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Original article

Prevalence of infectious diseases, immunity to vaccine-preventable diseases and chronic medical conditions among Ukrainian refugees in Germany – A cross sectional study from the German Network University Medicine (NUM)

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ABSTRACT

Background: Vulnerability to infectious diseases in refugees is dependent on country of origin, flight routes, and conditions. Information on specific medical needs of different groups of refugees is lacking. We assessed the prevalence of infectious diseases, immunity to vaccine-preventable diseases, and chronic medical

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conditions in children, adolescents, and adult refugees from Ukraine who arrived in Germany in 2022.
Methods: Using different media, we recruited Ukrainian refugees at 13 sites between 9–12/2022. An antigen test for acute respiratory syndrome coronavirus type 2 (SARS-CoV-2) infection, serologies for a range of vaccine-preventable diseases, as well as interferon gamma release assays (IGRAs) for tuberculosis (TB), and SARS-CoV-2 were performed. We assessed personal and family history of chronic medical conditions, infectious diseases, vaccination status, and conditions during migration.
Results: Overall, 1793 refugees (1401 adults and 392 children/adolescents) were included. Most participants were females (n = 1307; 72·3%) and from Eastern or Southern Ukraine. TB IGRA was positive in 13% (n = 184) of the adults and in 2% (n = 7) of the children.

Serology-based immunological response was insufficient in approximately 21% (360/1793) of the participants for measles, 32% (572/1793) for diphtheria, and 74% (1289/1793) for hepatitis B.
Conclusions: We show evidence of low serological response to vaccine-preventable infections and increased LTBI prevalence in Ukrainian refugees. These findings should be integrated into guidelines for screening and treatment of infectious diseases in migrants and refugees in Germany and Europe. Furthermore, low immunity for vaccine-preventable diseases in Ukrainians independent of their refugee status, calls for tailor-made communication efforts.

Evidence before this study

Prior to study initiation in mid-2022, PubMed was searched using the terms "Ukraine", "refugee", "health" and "infection". Previous research identified a number needed to screen of 862, to identify one active case of tuberculosis (TB) among Ukranian refugees. Two studies reported increased rates of TB, HIV, and hepatitis B and C in Ukrainian adults residing in Ukraine. In addition, an increased rate of chronic diseases and carriage of multidrug-resistant organisms was previously documented. None of the studies, however, included children and combined this information with vaccination rates and serological evidence of immunity to vaccine-preventable diseases.

Added value of this study

This study screened a large number of Ukrainian refugees during the first months of the war and provides information on their overall health and immunization status. The results reveal low immunity for vaccine-preventable infections and an increased prevalence of latent TB in this population.

Implications of all the available evidence

The results from this study could help to improve guidelines for screening and treatment of infectious diseases in migrants and refugees in Germany and Europe and to design tailor made communication efforts to reduce vaccine hesitancy.

Introduction

Since the beginning of the Russian war against Ukraine on February 24, 2022, many people from Ukraine have sought refuge in European countries. More than 1050,000 Ukrainian refugees have already arrived in Germany with no end to this conflict in sight [1]. In this context, health care for refugees must be guaranteed with a special focus on basic medical care, including mental health issues, and the prevention and control of infectious diseases. Vulnerability to infectious diseases in refugees is dependent on country of origin, flight routes and conditions, as well as refugee characteristics. The risk of transmission increases in accordance with the prevalence of chronic infections in the refugee population. Harmonized German or European guidelines recommending screening or other measures tailored to these characteristics are missing. This is particularly true for refugee children and adolescents. [2].

In Ukraine, infectious diseases and in particular tuberculosis (TB), human immunodeficiency virus (HIV), and hepatitis B and C play a major role in public health. In 2019, Ukraine reported the second highest number of TB cases (28,539) in Europe, with an incidence of 65 cases per 100,000 and a mortality rate of 7·3 per 100,000. Children and adolescents are at an increased risk of contracting or re-activating TB. [3] Ukraine is also one of the 10 countries worldwide with the highest number of multidrug-resistant TB (MDR-TB), (29% of new diagnoses in 2019). [4] In 2020, about 260,000 adults and children (about 1% of the population) were infected with HIV, only 58% of whom were receiving antiretroviral therapy (ART). [5] Furthermore, about 3·5% of the population is infected with hepatitis C, 10% of which is under medical treatment. Hepatitis B virus infections are also significantly more prevalent in Ukraine than in

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Germany. National vaccination recommendations in Ukraine are similar to most Western European countries with minor differences, such as mandatory BCG at birth and second MMR at 6 years of age. [6].

In addition to chronic infectious diseases, there is a high incidence of various vaccine-preventable diseases in Ukraine. Since the onset of the coronavirus disease 2019 (COVID-19) pandemic, a total of 5556,030 confirmed cases and 112,394 deaths have been reported in Ukraine as of June 7, 2023 (WHO). Shortly before the start of the war, the emergence of the Omicron variant led to a fourth and largest-ever wave of transmission of Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) in Ukraine. By the end of February 2022, about 35% of the population had been vaccinated twice, which is below the European average. [6] From 2018–2021, > 110,000 measles cases were reported in Ukraine. [4] In October 2021, an outbreak involving 21 people infected with circulating vaccine-associated poliovirus type 2 (cVDPV2) was reported in the northwest/west of the country, including 2 cases with flaccid paralysis. Third polio vaccination coverage is 84·2%. [7].

Given suspected gaps in standard vaccinations and high rates of vaccine-preventable infections, continuing routine vaccinations and identifying existing vaccination gaps, taking into account vaccination documentation, vaccination history, and the national recommendation are crucial to protect the health of refugee Ukrainians individually and to prevent outbreaks.

The Network University Medicine (NUM) was founded in 2020 to unite research efforts of university hospitals in Germany in response to the COVID 19 pandemic and the associated scientific, political, and social challenges. With the end of the pandemic, NUM is transitioning into other areas of research with a major impact on national health. With the beginning of the Ukraine war, the NU(M)KRAINE study was launched to investigate vaccinations and vaccine-preventable diseases as well as other important infections in a national and multicentre screening programme.

Methods

In this multicentre cross-sectional study, subjects were recruited at 13 sites (Augsburg, Berlin, Bochum, Dresden, Frankfurt am Main, Halle, Hamburg, Hannover, Kiel, Magdeburg, Munich, Oldenburg, and Würzburg) from 09/05/2022 to 12/21/2022. All study participants had fled from Ukraine to seek refuge in Germany. Adults and fully capable adolescents were required to provide personal informed consent, children and not fully capable adolescents required parental consent or alternatively consent of a person with custody or guardianship. There were no exclusion criteria. Recruitment strategies included inclusion of refugees hospitalized at the study sites for any reason, inclusion on site in an ambulatory setting or local inclusion in the refugees' local accommodations in cooperation with local health authorities. Dissemination of information intended to attract study participants was distributed through direct contact in the local accomodations, as well as through different social media channels (e.g. Facebook, WhatsApp, Viber, Telegram). All participant-related study activities were accompanied by interpreters, to overcome potential language barriers. Ethical approval for inclusion of adults (2022–831), adolescents and children (22–7623) had been obtained at all study sites prior to study initiation.

After provision of written informed consent, study participants underwent a semi-structured interview covering socio-demographic aspects, risk factors, prior medical history, current symptoms, as well as vaccination status and personal attitude towards different vaccinations (Supplement 1). Socio-demographic and data concerning the conditions of travel to Germany were retrieved from one household member only and considered representative of the entire household.

The interview was followed by a physical examination, draw of a blood sample (10 ml serum and 2 ×5 ml lithium heparin, volume adjustments according to age) and a nasopharyngeal COVID-19 rapid antigen test. In case of a positive rapid antigen test, two additional swabs were taken for confirmation by polymerase chain reaction (PCR) and strain sequencing. Serum samples were centrifuged on site at 2500xg for 15 min and transported along with the uncentrifuged lithium heprarin samples to the central laboratory at University Hospital Oldenburg within 24 h at + 4 °C to + 8 °C. PCRs were performed centrally at University Hospital Frankfurt.

Serum samples were used to determine antibodies against polio, diphtheria, tetanus, rubella, *H. influenzae*, measles, mumps, pertussis, HIV, hepatitis A, B and C, varicella, and SARS-CoV-2 (spike and nucleocapsid). In addition, interferon-gamma-releasing assays (IGRA) were performed for TB and SARS-CoV-2 using lithium heparin. Assays were performed according to the manufacturer's recommendations, further details are given in supplement 2.

Pseudonomyzation of patient data and management of analytical results was carried out using SecuTrial® and CentraXX®. Clincial and lab data were kept separately under different pseudonyms and were merged by a trusted third party. All data were subjected to plausibility checks, both during the ongoing recruitment process and after completion of the data.

Data were analyzed descriptively using the statistics software R (version 4.3.2.). Categorical variables are summarized in absolute and relative frequencies (percentages). For age, median, interquartile range and minimum and maximum were calculated. Prevalences were not adjusted for age or sex.

Results

In total, 1793 refugees, 1401 adults and 392 children/adolescents (0–18 years), were included into the study (Table 1 and Fig. 1). The majority were females (1307, 73%) with a median age of 41 years in adults (range: 18–90). Among 392 included children, gender was almost equally distributed with 55% females (n = 214) and a median age of 12 years (range: 11 months-18 years). Over 90% of the participants (n = 1646) were born in Ukraine. Most of the household members came either from the Kharkiv (n = 226, 19%) or Kyiv (n = 164, 14%) area. About 50% of the households came either from Eastern or Southern Ukraine and 60% (n = 709) from cities with > 500.000 inhabitants. Almost 60% (n = 829) of the adult participants had a completed university education and further 29% (n = 410) a high school diploma. Approximately 70% (n = 974) of the adults had a permanent employment before fleeing the country, 7% (n = 110) were pursuing further education and 8% (n = 114) were already retired. Most of the participants had only poor (n = 720, 41%) or no knowledge (n = 802, 46%) of German language at the time of examination. Even though recruitment of hospitalized patients was not forbidden, this recruitment pathway was scarcely used. With very few exceptions, participants were recruited at refugee centres and in outpatient departments.

Overall, 32% of the participants reported having any chronic disease (children: n = 43, 11%; adults: n = 513, 37%). Cardiovascular (n = 264, 19%), renal (n = 110, 8%), rheumatological (n = 101; 7%), and pulmonary diseases (n = 50, 4%), as well as neurological and psychiatric conditions (n = 84, 6%) were reported most frequently by adult participants. Regarding chronic infections, 14 (1·0%) adult participants reported a chronic hepatitis B, 22 (1·6%) chronic hepatitis C, and 21 (1·5%) reported being HIV positive. Eight participants (0·6%) self-reported active TB disease, of which four cases were pulmonary TB.

In up to 35% of participants, depending on the disease discussed, vaccination status was unknown, and documentation was missing. Overall, 855 adults, equaling 78% of those providing information on vaccination status, recalled that they had been vaccinated against

measles, 880 (88%) against pertussis, 974 (92%) against polio, 957 (69%) against SARS-CoV-2 and 1167 (93%) had a BCG vaccination. In children, the corresponding numbers were 89% (n = 319) for measles, 90% (n = 304) for pertussis, 95% for polio (n = 337), 105 (n = 39) for SARS-CoV-2% and 94% (n = 352) for TB.

Results of qualitative and quantitative serological analyses are shown in Tables 2 and 3, as well as in Fig. 2. Antibodies against polio as well as anti-S SARS-CoV-2 and anti-N SARS-CoV-2 antibodies were detectable in 99% (n = 1729/1793) and 95% (n = 1658/1793), respectively. The SARS IGRA was positive in 72% (n = 1220). Antibody levels against measles and mumps and pertussis were negative in 21% (n = 360), 25% (n = 444) and 94% (n = 1637), respectively. Vaccine or infection-induced immunity against hepatitis B was found in 26% (n = 454), whereas 1% (n = 15) had positive HbsAg as a marker of hepatitis B infection. Overall, 62 participants (3·6%), corresponding to three times the number of self-reported infections, were positive for hepatitis C and 646 (37%) had evidence of prior hepatitis A infection and/or immunization. All except one HIV positive individual (n = 22; 1·3%) had been aware of their diagnosis prior to their entry into Germany.

In comparison to the German population, the percentage of adult participants with evidence of immunity against hepatitis A and B was significantly higher (p < 0,01 for both), whereas this difference could not be observed in the paediatric participants. [10,11].

Significant differences between German and Ukrainian children (87.8% vs 64%; p < 0,01) were observed in varicella zoster immunity, probably reflecting different vaccination policies [21].

A total of 191 individuals (184 adults and 7 children; 11%) were found to have a positive TB IGRA and further investigation of active TB outside the study was recommended.

Discussion

To date, this is the largest study, assessing the health status of refugees from Ukraine arriving in Germany, with a focus on chronic infectious diseases and immunity against vaccine-preventable diseases. The study highlights the insufficient immunity to vaccine-preventable diseases that could fuel local outbreaks, particularly in aggregate settings, i.e. measles and pertussis. Furthermore, we demonstrated a substantial number of unrecognised exposures with hepatitis C virus and active HIV infections, as well as a substantial amount of pre-existing comorbidities.

Peitrowicz et al. and Pandey et al. described the expected spectrum of comorbidities in Ukrainian refugees and the specific challenges on the side of the receiving countries associated with the provision of medical care. [8] In line with these findings and as defined in the aims of our study, we were able to identify different aspects that may merit particular attention during the reception of Ukrainian refugees in Germany.

Although the median age was only 41 years in our cohort, we identified a high prevalence and broad range of comorbidities. Overall, 32% of the study participants presented with any kind of pre-existing comorbidity. Likewise, our results are in line with previous reports on the high prevalence of chronic infectious diseases in Ukraine and in Ukrainian refugees. [4,5,9] We detected a relatively high number of infections with hepatitis B virus (HBV, 1.1% in adults and 0% in children) and hepatitis C virus (HCV, 4·4% in adults and 0·6% in children) in the assessed population. In comparison, prevalence of HBV in the general German population equals 0·3% in adults and 0·2% in children showing a significantly higher percentage of infection in Ukrainian aduts, but not in children. [10,11] The prevalence of HCV in the adult German population was significantly lower and estimated as 0·3–0·6% (p < 0,01). [10,12] A diagnosis of HIV was confirmed in 1·5% of the adults and 0·3% of the children in our study. In contrast, the number of German adults and children infected with HIV is estimated to be lower at only 0·1% (n = 91,400)

Table 1
Socio-demographic and clinical data of the Ukrainian refugees included in the study.

	All (n = 1793)	Adults (n = 1401)	Children (n = 392)
Gender			
Female, n (%)	1307 (72·3)	1093 (78·1)	214 (54·7)
NA	2	1	1
Age [years]			
Median (IQR)	37 (20; 47)	41 (33; 51)	12 (8; 15)
Min – Max	< 1 - 90	18 - 90	< 1 – 18
Country of birth			
Ukraine, n (%)	1646 (91·9)	1261 (90·0)	385 (98·5)
Other country, n (%)	146 (8·2)	140 (10·0)	6 (1·5)
NA	1	-	1
Highest level of education			
Basic high school diploma (up to 12th grade), n (%)	-	153 (11·0)	-
Technical school, or college degree n (%) *	-	410 (29·5)	-
University degree, n (%)	-	829 (59·6)	-
NA	-	9	-
German language skills			
Very good, n (%)	8 (0·5)	6 (0·4)	2 (0·6)
Good, n (%)	37 (2·1)	31 (2·2)	6 (1·6)
Moderate, n (%)	192 (10·9)	146 (10·5)	46 (12·6)
Poor, n (%)	720 (40·9)	591 (42·4)	129 (35·3)
No relevant German skills, n (%)	802 (45·6)	620 (44·5)	182 (49·9)
NA	34	7	27
Employment			
Employed, n (%)	976 (56·5)	974 (70·6)	2 (0·6)
In education (incl. school), n (%)	425 (24·6)	110 (7·1)	315 (90·5)
Retired, n (%)	114 (6·6)	114 (8·3)	-
Not employed/in education for other reasons, n (%)	212 (12·3)	181 (13·1)	31 (8·9)
NA	66	22	44
Pregnancy, n (% of female)	-	7 (0·7)	-
NA of female	-	30	-
Chronic diseases			
Any chronic disease, n (%)	556 (31·7)	513 (37·4)	43 (11·4)
NA	41	28	13
Chronic hepatitis, n (%)	-	45 (3·3)	-
NA	-	47	-
Chronic hepatitis B, n	-	14	-
Chronic hepatitis C, n	-	22	-
Other chronic hepatitis, n	-	7	-
HIV infection, n (%)	-	21 (1·5)	-
NA	-	33	-
Tuberculosis, n (%)	-	8 (0·6)	-
NA	-	33	-
disseminated, n	-	1	-
Pulmonary	-	4	-
Extrapulmonary	-	2	-
Cardiovascular disease, n (%)	-	264 (19·6)	-
NA	-	57	-
Chronic lung disease, n (%)	-	50 (3·7)	-
NA	-	38	-
Chronic kidney disease, n (%)	-	110 (8·1)	-
NA	-	48	-
Rheumatic/ immunological disorder, n (%)	-	101 (7·4)	5 (1·33)
NA	-	41	17
Diabetes mellitus, n (%)	35 (2·0)	33 (2·4)	2 (0·5)
NA	61	47	14
Solid tumor, n (%)	52 (3·0)	50 (3·7)	2 (0·5)
NA	57	42	15
Hemato-oncological disease, n (%)	10 (0·6)	8 (0·6)	2 (0·5)
NA	47	32	15
Chronic neurological/ mental disorder, n (%)	-	84 (6·1)	7 (1·9)
NA	-	34	15
Congenital anomaly, n (%)	-	-	19 (5·1)
NA	-	-	17

(*continued on next page*)

Table 1 (*continued*)

	All (n = 1793)	Adults (n = 1401)	Children (n = 392)
Developmental disorder, n (%)	-	-	22 (5·9)
NA	-	-	18
Epilepsy, n (%)	-	-	5 (1·3)
NA	-	-	12

NA=unknown, percentages are calculated with reference to the known values
*primary level of higher education

and 0·007% (n = 801), respectively [13]. Based on our screening, one case of a previously unknown HIV infection could be identified. Similarly, previous assessments of Ukrainian refugees reported a low, yet detectable number of undiagnosed HIV infections in their cohort. [14] Based on this data, and due to the comparatively high overall prevalence of HIV in Ukraine, universal screening can be discussed. Likewise, patient-reported cases of active tuberculosis in our cohort were more frequent than one would expect in the German overall population with an incidence of 4·7/100,000 inhabitants. [14] As a limitation of our study, we were unable to follow-up all participants with a positive TB IGRA to exclude active TB, as the diagnostic follow-up was not part of our study. Patients with a positive TB IGRA were informed about the result, and performance of a chest x-ray outside the research setting was recommended.

The general reliability of comparison between the German overall population and our study population is limited by the fact that our study population was not selected using a randomized process, but awareness of the study on the side of the participants was raised through different channels of communication in both refugee camps and the refugee community. On this basis, we attracted refugees with an above-average education, who are generally less likely to suffer from chronic infectious diseases, due to their social status. On the other hand, participating sites approached a few locally hospitalized Ukrainian refugees. Their hospital admission was often due to complications of chronic infections, thus representing a recruitment bias towards a higher probability of infections. Another factor in the difference between the expected and observed prevalence rates could be that our study included a higher number of females and therefore does not mirror the distribution of sex in the Ukraine. Despite these methodological limitations, we believe that our results in the context of the existing evidence base justify recommendation of standard testing for HBV (HBs antigen and anti-HBc IgG/IgM), HCV (HCV antibody), HIV (HIV antibody/antigen), and TB (IGRA) in incoming Ukrainian refugees, but should also be offered to regular travellers from the same area. Especially testing for TB is further supported by the fact that Ukraine is among the highest-burden countries for drug-resistant TB worldwide. Refugees with positive TB IGRA should receive further diagnostics to rule out active TB. This approach is also supported by results of a screening intervention performed in a network of French TB centers. Guthman et al. identified a number needed to screen of 862 Ukrainian refugees, to identify one case of active TB. [9] Concerning children, respective screening guidelines have already been implemented in different European countries. [15,16] These, however, contrast with the recommendation of the guidance document of the European Centre for Disease Prevention and Control, which does not recommend universal TB screening in Ukrainian refugees. Besides this guidance document, which focusses on TB screening, no overarching national guidance documents on the general management of screening for chronic infections in Ukrainian refugees could be identified.

The other main focus of our analysis concerned the immunity against vaccine-preventable diseases in our cohort. For many of these communicable diseases, prevalence of protective immunoglobulin levels was low, particularly for measles, mumps, and pertussis. Given the crowded conditions of accommodation that refugees often face, such gaps in population immunity represent a major health risk not only to other refugees, but also to the local communities into which the refugees will be introduced. Particularly children in day-care facilities and schools may become index patients of local outbreaks in German communities with low vaccination rates. Fortunately, the presence of antibodies against the SARS-CoV 2 spike protein was surprisingly high in our study population, despite Ukraine's reportedly low vaccination rates of only around 40%. [17] As it is unlikely that the vaccination rates are substantially higher in the refugee population than in the general population, the high seroprevalence is most likely due to natural acquisition of antibody responses through infection, as confirmed by the high prevalence of SARS-CoV 2 nucleocapsid antibodies.

Vaccination hesitancy potentially accounts for the limited immunity to several vaccine-preventable diseases in our study population. Troiano et al. reported high percentages of Ukrainians refusing vaccination e.g. against hepatitis B, measles or human papilloma virus ranging from 25–100% for their children and reported reduced rates of vaccination even before the war. [18] Given the

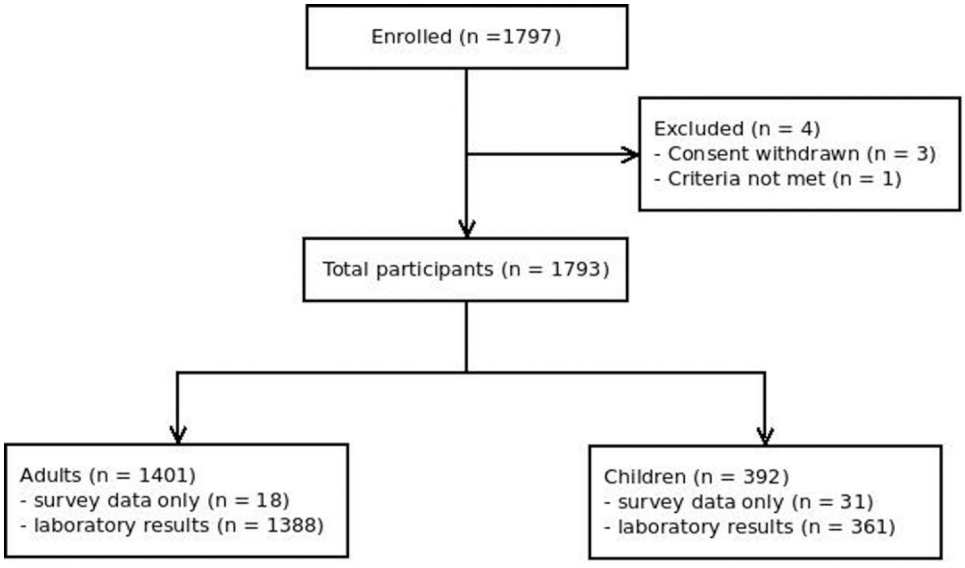

Fig. 1. Strobe Diagram.

Table 2
Serum levels of antibodies to acquired or vaccine preventable diseases.

Categorized Quantitative Analyte	Overall, N = 1793	Adult	Pediatric
Anti-HBs			
< 10	1289 (74%)	1131 (82%)	158 (44%)
> = 10	454 (26%)	252 (18%)	202 (56%)
Missing	50	18	32
***Bordetella pertussis* toxin IgG**			
< 40	1637 (94%)	1299 (94%)	338 (94%)
> = 40	106 (6·1%)	84 (6·1%)	22 (6·1%)
Missing	50	18	32
Diphtheria toxoid IgG			
< 0.01	138 (7·9%)	100 (7·2%)	38 (11%)
> = 0.01 & < = 0.09	434 (25%)	354 (26%)	80 (22%)
> 0.09 & < 1	1052 (60%)	852 (62%)	200 (56%)
> = 1	119 (6·8%)	77 (5·6%)	42 (12%)
Missing	50	18	32
***Haemophilus influenzae* B IgG**			
< 0.15	46 (2·6%)	41 (3·0%)	5 (1·4%)
> = 0.15 & < 1	668 (38%)	540 (39%)	128 (36%)
> = 1	1029 (59%)	802 (58%)	227 (63%)
Missing	50	18	32
Measels IgG			
< 16.5	360 (21%)	304 (22%)	56 (16%)
> = 16.5	1383 (79%)	1079 (78%)	304 (84%)
Missing	50	18	32
Mumps IgG			
< 11	444 (25%)	354 (26%)	90 (25%)
> = 11	1299 (75%)	1029 (74%)	270 (75%)
Missing	50	18	32
Poliomyelitis-1-3 IgG			
< 3	22 (1·3%)	10 (0·7%)	12 (3·3%)
> = 3	1721 (99%)	1373 (99%)	348 (97%)
Missing	50	18	32
Rubella IgG			
< 10	194 (11%)	167 (12%)	27 (7·5%)
> = 10	1549 (89%)	1216 (88%)	333 (93%)
Missing	50	18	32
SARS-CoV2 spike antigen			
< 0.7	14 (0·8%)	11 (0·8%)	3 (0·8%)
> = 0.7	1729 (99%)	1372 (99%)	357 (99%)
Missing	50	18	32
Tetanus toxoid IgG			
< 0.1	92 (5·3%)	56 (4·0%)	36 (10%)
> = 0.1 & < = 0.5	492 (28%)	411 (30%)	81 (23%)
> 0.5	1159 (66%)	916 (66%)	243 (68%)
Missing	50	18	32
VZV IgG			
< 150	229 (13%)	99 (7·2%)	130 (36%)
> = 150	1514 (87%)	1284 (93%)	230 (64%)
Missing	50	18	32

SARS-CoV2 =Severe Acute Respiratory Syndrome Coronavirus-2, IgG=immunoglobulin G, IgM=immunoglobulin M, VZV=varicella zoster virus

Table 3
Qualitative analysis of seroprevalence of acquired or vaccine-preventable diseases.

Qualitative Analyte	Overall, N = 1793	Adult	Pediatric
Anti HAV IgG/IgM positive			
Negative	1097 (63%)	766 (55%)	331 (92%)
Positive	646 (37%)	617 (45%)	29 (8·1%)
Missing	50	18	32
Anti-HBc IgG/IgM			
Negative	1577 (90%)	1219 (88%)	358 (99%)
Positive	166 (9·5%)	164 (12%)	2 (0·6%)
Missing	50	18	32
HCV antibody			
Negative	1669 (96%)	1313 (96%)	356 (99%)
Positive	62 (3·6%)	60 (4·4%)	2 (0·6%)
Missing	62	28	34
Anti-HCc IgM positive			
Negative	166 (100%)	164 (100%)	2 (100%)
Missing	1627	1237	390
HBs-antigen positive			
Negative	1727 (99%)	1368 (99%)	359 (100%)
Positive	15 (0·9%)	15 (1·1%)	0 (0%)
Missing	51	18	33
HIV antigen/antibody positive			
Negative	1720 (99%)	1362 (98%)	358 (100%)
Positive	22 (1·3%)	21 (1·5%)	1 (0·3%)
Missing	51	18	33
SARS-CoV2-nucleocapsid antibody positive			
Negative	85 (4·9%)	74 (5·4%)	11 (3·1%)
Positive	1658 (95%)	1309 (95%)	349 (97%)
Missing	50	18	32
SARS-CoV-2-IGRA positive			
Negative	469 (28%)	320 (24%)	149 (45%)
Positive	1220 (72%)	1037 (76%)	183 (55%)
Missing	104	44	60
TBC IGRA positive			
Negative	1535 (89%)	1187 (87%)	348 (98%)
Positive	191 (11%)	184 (13%)	7 (2·0%)
Missing	67	30	37

HAV=hepatitis A, HBc=hepatitis B core antigen, HBs=hepatitis B surface, HCc=hepatitis C core antigen, HCV=hepatitis C virus, HIV=human immunodeficiency virus, IgG=immunoglobulin G, IgM=immunoglobulin M

infrastructural challenges occurring in the context of war, it is likely that vaccination coverage will decrease even further as the war proceeds. While improving vaccination compliance in this population of refugees should be of highest interest to the receiving countries, achieving this goal represents a major challenge. Since the acceptance of vaccination per se seems to be low in Ukrainians independent of the refugee status, screening and vaccination programs will have to focus not only on offering these services in the native language of the refugees, but also on transforming their perception of the benefits of a complete immunization through vaccination.

Overall, our results suggest that screening for immunity to vaccine-preventable diseases is likely to identify refugees at risk of infection and subsequent transmission. Broad coverage of all vaccine-preventable diseases as practised in our study may not be feasible due to infrastructural and financial constraints. However, the results demonstrate the importance of catch-up vaccinations, considering previous vaccination records and the national recommendations of the host countries. Current recommendations of the German Robert Koch Institute suggest prioritizing performance of the vaccinations against the following infections in Ukrainian refugees (with specific recommendations according to age group): diphtheria, tetanus, pertussis, poliomyelitis, *Haemophilus influenza B*, hepatitis B, measles, mumps, rubella, varicella, saisonal influenca and COVID-19 [19].

As already discussed, our cohort of refugees may not be fully representative of the overall Ukrainian refugee population in Germany, as we cannot be sure whether the high proportion of participants with an advanced level of education is a selection bias during recruitment or a characteristic of the overall population of Ukrainian refugees. It is indeed possible that Ukrainians with a higher level are more likely to flee the country, based on their socio-economic situation. Another bias is introduced through the high proportion of adult females and children in this cohort, due to the fact that men aged 18–65 are not allowed to leave the country. Therefore, conclusions derived from our results may not be fully applicable to Ukrainian male refugees. Finally, we chose not to screen for multidrug-resistant bacterial organisms (MDRO) in our cohort. During the design of the study, we reasoned that detection of colonization with MDRO among refugees would not be likely to result in any benefit for the individual or its family, but potentially in disadvantages due to stigmatization. Other works have, however, shown an increased prevalence of MDRO carriage in Ukrainian refugees hospitalized in Germany [20].

In conclusion, we detected a relevant number of HBV, HCV, HIV, and latent TB infections in our study cohort, which in our view justifies universal screening in the population of Ukrainian refugees

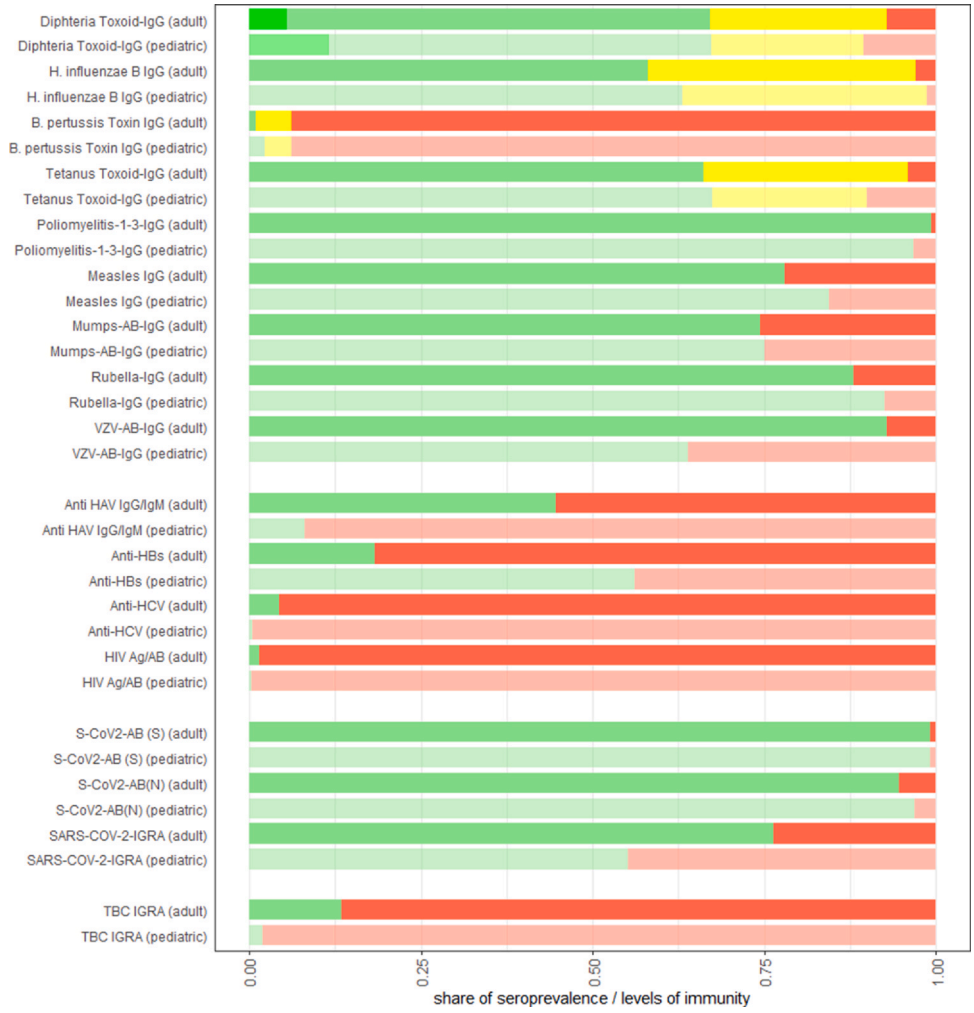

Fig. 2. Relative prevalence of serological responses in adults and children. Immunity, assessed by IgG levels, was categorized as follows: red = no immunity, yellow = immunity questionable (where applicable) and green = immunity. For hepatitis A, the assay included IgG and IgM, for hepatitis B further tests were included in the study, but are not displayed here (red = no virus contact, green = virus contact via infection or vaccination). HIV results were confirmed by a second test system in case of a first diagnosis (red = HIV negative, green = HIV positive). SARS antibody test against spike (S) and nuclecapsid (N) protein were based on IgG and IgM.

coming to Germany. In addition, the low general acceptance of vaccination programs in Ukrainians independent of their refugee status, suggests that tailor-made educational and communication measures beyond the mere offer to screen and vaccinate incoming refugees need to be taken to reduce the risk of vaccine-preventable diseases for Ukrainians and the receiving population.

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Credit authorship contribution statement

MJGTV, FB, AP, and AF made substantial contributions to the conception and design of the work, as well as to the acquisition, analysis, and interpretation of data for the work. In addition, they drafted the manuscript and reviewed it critically for important intellectual content. Finally, they provided final approval of the version to be published. They agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. PB, KG, CMD, CM, KS contributed data to the study through inclusion of patients, monitoring of data and reviewed the manuscript draft critically for important intellectual content and approved its final version. LH, ATH, GMB, AG, ADJ, RK, AL, WAW, RK, NT, AJK and YS contributed data to the study through inclusion of patients and helped with data quality control. OH, BL, MN contributed to study design, advised in data management and data analysis, reviewed the manuscript draft and approved its final version. OH contributed to recruitment procedures, supported training of recruiters and translators. AC, CM and LM, MS, MK, MN, SNM, DS and JV performed data quality control, data preparation and statistical analysis and reviewed the manuscript draft critically for important intellectual content and approved its final version. All authors reviewed the manuscript draft critically for important intellectual content and approved its final version.

Declaration of Competing Interest

The authors have no conflicts of interest.

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