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Original Research Article

Vaccine hesitancy among Croatian biology students with special emphasis on COVID-19 vaccine

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Abstract

Background and purpose: *The next challenge after development of COVID-19 vaccines is reaching adequate vaccine coverage, which could be hampered by COVID-19 vaccine hesitancy. The aim of this study was to assess general inclination towards vaccination among biology students, as well as prevalence of COVID-19 vaccine acceptance. Since participants of this study could be employed in educational institutions in the future, their knowledge and attitudes towards vaccination could have a role in forming the attitudes of the next generations.*

Materials and methods: *Biology students from two Universities in Croatia were questioned using an anonymous online survey about their inclination towards vaccination in general and intent to vaccinate against COVID-19 at the moment and from the perspective of a future teacher. Data analysis included descriptive statistics, Chi-square test, Fisher's exact test and binary logistic regression.*

Results: *Mostly positive opinion about vaccination was revealed among Croatian biology students, while 67.3% expressed willingness to vaccinate against COVID-19. COVID-19 vaccine compliance was not associated with gender, level of education or University they attended. However, opinion about safety and effectiveness of COVID-19 vaccines, perceiving vaccination as important for stopping current pandemic and feeling exposed to COVID-19 infection significantly affected the odds for accepting COVID-19 vaccine. Many students were aware of the opportunity to influence vaccination decisions of the next generations by providing knowledge regarding infectious diseases, immunity and vaccines as future biology teachers.*

Conclusions: *Increasing willingness and competence of biology students and biology teachers to promote vaccine-positive attitudes could be promising long-term strategy for decreasing vaccine hesitancy.*

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INTRODUCTION

Vaccination is considered to be one of the most cost-effective public health interventions *(1)*. It has contributed to reducing the incidence, mortality and morbidity of various infectious diseases and even eradication of certain diseases such as smallpox *(2)*. However, opposition to vaccination is as old as vaccines are *(3)*. A term vaccine hesitancy has been introduced and defined as "delay in acceptance or refusal of vaccination despite availability of vaccination services. Vaccine hesitancy is complex and context specific, varying across time, place and vaccines. It is influenced by factors such as complacency, convenience and confidence" *(4)*. Confidence is referring to trust in vaccine safety and effec-

tiveness and in overall healthcare system, complacency is referring to perceived risks of vaccine-preventable diseases and convenience is including availability, affordability and accessibility of vaccine. Reduced vaccine coverage due to increasing vaccine hesitancy resulted in increased rates of vaccine-preventable diseases outbreaks and became a public health threat *(2, 5)*.

Vaccine distrust within population may change over time and is frequently more expressed for some vaccines in particular *(6)*. It can also be more pronounced in specific sub-groups within population *(7)*. COVID-19 pandemic and prompt development of COVID-19 vaccines brought additional light on the issue of vaccine hesitancy. Individual decision to accept or not to accept COVID-19 vaccine, same as vaccination in general, is complex and can be influenced by various factors, such as a perceived risk of the disease, opinion about vaccine safety and efficacy, socio-demographic profile, psychological characteristics, e.g. trust in authority, altruism and religious or conspiratorial believes, as well as health literacy and sources of information regarding COVID-19 *(1, 4, 8–10)*. Several COVID-19 vaccines are currently authorized and approved for human use as a way to fight against the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). However, availability does not equal the acceptance of COVID-19 vaccines in general public and this could have significant impact on the success of vaccination program *(11, 12)*.

Initial survey in seven European countries revealed that 73.9% of participants were willing to accept COVID-19 vaccines and additional 18.9% were unsure, while 7.2% were not willing to vaccinate *(12)*. Thereafter, numerous conducted surveys showed that acceptance rate of COVID-19 vaccine is highly variable globally, ranging from 97% (Ecuador) to 23.6% (Kuwait) among adults representing the general public *(13)*. In a 32-country survey conducted between October 21 and December 16, 2020 highest acceptance rate of COVID-19 vaccine was in Vietnam (98%), followed by India and China (91%) and Denmark and South Korea (87%) while lowest was in Serbia (38%), Croatia (41%), France and Lebanon (44%) and Paraguay (51%) *(14)*. Adolescents and young adults, such as University students, could have significant role in accelerating as well as sustaining COVID-19 pandemic, therefore this population should not be neglected in public health response to the pandemic *(15, 16)*. Several studies about prevalence of COVID-19 vaccine hesitancy were conducted among University students considering this population as open-minded and educated *(15, 17–20)*. Special emphasis was placed on future health care workers for their occupational risk and for a significant role in providing information and recommendations about vaccination to general population *(21–23)*. However, vaccination attitudes are not shaped only by healthcare professionals *(24)*. One of the possible promising approaches in addressing the vaccine hesitancy is promoting the pro-vaccination behaviour in schools using age-appropriate approaches to teach children about health, science and critical thinking *(25)*. Information, including that related to health and vaccination, is nowadays readily available on the internet and each person can assess it. People, especially younger, use various information sources, including online and social media, where besides scientifically verified information, inaccurate and misleading information could be found *(25, 26)*. Therefore, education of young generations that will enable the acquisition of knowledge and ability to critically evaluate provided information is of highest importance.

In Croatia, as well as in many other countries, the basic knowledge regarding infectious diseases, immunity and vaccines is included in biology curriculum and biology-related subjects during primary and secondary education. Our study was conducted in order to assess prevalence of COVID-19 vaccine acceptance among biology students enrolled in Undergraduate and Graduate study levels at two Croatian Universities and to determine factors influencing intention to vaccinate against COVID-19, as well as to assess their general attitude towards vaccination. Significance of the obtained findings is discussed from the aspect of current COVID-19 pandemics. Besides the importance of the obtained findings for COVID-19 pandemics, additional implication refers to the fact that in the future, participants of this study may be employed in educational institutions where their knowledge and attitudes towards vaccination could have a role in forming the attitudes of the next generations.

MATERIALS AND METHODS

A cross-sectional study was conducted from March 17 to April 17, 2021. The participants were students attending Department of Biology, Josip Juraj Strossmayer University of Osijek and Department of Biology, Faculty of Science, University of Zagreb. Students enrolled in both Undergraduate studies (first, second and third year) and Graduate studies (first and second year) were included in the survey. An anonymous online survey consisting of 32 questions in total was designed and the invitation message with the URL to the online questionnaire was delivered to the students using official Faculty email addresses and posted on the official Faculty web-sites. Students were asked to voluntarily participate in the survey and their informed consent was obtained at the beginning of the questionnaire, before proceeding to answering questions. In total 355 students completed the questionnaire (Table 1).

Table 1. *Structure of the biology students participating in the survey.*

	Total (%)	University of Osijek (n=200)	University of Zagreb (n=155)
Male	88 (24.8%)	44	44
Female	267 (75.2%)	156	111
Undergraduate	273 (76.9%)	150	123
Graduate	82 (23.1%)	50	32

Table 2. *The questionnaire used in this study to assess the inclination towards vaccination and COVID-19 vaccine hesitancy among Croatian biology students.*

No.	Statement or Question	Possible answers	Required for
1	Gender	F/M	All participants
2	University	Zagreb/Osijek	All participants
3	Study level	Undergraduate/Graduate	All participants
4	Have you been diagnosed with COVID-19?	YES/NO	All participants
5	Have you personally or someone close to you experienced severe COVID-19 symptoms?	YES/NO	All participants
6	Are you going to get vaccinated against COVID-19?	YES/NO	All participants
7	Are you going to get vaccinated for your own health?	YES/NO	Only for those who answered YES to question No. 6
8	Are you going to get vaccinated for the health of your family members?	YES/NO	Only for those who answered YES to question No. 6
9	Are you going to get vaccinated because it is socially useful?	YES/NO	Only for those who answered YES to question No. 6
10	Are you going to get vaccinated just to ensure yourself freedom of movement?	YES/NO	Only for those who answered YES to question No. 6
11	Would you get vaccinated after more people get vaccinated?	YES/NO	Only for those who answered NO to question No. 6
12	Would you get vaccinated in case you could choose the vaccine?	YES/NO	Only for those who answered NO to question No. 6
13	Do you think that vaccination against infectious diseases is generally important for an individual's health?	YES/NO	All participants
14	Do you think that vaccination against infectious diseases is generally important for public health?	YES/NO	All participants
15	Do you think that vaccination according to the national immunization schedule should be mandatory?	YES/NO	All participants
16	Do you generally consider vaccines safe?	YES/NO	All participants
17	Do you generally consider vaccines effective?	YES/NO	All participants
18	Do you consider vaccines against COVID-19 currently available in the EU safe?	YES/NO/ONLY SOME	All participants
19	Do you consider vaccines against COVID-19 currently available in the EU effective?	YES/NO/ONLY SOME	All participants
20	Do you think that vaccination against COVID-19 is important for disease control?	YES/NO	All participants
21	Do you currently consider yourself exposed to COVID-19?	YES/NO	All participants
22	Do you consider yourself at significant risk of COVID-19?	YES/NO	All participants
23	Do you currently consider yourself competent to give advices about vaccination?	YES/NO	All participants
24	Do you think that you will be competent to give advices about vaccination after finishing current study program?	YES/NO	All participants
25	Would you advise others to get vaccinated according to the national immunization schedule?	YES/NO	All participants
26	Would you advise others to get vaccinated against COVID-19?	YES/NO	All participants
27	Do you think that your attitudes about vaccination affect the attitudes of people around you?	YES/NO	All participants
28	Do people around you ask you for vaccination advice?	YES/NO	All participants
29	Do you think it is because of your education?	YES/NO	Only for those who answered YES to question No. 28
30	In the position of a teacher, do you think you could significantly affect pupil's opinion about vaccination?	YES/NO	All participants
31	Do you use professional literature and scientific papers as a source of information?	YES/NO	All participants
32	In the position of a teacher, would you use additional literature (professional literature, scientific papers) in addition to the obligatory literature when preparing for classes?	YES/NO	All participants

The questionnaire was composed of forced-choice yes/no questions. This type of questions was chosen to encourage decision making and clear expression of preferences and intentions, as well as to ensure simplicity of the questionnaire and thus increase the likelihood of completing it to the end *(27)*. After providing general information including gender, University they attend and study level they are enrolled in (Undergraduate or Graduate), participants answered a forced-choice yes/no questions about: 1) intent to vaccinate against COVID-19 and personal experience with COVID-19, 2) general inclination towards vaccination and previous vaccination history, 3) opinion on advising vaccination in general and advising vaccination against COVID-19 at the moment and from the perspective of a future teacher. When questioning their attitude regarding safety and effectiveness of COVID-19 vaccine, along with "yes" and "no" answer, option "only some" was included due to availability of several approved vaccines. Participants willing to be vaccinated against COVID-19 were asked for reasons using forced-choice yes/no questions. Those not willing to be vaccinated were asked, using forced-choice yes/no questions, if they would accept COVID-19 vaccine after more people got vaccinated or in case they could choose the type of the vaccine. List of all questions is presented in Table 2.

Statistical data analysis was performed using the statistical program SPSS Statistics for Windows, Version 27.0. (Armonk, NY: IBM Corp) with $p<0.05$ indicating statistical significance. Statistical analysis included descriptive statistics, followed by Chi-square tests, but if frequency in some category was low (≤5), Fisher's exact test was used. Binary logistic regression was used in order to identify predictors of COVID-19 vaccine acceptance and goodness of fit of the logistic regression model was tested using the Hosmer-Lemeshow and Omnibus tests.

RESULTS

Among 355 biology students from two Universities in Croatia who completed the survey, 239 students in total (67.3%) were willing to be vaccinated against COVID-19, while 116 students (32.7%) were not. Since portion of COVID-19 vaccine accepting students did not differ among students from Josip Juraj Strossmayer University of Osijek and students from University of Zagreb (Chi-square=0.095; p=0.758) (Table 3), further analyses were performed on a total number of participants.

All responses along with results of Chi-square or Fisher exact test are presented in the Table 3. More female than male students participated in the study, which is consistent with the gender structure of the biology students at both Universities. Neither students' gender (Chi-square=0.039; p=0.843) nor level of education (Undergraduate or Graduate students) (Chi-square=1.038; p=0.184) were found to be associated with willingness to vaccinate against COVID-19. Among questioned students, 21.7% have been tested positive for COVID-19 and 22.8% answered that they or someone close to them had severe disease symptoms. However, being previously diagnosed with COVID-19 (Chi-square=1.766; p=0.184) or having severe disease symptoms themselves or among close family members (Chi-square=0.016; p=0.900) was not associated with COVID-19 vaccine acceptance.

Among 239 students that intend to vaccinate against COVID-19, 82% would do so for their own health, 97% would do so for the health of their family members, 94.1% because it is socially useful and only 4 students (1.67%) want to get vaccinated just to ensure themselves freedom of movement. Among those that are not willing to vaccinate at the moment, 49.1% would accept COVID-19 vaccine after more people got vaccinated and 44% would accept if they could choose the type of the vaccine.

A total of 85.9% of students think that vaccination against COVID-19 is important for disease control and students who have such opinion are statistically more willing to get vaccinated than those who think that vaccination against COVID-19 is not important for disease control ($p<0.001$). Approximately half of the students feel exposed to COVID-19 and 22.8% feel to be at a significant risk. Willingness to vaccinate differed between students who think that they are currently exposed to or at significant risk of COVID-19 ($p<0.01$) (Table 3).

A total of 30.1% of students currently consider themselves to be competent to provide advice about vaccination and such opinion was more frequent for Graduate compared to Undergraduate students (Chi-square=9.590; p=0.002). Among those who currently consider themselves to be competent to provide advice about vaccination (107 students), only 21 students do not intend to get vaccinated against COVID-19, while 86 intend to get vaccinated against COVID-19. A total of 59.7% of all questioned students think that they will be competent to provide advice after finishing current study program and 82% use professional literature and scientific papers as a source of information. Majority of students (84.8%) would advise others to vaccinate according to the recommended vaccination/immunization schedule and 72.7% would advise others to vaccinate against COVID-19. Approximately half of the tested students (53.2%) think that they have influence on the opinion of the people around them regarding vaccination and 54.4% were asked about their opinion by others (Table 3), mainly because of their education (83.4%).

Results of binary logistic regression (Table 4) indicate that students with the positive attitude regarding safety and effectiveness of COVID-19 vaccines and students considering vaccines generally safe and vaccination against COVID-19 important for disease control, as well as those who feel exposed to COVID-19 were more likely to accept COVID-19 vaccine. Neither students' gender, study level (Undergraduate or Graduate) nor reading professional literature and scientific papers is predictive of the

Table 3. *Responses of the students and comparison of responses among students that are hesitant about COVID-19 vaccine and those that are willing to be vaccinated against COVID-19. Statistically significant differences (p<0.05) between COVID-19 vaccine-hesitant and COVID-19 vaccine-accepting group obtained by Chi-square test or Fisher's exact test are indicated by asterisk (*).*

Question	Answers	N (%[a])	COVID-19 vaccine acceptance		Chi square; p value[b]
			No N=116 (32.7%)	Yes N=239 (67.3%)	
Gender	Male	88 (24.8%)	28	60	0.039;
	Female	267 (75.2%)	88	179	0.843
University	Osijek	200 (56.3%)	64	136	0.095;
	Zagreb	155 (43.7%)	52	103	0.758
Study level	Undergraduate	273 (76.9%)	93	180	1.038;
	Graduate	82 (23.1%)	23	59	0.184
Have you been diagnosed with COVID-19?	No	278 (78.3%)	86	192	1.766;
	Yes	77 (21.7%)	30	47	0.184
Have you personally or someone close to you experienced severe COVID-19 symptoms?	No	274 (77.2%)	90	184	0.016;
	Yes	81 (22.8%)	26	55	0.900
Do you think that vaccination against infectious diseases is generally important for an individual's health?	No	17 (4.8%)	12	5	0.002*
	Yes	338 (95.2%)	104	234	
Do you think that vaccination against infectious diseases is generally important for public health?	No	13 (3.7%)	10	3	0.001*
	Yes	342 (96.3%)	106	236	
Do you think that vaccination according to national immunization schedule should be mandatory?	No	99 (27.9%)	58	41	41.894;
	Yes	256 (72.1%)	58	198	<0.001*
Do you generally consider vaccines safe?	No	39 (11%)	34	5	<0.001*
	Yes	316 (89%)	82	234	
Do you generally consider vaccines effective?	No	11 (3.1%)	11	0	<0.001*
	Yes	344 (96.9%)	105	239	
Do you consider vaccines against COVID-19 currently available in the EU safe?	No	74 (20.8%)	62	12	120.933;
	Only some	149 (42%)	41	108	<0.001*
	Yes	132 (37.2%)	13	119	
Do you consider vaccines against COVID-19 currently available in the EU effective?	No	55 (15.5%)	48	7	107.089;
	Only some	118 (33.2%)	44	74	<0.001*
	Yes	182 (51.3%)	24	158	
Do you think that vaccination against COVID-19 is important for disease control?	No	50 (14.1%)	45	5	<0.001*
	Yes	305 (85.9%)	71	234	
Do you currently consider yourself exposed to COVID-19?	No	177 (49.9%)	83	94	32.432;
	Yes	178 (50.1%)	33	145	<0.001*
Do you consider yourself at significant risk of COVID-19?	No	274 (72.2%)	105	169	17.396;
	Yes	81 (22.8%)	11	70	<0.001*
Do you currently consider yourself competent to give advices about vaccination?	No	248 (69.9%)	95	153	11.857;
	Yes	107 (30.1%)	21	86	0.001*
Do you think that you will be competent to give advices about vaccination after finishing current study program?	No	143 (40.3%)	64	79	15.882;
	Yes	212 (59.7%)	52	160	<0.001*
Would you advise others to get vaccinated according to the national immunization schedule?	No	54 (15.2%)	42	12	58.890;
	Yes	301 (84.8%)	74	227	<0.001*
Would you advise others to get vaccinated against COVID-19?	No	97 (27.3%)	70	96	12.772;
	Yes	258 (72.7%)	46	143	<0.001*
Do you think that your attitudes about vaccination affect the attitudes of people around you?	No	166 (46.8%)	64	98	6.319;
	Yes	189 (53.2%)	52	141	0.012*
Do people around you ask you for vaccination advice?	No	162 (45.6%)	81	16	156.749;
	Yes	193 (54.4%)	35	223	<0.001*
In the position of a teacher, do you think you could significantly affect pupil's opinion about vaccination?	No	58 (16.3%)	27	31	6.067;
	Yes	297 (83.7%)	89	208	<0.001*
Do you use professional literature and scientific papers as a source of information?	No	64 (18%)	26	38	2.243;
	Yes	291 (82%)	90	201	0.134
In the position of a teacher, would you use additional literature (professional literature, scientific papers) in addition to the obligatory literature when preparing for classes?	No	6 (1.7%)	2	4	1.000
	Yes	349 (98.3%)	114	235	

[a] Represents the percent from total number of participants (N=355).
[b] If only the p value was presented, but not the Chi-square value, then Fishers exact test was used.

Table 4. *Results of binary logistics regression model presented as adjusted odds ratio (Exp(B)), confidence interval (95% CI) and p value. Statistically significant p values are indicated with asterisk (*).*

Variable	Exp(B)	95% CI	P value
Gender	1.254	0.572 – 2.748	0.572
Study level	1.145	0.503 – 2.606	0.746
Have you been diagnosed with COVID-19?	0.883	0.411 – 1.895	0.749
Have you personally or someone close to you experienced severe COVID-19 symptoms?	0.537	0.257 – 1.122	0.098
Do you think that vaccination against infectious diseases is generally important for an individual's health?	1.968	0.233 – 16.603	0.534
Do you think that vaccination against infectious diseases is generally important for public health	0.289	0.015 – 5.729	0.415
Do you generally consider vaccines safe?	5.546	1.644 – 18.708	0.006*
Do you consider vaccines against COVID-19 currently available in the EU safe?	2.826	1.529 – 5.221	0.001*
Do you consider vaccines against COVID-19 currently available in the EU effective?	2.495	1.390 – 4.479	0.002*
Do you think that vaccination against COVID-19 is important for disease control?	11.241	3.348 – 37.743	<0.001*
Do you currently consider yourself exposed to COVID-19?	2.375	1.196 – 4.713	0.013*
Do you consider yourself at significant risk of COVID-19?	2.480	0.949 – 6.482	0.064
Do you currently consider yourself competent to give advices about vaccination?	1.637	0.740 – 3.623	0.224
Do you use professional literature and scientific papers as a source of information?	0.876	0.378 – 2.029	0.757
Constant	0.009		<0.001

odds to accept COVID-19 vaccine, same as previous experience with COVID-19 (i.e. being infected, experiencing severe COVID-19 symptoms or knowing someone close to them who experienced severe COVID-19 symptoms). The Hosmer-Lemeshow (Chi-square=6.597; p=0.581) as well as Omnibus tests (Chi square=199.112; p<0.001) indicated goodness of fit of the model.

DISCUSSION

Results of our study revealed substantial portion of Croatian biology students hesitant about COVID-19 vaccine. Although their general opinion about vaccination was mostly positive, approximately one third of biology students did not intend to be vaccinated against COVID-19 at the time of questioning.

Vaccine hesitancy has been previously recognized as a problem in Croatia. Hesitancy has been recorded among health care providers *(28, 29)* and also towards mandatory child vaccination programs *(30–32)*. According to available data, level of COVID-19 vaccine acceptance in Croatia in November 2020 was very low (41%) *(14)*. Undeniably, questioned Croatian biology students showed substantially higher COVID-19 acceptance rate (67.3%) compared to rate reported by Wouters et al. *(14)*, which is a promising finding. However, overall level of vaccine acceptance in Croatia might still not be sufficient for reaching herd immunity *(33, 34)*.

In comparison to Croatia, university students in some other countries were more willing to get vaccinated against COVID-19. A 91.64% of students from university in the northwest United States reported intentions to accept COVID-19 vaccine in November 2020 *(15)*. Study conducted in China from the end of December 2020 to the mid of the January 2021 revealed that 76.3% of Chinese college students were willing to vaccinate *(18)*, while in two studies conducted in Italy, 86.1% *(17)* and 94.73% *(19)* of students reported intention to vaccinate, respectively. On the other hand, lower intention to vaccinate than determined in this study, was observed in January 2021 among university students in Jordan where only 34.9% intend to vaccinate, while another 25.5% would maybe accept COVID-19 vaccine *(20)*. COVID-19 vaccine acceptance was also low among medical students in Egypt with 35% of acceptance and considerably high hesitancy and refusal rate *(23)*. Differences reported from the studies conducted in different countries might reflect overall attitude in particular country, but may also be associated with time of questioning. Palamengi et al. *(35)* observed decrease of COVID-19 compliance due to decrease of trust in science and vaccination between first and second phase of the Italian pandemic. However, more positive opinion might be established over time, as more and more people receive vaccine without consequences. Our study has been conducted in the time when several COVID-19 vaccines were authorized and vaccination was in process. Nevertheless, as indicated by this study, Croatian biology students have concerns about safety and effectiveness of all or some of available COVID-19 vaccines, despite being approved for human use and intensively

administered worldwide. The problem of low public trust in COVID-19 vaccine due to its development being significantly faster than usual is evident from many previous surveys and considered to be one of the main issues contributing the COVID-19 vaccine hesitancy *(12, 14)*. Worrying about side effects, safety and efficiency was shown to affect COVID-19 vaccine acceptance *(12, 21, 36)*. Croatian biology students expressed concerns about safety, with 20.8% of students revealing that they do not think COVID-19 vaccines are safe, but also about effectiveness, with 15.5% of students revealing that they do not think COVID-19 vaccines are effective. Substantial portion of tested students considers some but not all approved COVID-19 vaccines safe and efficient, 42% and 33.2%, respectively. Opinion about safety and effectiveness of COVID-19 vaccines was significantly associated with vaccination decision. Students who consider vaccines against COVID-19 available in EU safe and effective had higher odds for accepting vaccination. Results obtained in this study support presumption that, along with safety, efficiency and affordability, public confidence and trust in COVID-19 vaccines and those who deliver them is crucial for increasing vaccine acceptance *(14)*. The importance of reassuring students in COVID-19 vaccines' safety in order to increase number of those willing to vaccinate is also evident from response that approximately half of those who are currently not willing to vaccinate would accept vaccination after more testing.

Significant positive predictor of higher odds for vaccination acceptance in this study was perceived importance of COVID-19 vaccination. Students who think that vaccination against COVID-19 is important for disease control were more likely to accept COVID-19 vaccines. Only 22.8% of students responded that they feel at a significant risk, which might be due to generally low risk assessment for young and healthy individuals *(37, 38)*, however more were aware that they are exposed to COVID-19 and might get infected (50.1%). This was also shown to be associated with COVID-19 vaccine acceptance among students in this study. Significance of the perceived risk of the disease and a perceived likelihood of COVID-19 infection was in some cases, but not always, shown to be a predictor of vaccination intention *(36)*. On the other hand, being tested positive or experiencing severe COVID-19 symptoms, personally or among close ones, was not found to be associated with COVID-19 vaccines acceptance.

Various sociodemographic factors (e.g. gender, age, level of education, income, marriage status, being parent or not, living in urban or rural area) were found to be associated with the willingness to be vaccinated against COVID-19. However, this was not generally applicable and significance of particular factor in making decision about COVID-19 vaccination is variable among different populations *(9, 11, 18, 35, 39, 40)*. Effect of gender was assessed in this study as well, but it was not shown to be associated with COVID-19 vaccines compliance. This study included students from two Croatian Universities located at the opposite sides of country, of which one is within the capital of Croatia. However, their intent to vaccinate was not found to be associated with University they attended. The level of education (Undergraduate or Graduate) also did not affect odds of COVID-19 acceptance. Although some investigations indicated that study curricula can affect knowledge and attitude towards COVID-19 and vaccination in general *(18, 41)*, the literacy on health-related issues might not be the most important factor shaping the students' vaccination attitude, rather other motivational and physiological factors might be included in making decision regarding vaccination *(17)*. Prior to COVID-19 outbreak vaccine hesitancy and refusal *(42)*, as well as low vaccine coverage *(43)* were reported among healthcare students. Furthermore, Barello et al. *(17)* did not observe difference in the intention to vaccinate against COVID-19 among health-care and non-healthcare students in Italy and low COVID-19 vaccine acceptance and high levels of hesitancy and refusal was reported among medical students in Egypt *(23)*. It would be valuable to compare opinion of biology students with students of other study programs in Croatia and test whether biology curricula affect attitude towards COVID-19 and vaccination. Along with confidence, complacency and convenience *(4)*, additional factors such as calculation (engagement in extensive information searching) and aspects pertaining to collective responsibility (willingness to protect others) are considered to be important in forming the vaccination behaviour of an individual *(44)*. According to the reasons indicated by those who are currently willing to vaccinate, sense of social solidarity and collective responsibility *(44, 45)* might be highly important for Croatian biology students. Compared to 82% that are willing to vaccinate against COVID-19 for their own health, 97% would do so for the health of their family members and 94.1% because it is socially useful.

Use of professional literature and scientific papers as a source of information was indicated by 82% of students, but not all of them intend to get vaccinated against COVID-19. This question was very general and it presumes that all students are able to differentiate peer-reviewed and reliable literature from other available information sources of which some possibly disseminate pseudoscientific fallacies. However, some participants might not be able to do so, although we do not consider this to be main reason for the observed result, since their general opinion on vaccination is mainly positive and the majority generally considers vaccines to be safe and effective. It has to be pointed out that some potentially important aspects were not included in the study, such as the impact of family influence, intentions of students' parents and close family members as well as their friends to vaccinate against COVID-19. This could significantly shape stu-

dent's final decision to accept or not to accept vaccination, regardless of the scientific knowledge they possibly adopted by reading the scientific literature.

Highly specific subpopulation has been questioned in this study. Although obtained results could not be used to predict overall attitude of Croatian citizens towards COVID-19 vaccine, willingness of young adults to get vaccinated could significantly contribute to stopping the pandemic *(16)*. One of the reasons for choosing biology students in this survey is their potential role in rising awareness about importance of vaccinations among others. The students seem to be aware of this. More than half of them were asked about vaccination by others, mainly due to their education, and 83.7% think that in the future as a teacher they could significantly influence pupil's opinion about vaccines. However, only 59.7% of students think that they will be competent to give advice about vaccination after finishing current study program and only 30.1% feel competent at the moment. Among those that consider themselves to be competent at the moment to give advice about vaccination, the majority intends to get vaccinated against COVID-19, which could contribute to promoting vaccination. On the down side, some do not intend to get vaccinated against COVID-19 and could advocate COVID-19 vaccine hesitancy to others. Although during their study they receive basic knowledge regarding infectious diseases and vaccination, they are not trained to provide advices regarding vaccination. Regardless, the majority of students would advise vaccination according to national vaccination schedule. After decades of high vaccine coverage for mandatory vaccines, slow decrease has been observed in the last years *(31)*. More intensive involvement of biology teachers and future biology teachers in promoting vaccine-positive attitudes might be a promising strategy for ensuring optimal vaccine coverage. This would influence vaccine behaviour of the new generations with a long-term benefit for public health. Additionally, it can indirectly support changes of the attitudes of children's vaccine hesitant family members, since it was suggested that health education brought by children from school can positively affect their parents' opinion about health-related issues *(25)*.

Simplicity of the questionnaire consisting of forced-choice yes/no questions does not enable assessment of all aspects of vaccine hesitancy among students. However, results of this study provide first insight into intention of Croatian biology students to vaccinate against COVID-19, factors which affect the odds for accepting COVID-19 vaccine as well as their intention to promote vaccine-positive attitudes. Additional future surveys should also include a continuous measure of the attitude. This would give more detail insight into the problem of vaccine hesitancy, thereby contributing in defining the guidelines for effective actions to decrease this important public health problem.

CONCLUSIONS

Concerns about safety and effectiveness of COVID-19 vaccines, perceived importance of vaccination for stopping COVID-19 and perceived personal risk for becoming infected were shown to significantly influence acceptance of COVID-19 vaccines among Croatian biology students, while COVID-19 vaccine compliance could not be associated with gender, level of education or the University they attend. Lack of confidence in COVID-19 vaccines seems to have prevailed students' general positive attitude and baseline knowledge regarding vaccination. Obtained results indicate urgent need to find appropriate approach for addressing concerns regarding safety and effectiveness of COVID-19 vaccines as well as to raise students' awareness about their possible role in current pandemic and overall public health. Increasing competence of biology students as future biology teachers to provide scientifically based information about vaccination using age-appropriate teaching methods could significantly contribute to decreasing vaccine hesitancy in general population.

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Availability of data and material: The data presented in this study are available on request from the corresponding author.

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