women = 5.73, and for men = 5.98 ($p = 0.071$).

Of those who stated that they did not intend to get vaccinated against SARS-CoV-2, significantly more women than men indicated one of the reasons the opinion that the vaccine was not sufficiently tested (10.48% and 2.86%, respectively, $p = 0.048$).

Only one respondent described himself as non-binary – due to the very small sample, this category was not included in the gender comparison.

FIELDS OF STUDY COMPARISON

A significant difference ($p = 0.006$) was observed in the question about using scientific articles as a source of information about diseases. The percentage of students who claimed to use them exceeded 58% in all OECD study fields. However, in groups of students studying MED or AGR, the percentage was much higher (84.75% and 81.82%, respectively) than in others. A similar difference was noted in the question about using scientific sources as a source of information about vaccines ($p = 0.006$). In 4 (NAT, ENG, SOC, HUM) out of 6 fields, the results were quite similar – at least 55% of students claimed to use scientific sources, whereas, in MED or AGR fields, there were respectively 86.44% and 78.79%.

Another significant difference ($p = 0.001$) was obtained in the question about the trust in the effectiveness of vaccines. In 4 fields (NAT, ENG, AGR, HUM), the percentage of students who claimed to trust vaccines was near 80%, but in the MED, the value was 94.92%, while in the SOC, it was only 65.85%. The results were similar in the question about the willingness to be vaccinated ($p = 0.003$) – the MED represented the highest, and the SOC represented the lowest percentage of students willing to be vaccinated (94.92% and 65.85%, respectively).

On the other hand, more students of HUM and SOC claimed not to have sufficient knowledge about vaccines (63.89% and 67.07%, respectively), whereas other students (NAT, ENG, MED, AGR) had comparable results approaching 50% (with the exception of the MED group with 40.68%). The *p*-value was 0.024.

Among students who answered that they considered vaccinating their children only with the obligatory vaccines, the vast majority denied that it was because of a lack of trust towards vaccine manufacturers. However, a significant difference ($p = 0.033$) was noted for this question because the percentages of AGR and SOC students who denied it did not exceed 90% (as it did in other fields) but were 84.85% and 87.80%, respectively, while the percentage of MED students was 100%.

Table 3 presents data concerning students' willingness to vaccinate against SARS-CoV-2 depending on their field of studies. Students who claimed they did not want to be vaccinated against SARS-CoV-2 were also asked for an explanation. The majority of each study field group denied the option "I am afraid for my life and health" and agreed with the option "I am afraid for my and my relatives' life and health." However, the vast difference was among the MED students – 91.53% claimed not to be afraid for their life and health, and 74.58% denied also being afraid for their and their relatives' life and health. A noticeable difference was also observed in

TABLE 2. General distribution of answers to questions (MC – multiple choice), *N* = 301

Questions	Answers, %
Sources of knowledge about diseases (MC)	
Scientific articles and textbooks	67.44
Information portals, TV, radio	41.20
Social media	15.28
Popular science blogs	34.22
Experts or doctors	80.07
Friends or family	36.88
Do you trust in vaccinations' effectiveness?	
Yes	79.73
No	20.27
Is your knowledge about vaccines sufficient?	
Yes	46.18
No	53.82
Do you undergo vaccinations (both the obligatory and optional) willingly?	
Yes	78.41
No	21.59
Should the society invest in the development of vaccines against some serious illnesses, e.g., HIV?	
Yes	95.35
No	4.65
Should the obligatory vaccines included in the current vaccination schedule remain obligatory?	
Yes	88.37
No	11.63
Have you (or your relative) ever developed, after immunization, an illness that a vaccine should protect you against?	
Yes	17.61
No	82.39
Have you ever experienced an adverse effect following immunization?	
Yes	52.16
No	47.84
Have you been hospitalized due to an adverse effect following immunization?	
Yes	2.55
No	97.45
Are you considering vaccinating your children?	
Yes, both with the obligatory and optional vaccines	73.75
Yes, but only with the obligatory vaccines	21.93
No	4.32

TABLE 2. Cont.

Questions	Answers, %
Why are you considering vaccinating your children only with the obligatory vaccines? (MC)	
Anxiety about adverse effect following immunization	51.52
Lack of trust in vaccine manufacturers	33.33
Lack of trust in vaccines' effectiveness	39.39
Expensiveness of the optional vaccines	22.73
As they are optional, there is no need to apply them	34.85
Anxiety about retribution for avoidance of obligatory vaccines	4.55
Why are you not considering vaccinating your children at all? (MC)	
Anxiety about adverse effects following immunization	46.15
Anxiety about permanent adverse effects following immunization	38.46
Lack of trust in vaccine manufacturers	53.85
Lack of trust in vaccines' effectiveness	53.85
Infectious diseases are not as dangerous	30.77
Do you want to get vaccinated against SARS-CoV-2?	
I have already been vaccinated	18.27
Yes, as soon as possible	45.18
Yes, when I am certain about the safety of the vaccine	24.58
No	11.96
I do not want to get vaccinated against SARS-CoV-2 becauseMC	
I am not afraid of the virus	25.00
I have recovered from COVID-19	41.67
The vaccines are not tested enough	72.22
SARS-CoV-2 does not exist	5.56
I want to vaccinate against SARS-CoV-2 because (MC)	
I am afraid for my own life	46.19
I am afraid for the lives of my relatives	74.76
I want to contribute to ending the pandemic	82.38
I want to avoid restrictions	54.29
It is necessary for my job	19.05
Can the mRNA component of some vaccines against SARS-CoV-2 change the human genome?	
Yes	8.97
No	91.03

TABLE 3. Willingness to get vaccinated against SARS-CoV-2 depending on students' field of studies

	Willingness to get vaccinated against SARS-CoV-2 [%]			
	Already vaccinated	Willing to get vaccinated ASAP	Willing to get vaccinated when certain of the safety	Not willing to get vaccinated
Field of study				
NAT (n = 43)	9.30	53.49	27.91	9.30
ENG (n = 48)	2.08	56.25	35.42	6.25
MED (n = 59)	64.41	20.34	11.86	3.39
AGR (n = 33)	3.03	54.55	36.36	6.06
SOC (n = 82)	7.32	43.90	24.39	24.39
HUM (n = 36)	13.89	55.56	16.67	13.89
Sources of knowledge about vaccines				
SCI (n = 108)	19.44	46.30	22.22	12.04
MSCI (n = 78)	24.36	42.31	28.21	5.13
EQL (n = 57)	12.28	56.14	19.30	12.28
MUCI (n = 26)	19.23	46.15	26.92	7.69
UCI (n = 32)	9.38	28.13	31.25	31.25

NAT – natural sciences, ENG – engineering & technology, MED – medical & health sciences, AGR – agricultural sciences, SOC – social sciences, HUM – humanities), and the type of sources of knowledge they used (SCI – only scientific, MSCI – mostly scientific, EQL – equal numbers of scientific and unscientific sources, MUCI – mostly unscientific, UCI – only unscientific)

the answers for the option "The vaccine is not examined sufficiently." Only the groups of HUM and SOC students agreed with this statement by more than 10% (11.11% and 18.29%, respectively). A noticeable difference was also found for the option "I want to contribute to the ending of the pandemic" since the vast majority of MED students denied this statement, which corresponded with their denial of the option "I want to avoid restrictions related to the pandemic" too.

Another statistically significant difference (p = 0.002) in responses from students of different fields was found in the comparison of their level of knowledge about vaccines.

YEARS 1-3 VS. YEARS 4-6

No statistically significant differences were found when dividing students into two groups by their university level – bachelor's degree and master's degree.

SOURCES OF KNOWLEDGE COMPARISON

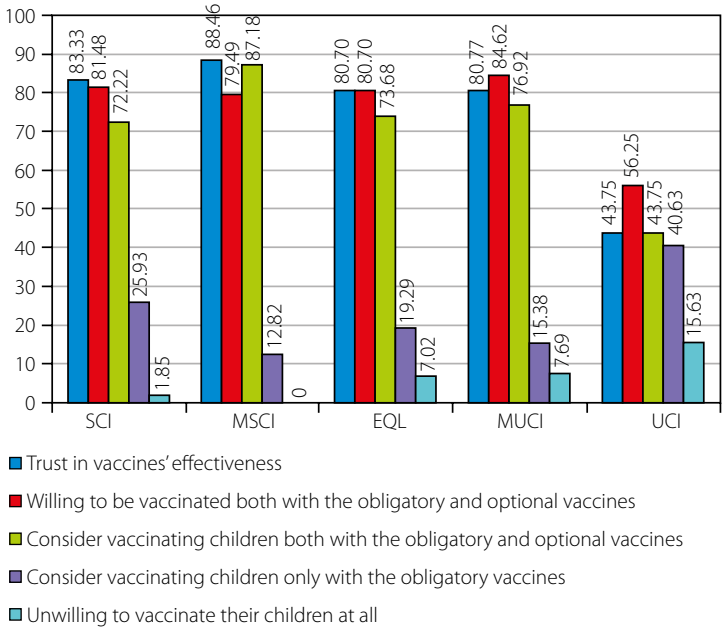
The frequency of using particular sources of knowledge about diseases in the groups mentioned above was different than in the matter of the vaccines. In all the groups, "experts and doctors" was the most popular answer (SCI = 77.78%, MSCI = 92.31%, EQL = 82.46%, MUCI = 80.77%, UCI = 53.13%), but among those who chose only unscientific sources of knowledge about vaccines, the option "information portals, TV and radio" as a source of knowledge about diseases was selected with the same frequency as "experts and doctors" (53.13%).

Another significant difference (p < 0.001) was found in the answers concerning respondents' trust in vaccines' effectiveness. The percentage of those who said they trusted in vaccines exceeded 80% in all the groups, except the UCI, where the percentage decreased approximately by half, reaching 43.75%. The results were quite similar when students were asked about their willingness to be vaccinated (both with the obligatory and optional vaccines; p = 0.031) (Figure 1).

The vast majority of participants agreed with the statement that the vaccines which were mandatory in Poland at the time of conducting this research should remain obligatory (p = 0.016). In 3 out of 5 groups, more than 90% of respondents agreed with this sentence (SCI, MSCI, MUCI = 92.59%, 91.03%, 92.31%, respectively). The percentage was slightly lower among the EQL group (84.21%) and significantly lower in the UCI group (71.87%). Significant differences were found in students' willingness to vaccinate their children (p < 0.001) – see Figure 1 for details.

Those respondents who claimed they did not want to have their children vaccinated at all were asked for the reasons for such a decision (compare with Webappendix 1). In the SCI and the EQL group, all answers were chosen with similar frequency without any significant difference. MUCI more frequently indicated "no trust in vaccine manufacturers" and "no trust in vaccines' effectiveness," while in the UCI group, "no trust in vaccine manufacturers" was the most popular reason.

A similar question was posed to those who said they were willing to vaccinate their children only with



(SCI – only scientific, MSCI – mostly scientific, EQL – equal numbers of scientific and unscientific sources, MUCI – mostly unscientific, UCI – only unscientific)

FIGURE 1. Respondents' trust in vaccines' effectiveness and their willingness to be vaccinated and to vaccinate their children depending on the type of sources of knowledge they used

the obligatory vaccines. In all the groups, except for one (MSCI), "fear of adverse effects following immunization and long-lasting adverse effects" was the most frequently chosen option. In the MUCI group, most respondents stated that "no trust in optional vaccines' effectiveness" was one of the reasons behind their decision.

Another difference was related to the question whether respondents wanted to get vaccinated against SARS-CoV-2 (or whether they had already been vaccinated) – $p = 0.014$. Details are presented in Table 3. Those who wanted to vaccinate against SARS-CoV-2, in general, were asked for their motivation. The SCI, MSCI, and UCI groups most frequently indicated their willingness to contribute to the end of the pandemic. In the EQL and MUCI groups, concern for their and their families' health and life was the prevailing answer. Respondents who claimed they did not want to vaccinate against SARS-CoV-2 at all were also asked for their reasons. Besides the MUCI group, in which no fear of the virus was the most popular answer, the rest indicated no certainty of the vaccines' safety with the highest frequency.

Students answered significantly differently ($p = 0.001$) when asked about the possibility of the whole genetic material in the human body being changed by mRNA, which is a component of some of the vaccines against SARS-CoV-2. The fraction of those who agreed with such a possibility was the largest among UCI (28.13%) and the smallest in the MSCI group (2.56%). In the other groups, the following fractions of respondents answered similarly: SCI – 6.48%, EQL – 10.53%, and MUCI – 11.54%.

The last variable with a significant difference ($p = 0.004$) in this section was the one with students' levels of knowledge about vaccines. The highest percentage of those who represented the worst level of knowledge belonged to the UCI group (6.25%), while the lowest belonged to the MSCI group (0.00%). Moreover, UCI had the lowest percentage of respondents with remarkably high levels of knowledge about vaccines (21.88%). The MSCI was the best in this comparison (52.56%). For details (Table 3).

LEVEL OF KNOWLEDGE COMPARISON

The trust in the effectiveness of vaccines increased with the level of knowledge ($p < 0.001$). Those whose knowledge was very poor or poor often answered that they did not trust it (80.00% and 62.07%, respectively) compared to those with good and very good knowledge (23.13% and 6.02%, respectively).

Those whose knowledge was very poor significantly more often ($p < 0.001$) chose not to vaccinate their children (60.00%) than those with poor, good, or very good knowledge (17.24%, 2.99%, and 0.75%, respectively).

Significantly more ($p < 0.001$) students with very poor and poor knowledge were not willing to get vaccinated (60.00% and 62.07%, respectively), unlike those with good and very good knowledge, who mostly willingly vaccinated themselves (76.12% and 90.98%, respectively).

Students whose knowledge was very poor or poor significantly more often ($p < 0.001$) answered that the obligatory vaccines included in the vaccination schedule current at the time of conducting research should not

have been obligatory (60.00% and 41.38%, respectively). In comparison, most of those with good or very good knowledge responded that they should have remained compulsory (90.29% and 94.74%, respectively).

There was a significant association between the level of knowledge and the attitude towards investing in developing vaccines against some serious pathogens, such as HIV ($p < 0.001$). Those with very poor and poor knowledge more often answered against such an investment (40% and 13.79%, respectively) than students with good and very good knowledge (1.49% and 4.51%, respectively).

There was also a significant association ($p < 0.001$) between the attitude to the vaccination against SARS-CoV-2 and the level of knowledge about vaccines (Table 3).

OTHER COMPARISONS

Students who did not deny mercury being one of the components of vaccines significantly more often claimed that they did not trust the effectiveness of vaccines (30.2% compared to 17.35% among the others, $p = 0.010$) and did not undergo vaccination willingly (32.2% compared to 19.00% among the others, $p = 0.030$). They were also less likely to answer that doctors or experts were their sources of knowledge about vaccines compared to the others (44.07% and 64.46%, respectively, $p = 0.004$). Moreover, those students more often replied that they did not want to vaccinate their children (11.11%) or that they wanted to vaccinate them only with the obligatory vaccines (43.21%), compared to the other group (1.82% and 14.09%, respectively).

52.16% of respondents stated that they experienced an adverse effect following immunization. There was a significantly higher ($p = 0.048$) number of students who replied that they did not trust vaccines' effectiveness among those who answered that they had such an experience (30.19%) vs. those who answered that they had not experienced it (18.14%). In the group of students that experienced the development of an illness that a vaccine should protect against (17.61%), there was a significantly higher ($p = 0.011$) proportion of those who claimed no willingness to be vaccinated against SARS-CoV-2 (22.64%) versus those with no experience of such an issue (9.67%). The "experienced" group more rarely chose the answer "I want to be vaccinated as soon as possible" (35.45% vs. 47.18% in the "inexperienced" group), and more often, "I want to be vaccinated when I am certain of the safety of the vaccine" (28.3% vs. 23.79% in the "inexperienced" group, $p = 0.011$).

DISCUSSION

Since education in Poland is compulsory under 18 for each child regardless of gender, their knowledge should not show significant disparity, which was reflected in our results. Moreover, the survey's findings did not show a significant difference according to university level since the questions concerning knowledge about vaccines were mainly general and did not demand specific schooling in the medical or biological field.

In questions about knowledge concerning diseases and vaccines, trust in their effectiveness and safety, and willingness to vaccinate their children, in which a significant difference was found, the MED group dominated as the one with the best knowledge level and highest trust or willingness to vaccinate children. On the opposite side were usually SOC and HUM groups. This disparity may be due to diverse interests and research backgrounds related to their fields of study. The MED group is more exposed to medical information, including vaccines and diseases, or seeks this kind of information more often than any other group. Furthermore, SOC and HUM groups may concentrate more on working with other people based on their creativity, while the MED group focuses more on facts and evidence gathered by other scientists.

In general, the MED group was most knowledgeable about vaccines, but one would expect 100% of respondents in this group to have reliable knowledge and attitudes on this topic. Unfortunately, many medical schools lack dedicated vaccinology courses, which may be the reason for the mentioned deficiencies in this respect.

Those who mostly relied for their vaccine knowledge on information portals, media, and social media might be prone to anti-vaccination movements' agenda that uses conspiracy theories and emotional language to impact students' views on vaccination [15].

According to Betsch *et al.* [16], visiting a website that contains anti-vaccine content (just for approximately 5-10 minutes) negatively impacts visitors by reducing willingness to vaccinate and increasing distrust of vaccines' effectiveness.

In our research, similar results were obtained. The discussed group of students more often undermined the effectiveness and safety of vaccines, which could cause some hesitation in the matter of their and their children's vaccination. Moreover, they were probably open to fake theories about mercury's presence in vaccines – one of the flagships of an anti-vaccination movement [17] – which was reflected in our study by the answers (of those who did not reject the presence of mercury in vaccines) to the questions about the willingness to be vaccinated, children's vaccination, trust in the effectiveness of vaccines, and sources of knowledge about vaccines. Also, the group mentioned above rarely expressed a desire to vaccinate against SARS-CoV-2. It is worth noting that pure mercury has never been an ingredient in vaccines. Some old vaccines (no longer available) used mercury salts, such as thiomersal, as an antibacterial and antifungal preservative [18].

Along with the increasing number of such opinions on vaccines [19] and negligence in education about them, society might face the global problem of denying the benefits of vaccines.

Concerning the increasing frequency of children's vaccination refusal in Poland, the remarkable differences which were noted between students who based their views on non-scientific sources and those whose major source was based on scientific evidence are crucial in the context of their parenthood – since students, future parents, tend to be more influenced by media and the Internet than older people [19, 20]. USCI students' knowledge was on a much lower level. Also, they more often rejected vaccination against SARS-CoV-2 and more frequently questioned vaccines' effectiveness and safety of vaccines, in general. Moreover, this group less frequently answered that they wanted to vaccinate their children. That state of affairs could put their children in danger of some rare illnesses, such as measles, which tends to be a more common disease in Poland (339 cases in 2018 and 1492 in 2019) [21] and break the herd immunity. It is alarming, especially because students, in general, are more likely to use scientific sources than the rest of the population.

Regardless of students' sources of knowledge about vaccines (even if they were only unscientific), considering sources of knowledge about diseases, the most popular answer was "experts or doctors." We may assume that some of the respondents did not seek out knowledge regarding immunization from experts (even if they did so in the case of diseases) or did not receive such information. Independently of the cause, doctors and other healthcare professionals should remember that they strongly impact patients' attitudes towards vaccination. The research by Kundi *et al.* [22] showed that parents followed vaccine recommendations more willingly when their parent-doctor relationship was better – doctors treated them respectfully and gave them enough time to pose questions. It was also essential to explain to parents both the benefits and risks of vaccination [23].

Moreover, our results showed that the MSCI group had a higher knowledge level than the SCI group, which may reflect the impact of social media in which medical professionals are more present and have remarkable opportunities to share scientific knowledge among all. Unfortunately, according to a survey by Davis *et al.* [23], approximately one-quarter of doctors believed that informing parents about risks may be unnecessarily alarming. Further healthcare professionals' education should be focused on the fact that their actions are very significant for the problem of vaccine hesitancy.

Our results indicated that medical professionals ("experts and doctors") were the most popular source of knowledge about health and diseases despite the respondents' preferred source of knowledge about vaccines. This agrees with the recently published data from other developed countries – Greece [24], Saudi Arabia [25], and the USA [26]. While online sources – such as social media or internet blogs – are gaining in popularity, educated medical professionals are still the most trusted sources of knowledge about health.

CONCLUSIONS

The research emphasized some important issues in the matter of the attitudes towards and knowledge about vaccines among surveyed Polish students. There were significant differences between various groups of students in their knowledge, attitude, source of information about vaccines, etc.

The results might indicate a substantial lack of education about vaccines and trust in healthcare workers' knowledge among the students. This gap could be filled by the anti-vaccination movements' propaganda which caused some hesitation in students in this matter and may contribute to the future failure of the nationwide vaccination program. We may also assume that public health attitudes and choices directly relate to education and knowledge levels.

Despite those possibilities, there is still a prospect that the medical community in Poland will prevent reluctance to vaccinate by the noticeable presence in social media – one of the most popular sources of information for young Poles. There is a need to overcome conspiracy theories about vaccines with reliable information based on scientific evidence from scientists and medical professionals.

It is also crucial to introduce courses devoted especially to vaccinology into university curriculums – particularly in medical faculties. Elements of this knowledge should also be included in science classes in compulsory primary and secondary education.

DISCLOSURE

The authors report no conflict of interest.

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AUTHORS' CONTRIBUTIONS

OW, MW, HB, FB, DPL prepared the concept of the paper. OW, MW, HB collected and analysed data. OW, MW, HB wrote the article. All authors have given their final approval to the final version of the paper.

WEBAPPENDIX 1. STUDY QUESTIONNAIRE

1. Sex
   a. Female
   b. Male
   c. Other
2. What is the field of your study?
   a. Natural sciences
   b. Engineering & technology
   c. Medical & health sciences
   d. Agricultural sciences
   e. Social sciences
   f. Humanities
3. What is your college level?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
4. What is your source of knowledge about diseases?
   a. Scientific articles and textbooks
   b. Information portals, TV, radio
   c. Social media
   d. Popular science blogs
   e. Experts or doctors
   f. Friends or family
5. What is your source of knowledge about vaccines?
   a. Scientific articles and textbooks
   b. Information portals, TV, radio
   c. Social media
   d. Popular science blogs
   e. Experts or doctors
   f. Friends or family
6. Do you trust in vaccines' effectiveness?
   a. Yes
   b. No
7. Is your knowledge about vaccines sufficient?
   a. Yes
   b. No
8. Do you undergo vaccinations (both compulsory and optional) willingly?
   a. Yes
   b. No
9. Is a vaccine a preparation that triggers the immune system to produce antibodies?
   a. Yes
   b. No
10. Does natural immunity last longer and is it safer than the one obtained as a result of vaccination?
    a. Yes
    b. No
11. May vaccines cause an illness that they should protect us against?
    a. Yes
    b. No
12. Are vaccines administered directly into the bloodstream?
    a. Yes
    b. No
13. Which of these are not components of vaccines?
    a. Antigens
    b. Immunologic adjuvants
    c. Mercury
    d. Stabilizers
14. Should the society invest in the development of vaccines against some serious illnesses e.g., HIV?
    a. Yes
    b. No
15. Should the obligatory vaccines included in the current vaccination schedule remain obligatory?
    a. Yes
    b. No
16. Have you (or your relative) ever developed, after immunization, an illness that a vaccine should protect against?
    a. Yes
    b. No
17. What was the illness? (ref. to question 17)
    Open-text question
18. Have you ever experienced an AEFI (adverse effect following immunization)?
    a. Yes
    b. No
19. Have you been hospitalized due to an AEFI? (ref. to question 19)
    a. Yes
    b. No
20. Are you considering vaccinating your children?
    a. Yes, both with the obligatory and optional vaccines
    b. Yes, but only with the obligatory vaccines
    c. No
21. Why are you considering vaccinating your children only with the obligatory vaccines? (multiple choice) (ref. to answer "b" of question 21)
    a. Anxiety about AEFI
    b. Lack of trust in vaccine manufacturers
    c. Lack of trust in vaccines' effectiveness
    d. Expensiveness of the optional vaccines
    e. As they are optional, there is no need to apply them
    f. Anxiety about retribution for avoidance of obligatory vaccines
22. Why are you not considering vaccinating your children at all? (multiple choice) (ref. to answer "c" of question 21)
    a. Anxiety about AEFI
    b. Anxiety about permanent AEFI

c. Lack of trust in vaccine manufacturers
d. Lack of trust in vaccines' effectiveness
e. Infectious diseases are not as dangerous

23. Do you want to get vaccinated against SARS-CoV-2?
    a. I have already been vaccinated
    b. Yes, as soon as possible
    c. Yes, when I am certain about the safety of the vaccine
    d. No
24. I do not want to get vaccinated against SARS-CoV-2 because: (multiple choice) (ref. to answer "d" of question 24)
    a. I am not afraid of the virus
    b. I have recovered from COVID-19
    c. The vaccines are not tested enough
    d. SARS-CoV-2 does not exist
25. I want to vaccinate against SARS-CoV-2 because: (multiple choice) (ref. to answers "b" and "c" of question 24)
    a. I am afraid for my own life
    b. I am afraid for the lives of my relatives
    c. I want to contribute to ending the pandemic
    d. I want to avoid restrictions
    e. It is necessary for my job
26. Can the mRNA component of some vaccines against SARS-CoV-2 change the human genome?
    a. Yes
    b. No
27. Choose two sentences about AEFI which are, in your opinion, true. (multiple choice)
    a. Every reaction following immunization is an AEFI
    b. Not every reaction following immunization is an AEFI
    c. An AEFI is a condition which occurs within 4 weeks after immunization
    d. An AEFI is a condition which occurs at any time in a person's life after the vaccine's administration
28. What may be the cause of AEFI? (multiple choice)
    a. Symptoms occurring after immunization just by a coincidence in time and are not triggered by the vaccine
    b. Improper administration of the vaccine
    c. Individual reaction to the vaccine's administration
    d. The way the vaccine works (e.g., allergy to its components – usually related to non-compliance with the product's contraindications)