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Differences in timeliness, completeness and drop-out rates of MMRV and DTP containing vaccines among Ultra-Orthodox Jews and others in a deprived Northern Israel city: an ecological study

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Abstract

Background The Ultra-Orthodox Jewish (UO) population has been affected by pertussis, polio, and measles outbreaks. Safed, a deprived, undervaccinated city in Israel's North, has a large UO population concentrated in specific neighborhoods. We determined whether in Safed UO population concentration was associated with DTP- containing and MMRV1 vaccines coverage, timeliness and drop-out rates.

Method For each of Safed's statistical areas, we estimated UO population based on the proportion of votes for UO political parties in Israel's 2020 general elections. We determined whether this proportion was associated with timely and delayed MMRV1 and DTP vaccine coverage for children born 2017–2022 using simple linear regression. We compared DTP and MMRV1 coverage and drop-out rates in UO areas (> 50% vote for UO parties) to others, using chi-square tests.

Results All eligible 4385 children residing in Safed were included in the MMRV1 and DTP analyses. Vaccine coverage was significantly lower in UO areas compared to non-UO for all doses of DTP and MMRV1 at expected age (-11.8, -15.8, -16.6, -11.8 and − 7.1% points (pp) respectively, $P < 0.005$) - and at 36 months old (-0.5, -3.9, -6.2, -9.3 and − 2% points respectively, $P < 0.005$). Gaps narrowed more for MMRV1 (from 7.1 to2 pp), than for DTP4 (from 11.8 to9.3 pp). Increasing UO vote was associated with decreased timely coverage for DTP but not MMRV. DTP1-4 drop-out rates were larger in the UO areas than in non-UO areas (26.2% vs. 18%).

Conclusions Vaccine coverage was lower in UO neighborhoods, even in a peripheral city where coverage in non-UO areas is already low. Coverage differences between UO and non-UO populations decreased with time for MMRV1 but not DTP. Our findings suggest timeliness should be considered alongside non-vaccination, and vaccination behavior may be vaccine-specific in the UO population.

Keywords Equity, Jewish, Israel, MMRV, DTP, Religion, Vaccine coverage

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Introduction

Vaccination plays a crucial role in global public health by preventing the spread of infectious diseases and reducing mortality, especially among children [1]. Measles, Mumps, and Rubella-containing vaccines (in Israel mainly MMRV) and Diphtheria, Tetanus, and Pertussis containing vaccines (in Israel mainly DTaP-Hib-IPV referred to henceforth as MMRV and DTP, respectively) constitute the backbone of routine childhood immunization programmes worldwide [2]. According to the World Health Organization (WHO), at least 95% coverage for two doses of measles containing vaccines (MCV2) should be the standard for all national immunization programmes [3]. While there is no formal target for DTP containing vaccines, many countries have also adopted a 95% target as a programmatic objective [4]. While global MMR and DTP vaccination coverage has increased over the past decades from <5% in 1974 to 86% in 2018 for DTP and 16% in 1980 to 86% in 2018 for Measles containing vaccines, disparities remain between different regions [5]. Ongoing challenges such as access to vaccines, misinformation, lack of resources, and conflict and instability sustain and even increase immunization inequity between countries and regions [6]. The COVID-19 pandemic resulted in major decreases in global vaccination coverage [7]. Post-2022, the situation has improved, but vaccination coverage has not returned to pre-pandemic levels everywhere [8]. In addition to between countries, within-countries inequity, where individual and populations with specific characteristics such as ethnicity, religion, or immigration status experience lower coverage than the general population, also exists. Examples of within countries inequities in the WHO European region can be found among migrants, Roma, Irish travelers and Ultra-Orthodox Jewish (UO) communities [9].

In Israel, the DTap + IPV + Hib (DTP) vaccine is administered following a six-dose schedule, given at two, four, six, and twelve months in government run children's clinics (called "Tipat Chalav") and then at school in grades 2 and 8 [10]. The MMR vaccine (combined with varicella, MMRV) is given at 12 months and a second dose at school during first grade. As of 2022, national coverage at the age of 24 months was 91% for DTP4 and 95.6% for MMRV1 [11]. However, certain communities, particularly the UO Jewish populations, achieve lower vaccination coverage: for example, in Jerusalem the coverage was 68% for DTP4 and 85% for MMRV1 at 24 months of age for UO children's born in 2009) [12], leading since the 1990s to periodic outbreaks. For example, the UO population experienced measles outbreaks in 2003–2004, 2007–2008 and 2018–2019 [13–16], a pertussis ourtbreak in 2023 [17] and polio cases in 2022 [18].

The UO community in Israel, also known as Haredi, represents approximately 12% of the country's population and is characterized by a strict adherence to Jewish law and traditions, with a lifestyle centered around religious observance [19]. While the UO population may seem homogenous and is often treated as such in health programmes, it is in reality diverse, and includes various subgroups with distinct customs, interpretations of Jewish law, and cultural practices [20]. Major subgroups include the Lithuanian (Litvish), Hasidic, and Sephardic Haredim, each with its own leadership, yeshivas (religious schools), and social structures. Despite their shared commitment to religious values, internal differences in religious customs, political affiliations, and levels of engagement with secular society contribute to its rich complexity. Specific communities congregate in specific locations, leading to major differences, including in health outcomes, between towns and cities with a large UO population in Israel. Political representation is similarly varied, with parties such as Shas [21], representing Sephardic Haredim, and United Torah Judaism, a coalition primarily representing Lithuanian and Hasidic Haredim [22]. These parties play a significant role in Israeli politics, often focusing on issues pertinent to their communities, such as religious education, welfare, and housing policies. This variability necessitates nuanced approaches in local and national health policy and community outreach to address the unique needs and perspectives within the UO population.

A systematic review of the literature highlighted that barriers to vaccination among the UO community have been primarily logistical, with minimal religious framing [23]. These logistical barriers include challenges of juggling the multiple needs of many children in large families, where the mother is the main caregiver for children as well as the breadwinner, and struggling to find time for vaccination due to inconvenient clinic hours and insufficient availability of appointments [23]. However, in recent years, the traditionally pro-vaccine mainstream religious leadership has seen a decline in influence. Simultaneously, anti-vaccination movements targeting the UO community have gained traction, resulting in an increasing availability and popularity of anti-vaccination sentiment [23].

Safed, is one of the most socio-economically deprived cities in Israel, with a population of 40,000 residents, 40% of them under the age of 18 [24]. Although precise estimates are not available, approximately half of the city's population is UO, and overall, the city achieves below-national average vaccine coverage for most routine vaccines, with MMRV vaccination between 2015 and 18 consistently under 90% [25]. In recent years, Safed has experienced outbreaks of vaccine-preventable diseases (VPDs), including a measles outbreak in 2018 [26] and a case of polio in the past year, indicating sub-optimal herd immunity.

In Israel, the religious status of individuals is not routinely included in vaccination statistics, and therefore it is not possible to easily calculate vaccine coverage in the UO population. Place of residence is however available in routine data. Therefore, cities that are homogenously UO such as Bnei Brak, Modi'in Illit or Beitar Illit provide an insight into vaccination among the UO. However, understanding vaccine coverage at the community level in mixed cities (where the population is split between UO and non UO) is more complex because there is no indication of who belongs to the UO community in formal data sources. The purpose of this study was to examine vaccination coverage and timeliness for DTP and MMRV containing vaccines and drop-out for DTP among UO and non-UO areas in Safed. As there is no formal neighbourhood classification, we make use of elections data to identify UO areas.

Methods

Setting and study population

The city of Safed is divided into 11 different statistical areas (Fig. 1), with no formal categorization of UO neighborhoods. One area (area 11), is a separate village with a totally distinct population, administratively dependent but geographically and socio-culturally distinct from Safed; we therefore did not include it in the study. Another area (area 9) is an unbuilt area with no residents and is therefore not relevant to the analysis. In order to estimate the proportion of UO population in each area, we used data from the results of the 2020 general elections [27], taking advantage of the fact that by and large the UO vote for UO parties (namely Shas and United Torah Judaism) and vote for UO parties among the non-UO population is marginal. As such, we estimated the proportion of the adult population who is UO in each statistical area by analyzing voting patterns in voting offices located in each of the nine statistical areas. This was made possible by the availability of the number of registered voters voting for each party on the election website. The proportion voting for each party was determined as the number of voters for a specific party, divided by the total number of voting. Areas with over 50% of voters voting for a UO party (Shas or UTJ) were classified as UO and referred henceforth as a UO area. For each statistical area, we received anonymized, individual-level data from the Ministry of Health that included every child born between 2017 and 2022 living in Safed, so the study is based on the whole population, not a sample. Collected variables included year of birth, statistical area of residence and age in months of receipt of MMRV1 and each dose of DTP-containing vaccines. MMRV2 is given through schools rather than health clinics and collected

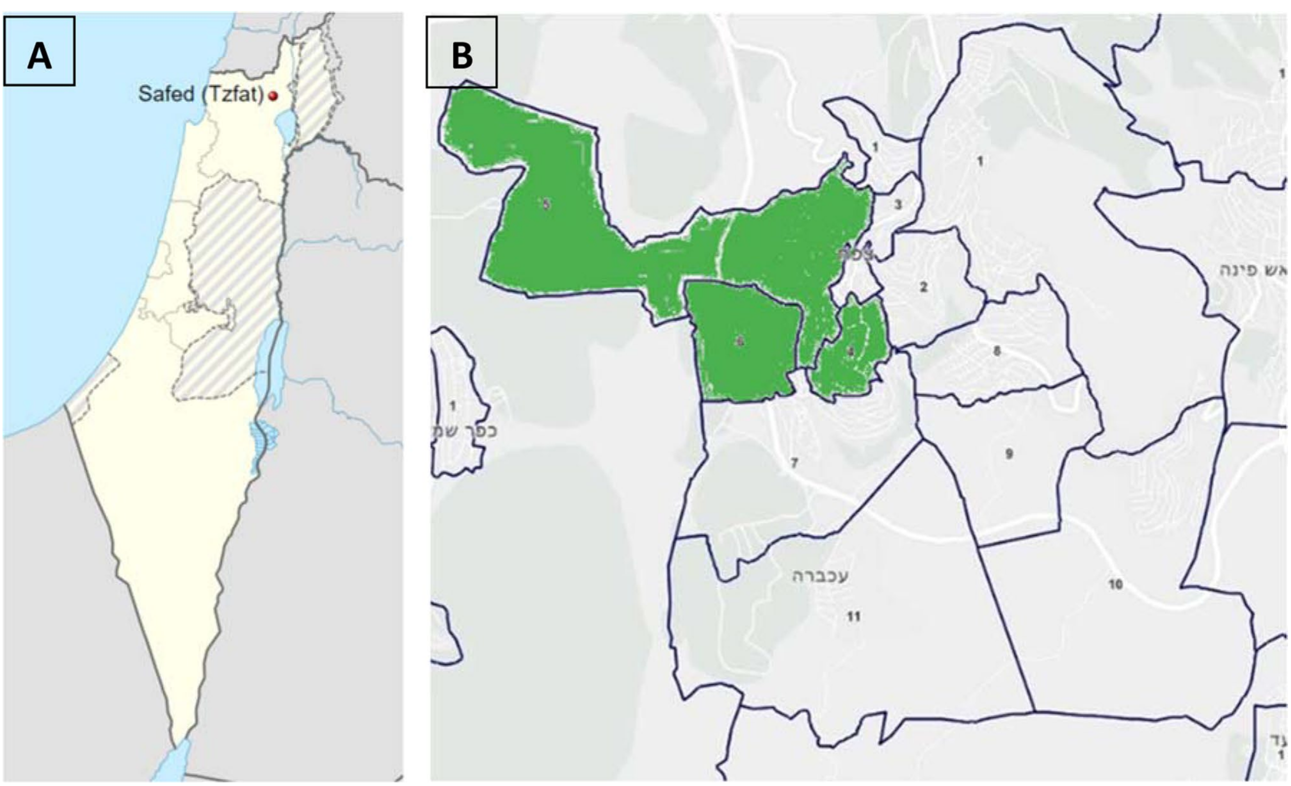

Fig. 1 (**A**) The location of Safed in Israels map. (**B**) The map of the city of Safed, divided into statistical areas [28]. The areas colored green marks areas with voting rates for UO parties larger than 50%

through a different system which we could not access. Because statistical areas 3 and 10 were small, the Ministry of Health required that area 3 be combined with area 4 and area 8 with area 10 to avoid deductive disclosure, with 7 combined statistical areas remaining.

Data analysis

We performed linear regressions to determine associations between the percentage of vote for UO parties and vaccine coverage for DTP1 at the ages of 3 and 6 months, DTP2 at 5 and 8 months, DTP3 at 7 and 12 months, DTP4 at 12 and 18 months, and MMRV1 at 12 and 18 months. These times intervals were chosen to demonstrate timely vaccination as well as delayed vaccination.

We classified areas according to the proportion of UO vote. Areas with more than 50% voting percentages for UO parties were considered UO-area. We described cumulative DTP and MMRV1 vaccine coverage by month and compared MMRV1 and DTP4 coverage, both scheduled at 12 months of age, between UO non-UO areas at the ages of 13,18 and 36 months, using chi square tests.

We also compared the DTP1/DTP4 drop-out rate (measure as ((DTP1-DTP4)/DTP1)*100) and the interval between vaccination doses in UO and non-UO areas, using t-tests. Because we could not access MMRV2 data it was not possible to calculate dropout rates for MMRV.

Statistical analyses were performed using MS Excel and SPSS version 29.

Results

In total, 4385 children born between 2017 and 2022 residing across the 9 statistical areas of Safed (Table 1) were identified in the DTP register, and 4371 in the MMRV one. Areas 4, 5 and 6 reported over 50% vote for UO parties and were therefore considered UO areas (Table 1). A map of Safed and the division into statistical areas is shown in Fig. 1.

Table 1 Voting rates for UO parties and population size by Safed's statistical areas

Statistical area	Vote for UO parties (%)	Number eligible children on the DTP register	Number of eligible children on the MMRV register
1	12.76	439	443
2	39.05	285	295
3	25	43	612
4	52.16	579	
5	53.9	1481	1483
6	66.32	176	173
7	47.79	848	829
8	14.37	402	536
10	5.14	132	
Total		4385	4371

When measuring timely DTP vaccination (DTP1 at 3 months, DTP2 at 5 months, DTP3 at 7 months, DTP4 at 13 months), increased UO vote was associated with decreased vaccine coverage ($p < 0.05$ for each vaccine, Fig. 2 panels 1–4). When looking at delayed vaccination, (DTP 1 at 6 months, DTP 2 at 8 months, DTP 3 at 12 months DTP 4 at 18 months and MMRV1 at 18 months), associations were only significant for DTP 3 and 4. (Fig. 3 panels 3–4). No significant associations were found for MMRV1 at either 13 (Fig. 2, panel 5) or 18 months old (Fig. 3 panel 5).

Overall, vaccine coverage was lower in UO areas compared to non-UO for all doses of both vaccines both initially (timely vaccination) and at the final measurement (Table 2; Fig. 4)), with initial gaps of 11.81% in DTP1, 15.81% in DTP2, 16.65% in DTP3, 11.8% in DTP4, and 7.19% in MMRV1. Gaps narrowed for MMRV1 (7% point difference at 13 months vs. 2 at 36 months), less so for DTP4 (12% points difference for DTP4 at 13 months vs. 9 at 36 months, Table 2; Fig. 4).

Completion

In UO areas, among children at 24 months of age, DTP1/4 drop out rate was 26.2%, compared to 18% in non-UO areas (Fig. 5).

The mean age of initiation for DTP1 was 3.3 months in non-UO areas, compared to 4.28 months in UO areas ($p < 0.001$). For MMRV1, mean initiation age in UO areas was 14.2 months, vs. 13.7 months in non-UO areas ($p = 0.006$). When examining interval between dosages, the mean interval between dose one and dose 2 of the DTP- containing vaccine was 2.3 months (SD = 6.98, interval according to schedule: 2 months), with no significant difference between UO and non UO areas. Likewise, no difference was found between the groups in the interval between doses 2 and 3 (mean 2.3 months, SD = 6.37, interval according to schedule: 2 months). However, the interval between doses 3 and 4 was significantly longer in non-UO areas compared to UO areas (5.15 vs. 6.6 months, $p < 0.01$, interval according to schedule: 6 months).

Discussion

Our data shows that overall, in Safed, vaccination coverage is suboptimal: DTP4 coverage at 24 months for children born 2017-22 was 73.7%, and MMRV1 coverage was 88.8%, below WHO recommendations and Israel's national average. Making innovative use of elections data, we showed inequity within the city: our research reveals significantly lower and delayed initiation, less timeliness and a higher drop-out rate in UO areas compared to non-UO areas. While a gap persists for both MMRV1 and DTP4 at 36 months, there are differences between vaccines, with gaps significantly reducing over time for

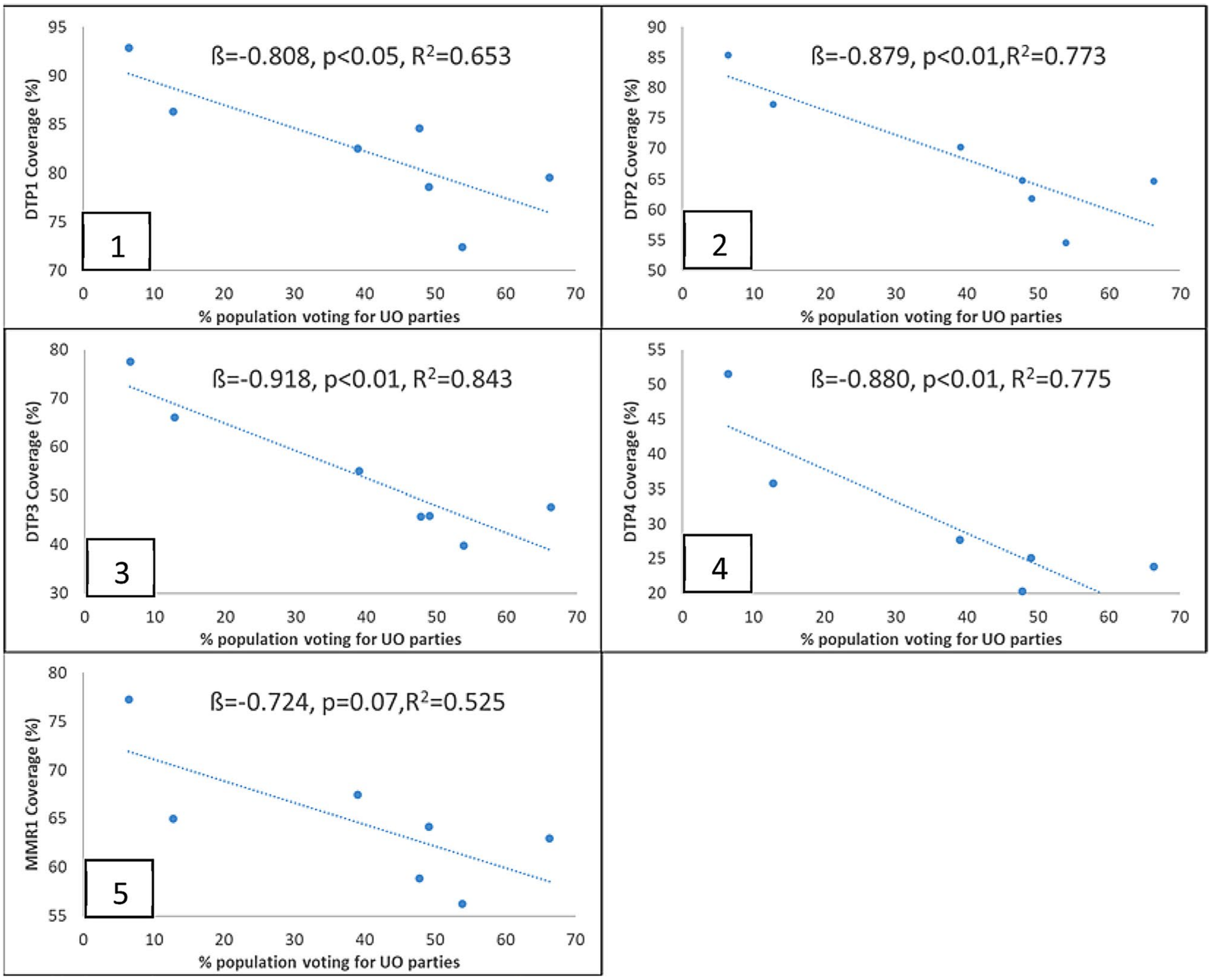

Fig. 2 Association between Proportion of UO vote and timely coverage for DTP1 at 3 months (Panel 1), DTP2 at 5 months (Panel 2), DTP3 at 7 months (Panel 3), DTP4 at 13 months (Panel 4) and MMRV1 at 13 months (Panel 5)

MMRV1 compared to DTP. These findings suggest that the UO population faces unique challenges in vaccine initiation, completion and timeliness in the context of a city where coverage is low to begin with. Significant pattern differences between MMRV1 and DTP suggest some elements of vaccine behaviour might be vaccine-specific rather than related to vaccines in general.

The pattern of vaccine coverage found in our study in Safed aligns with the pattern observed in a 2017 study of the UO community in Jerusalem [12], where gaps in vaccination coverage also decreased with age. Both studies suggest complex barriers to vaccination rather than outright refusal (where one would expect similarly low coverage for earlier and later DTP doses), and an issue with timeliness. Unlike Jerusalem, where the UO community mainly belongs to the mainstream, which includes old, established, and influential communities [29], Safed's UO community is much more heterogeneous and includes individuals living on the fringes of the UO community, including newly religious individuals, new immigrants from the USA, and a peripheral UO population in socio-economic and geographical aspects [30], who are more likely to combine UO-specific barriers to vaccination with barriers related to their other characteristics, such as connections to anti-vaccination movements in the USA [31]; the extent of this intersectionality has not been investigated. Additionally, in Jerusalem, vaccination coverage in UO neighborhoods is low compared to the high coverage in general neighborhoods. In Safed, low vaccination rate among the UO population happens in a context of overall low vaccination rate in the city. These situations warrant different approaches when it comes to improving uptake.

The examination of UO communities reveals both notable similarities and distinct differences among them, underscoring the need for targeted studies on specific

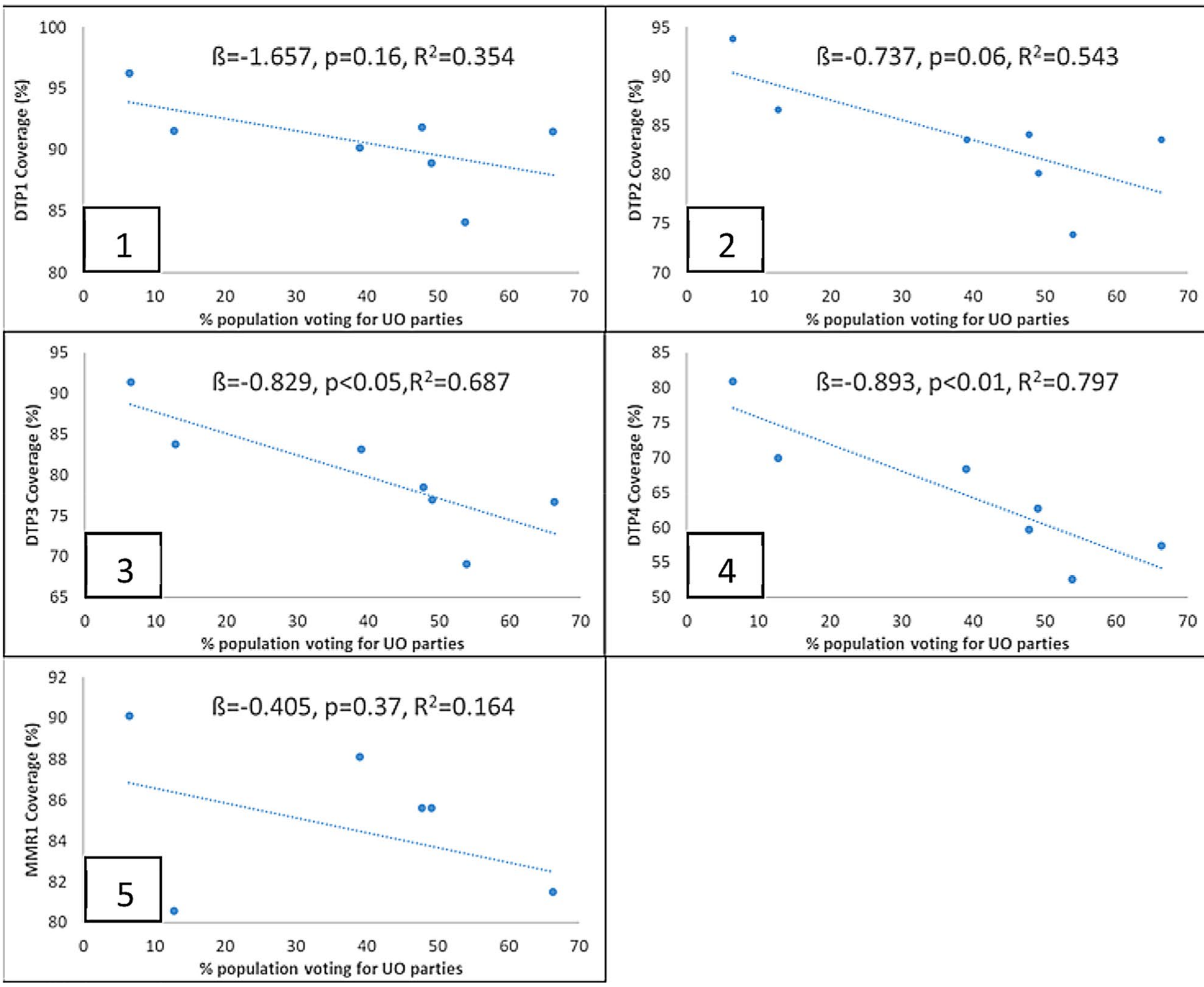

Fig. 3 Association between Proportion of UO vote and delayed coverage for DTP1 at 6 months (Panel 1), DTP2 at 8 months (panel 2), DTP3 at 12 months (panel 3), DTP4 at 18 months (panel 4) and MMRV1 at 18 months (panel 5)

sub-communities within UO society. Despite the presence of overarching barriers and enablers that impact the entire UO population such as barriers to access, convenience and competing priorities [23], other barriers such as being targeted by the global anti-vaccination movement [31], may be more prevalent within different sub-communities, indicating a heterogeneity that challenges the perception of a monolithic community. This phenomenon parallels findings in research on other ethnic minorities, such as Indian communities in Britain [32] or Black immigrant populations in the United States [33], which often face a tendency to be regarded as homogeneous entities. In reality, significant intra-group variations exist among subgroups within these minority populations, highlighting the importance of nuanced, subgroup-specific analyses.

One of the main challenges in this study was identifying the UO population at the sub-municipality level, where no available official data source exists. Therefore, this study made innovative use of election voting data to classify areas as UO or non-UO. Although studies have examined association between vaccination, religion and voting patterns in the context of the COVID-19 pandemic [34], to the best of our knowledge, election data have not been used in the context of routine childhood immunization. This ecological approach has limitations and presents a risk of misclassification, in particular in voting patterns for the Shas party, whose agenda addresses, in addition to UO values, discrimination against Mizrahi Jews (Jews originating from Arab countries), therefor garnering support of some non-UO voters as well [21]. However, in recent years, Shas has increasingly aligned with the UO agenda, reducing its non-UO Mizrahi voter base, thus making this classification index more reliable [35]. To the best of our knowledge, using voting data to identify the UO population is novel and

Table 2 Comparison of timely, delayed and final vaccine coverage for DTP and MMRV1 vaccines among children born 2017–2022 in safed: UO vs. non UO areas

		Timely measurement (DTP1 at 3 months, DTP2 at 5 months, DTP3 at 7 months, DTP4 at 13 months, MMRV1 at 13 months)		Delayed measurement (DTP1 at 6 months, DTP2 at 8 months, DTP3 at 12 months, DTP4 at 18 months, MMRV1 at 18 months)		Final measurement- all measurements at 36 months	
		UO areas	Non UO areas	UO areas	Non UO areas	UO areas	Non UO areas
DTP1	Coverage (%)	74.69	86.51	85.96	92.55	98.79	99.30
	Coverage Difference (percentage points)	11.81		6.59		0.51	
	P value	< 0.001		< 0.001		< 0.001	
DTP2	Coverage (%)	57.29	73.10	76.34	86.74	92.58	96.51
	Coverage Difference	15.81		10.4		3.93	
	P value	< 0.001		< 0.001		< 0.001	
DTP3	Coverage (%)	42.4	59.05	71.82	83.29	87.43	93.67
	Coverage Difference	16.65		11.47		6.24	
	P value	< 0.001		< 0.001		< 0.001	
DTP4	Coverage (%)	20.71	32.48	55.55	68.31	76.03	85.39
	Coverage Difference	11.8		12.76		9.36	
	P value	< 0.001		< 0.001		< 0.001	
MMRV1	Coverage (%)	58.81	66.00	81.38	85.98	90.47	92.55
	Coverage Difference	7.19		4.6		2.08	
	P value	< 0.001		< 0.001		< 0.001	

Number of eligible children for DTP: in non UO areas $n = 2149$; in UO areas $n = 2236$

Number of eligible children for MMRV1: in non UO areas $n = 2147$; in UO areas $n = 2224$

UO areas > 50% vote for the UO parties

replicable for future research in this field. Another limitation is that we could not take into account absention rates. In addition, while our study showed an association between the proportion of UO population in an area and vaccination coverage, the study does not purport to determine which aspect of UO communities most influence vaccination behaviour. For example, within Safed, UO areas are more socio-economically deprived than non-UO areas [36]. Poverty is a well-described characteristic of UO populations in Israel; [37] we have therefore decided not to adjust for it since we conceptualize it as part of the defining characteristics of the UO population, rather than a confounding factor. It was outside of the scope ouf our study to determine whether poverty was the defining factor in low vaccine coverage among the UO population. Data suggests the reality is more complex: While poverty among the UO has substantially reduced in the last 10 years [37], vaccine coverage has not increased: in Beitar Illit for example, a major fully UO city, MMRV coverage decreased from 95 to 88% between 2015 and 2020; in Rechasim, another fully UO city, coverage decreased from 98 to 94% for MMRV in the same time period [38].

The findings of this study emphasize the importance of examining immunization inequity beyond coverage, and the importance of timeliness and drop-out rates. The narrowing gap in vaccination coverage over time in UO areas indicate that barriers to vaccination are not solely based on principled opposition, but include factors that lead to delays rather than outright refusal. These barriers may range from logistical challenges, competing priorities, lack of confidence, insufficient health literacy [23], which can cause parents to delay their decision until the child is older. Delays in vaccination can be as important as non-vaccination if vaccination occurs after the period of highest risk, as evidenced by outbreaks occurrences in UO communities where parents intended to vaccinate but were delayed. This finding is important for planning future intervention programs that focus on identifying the barriers to timely vaccinations and not just on vaccination itself.

Previous intervention programs aimed at increasing vaccination rates within ultra-Orthodox communities have occasionally acknowledged the issue of delayed vaccination [39]. However, it appears that these programs have not sufficiently prioritized timely vaccination as a central component. We suggest that future intervention strategies should explicitly emphasize the importance of timely vaccination during their planning phases to effectively enhance both overall vaccination rates and adherence to recommended vaccination schedules within ultra-Orthodox populations.

The difference in vaccination coverage between MMRV and DTP, and in particular the narrowing of the gap

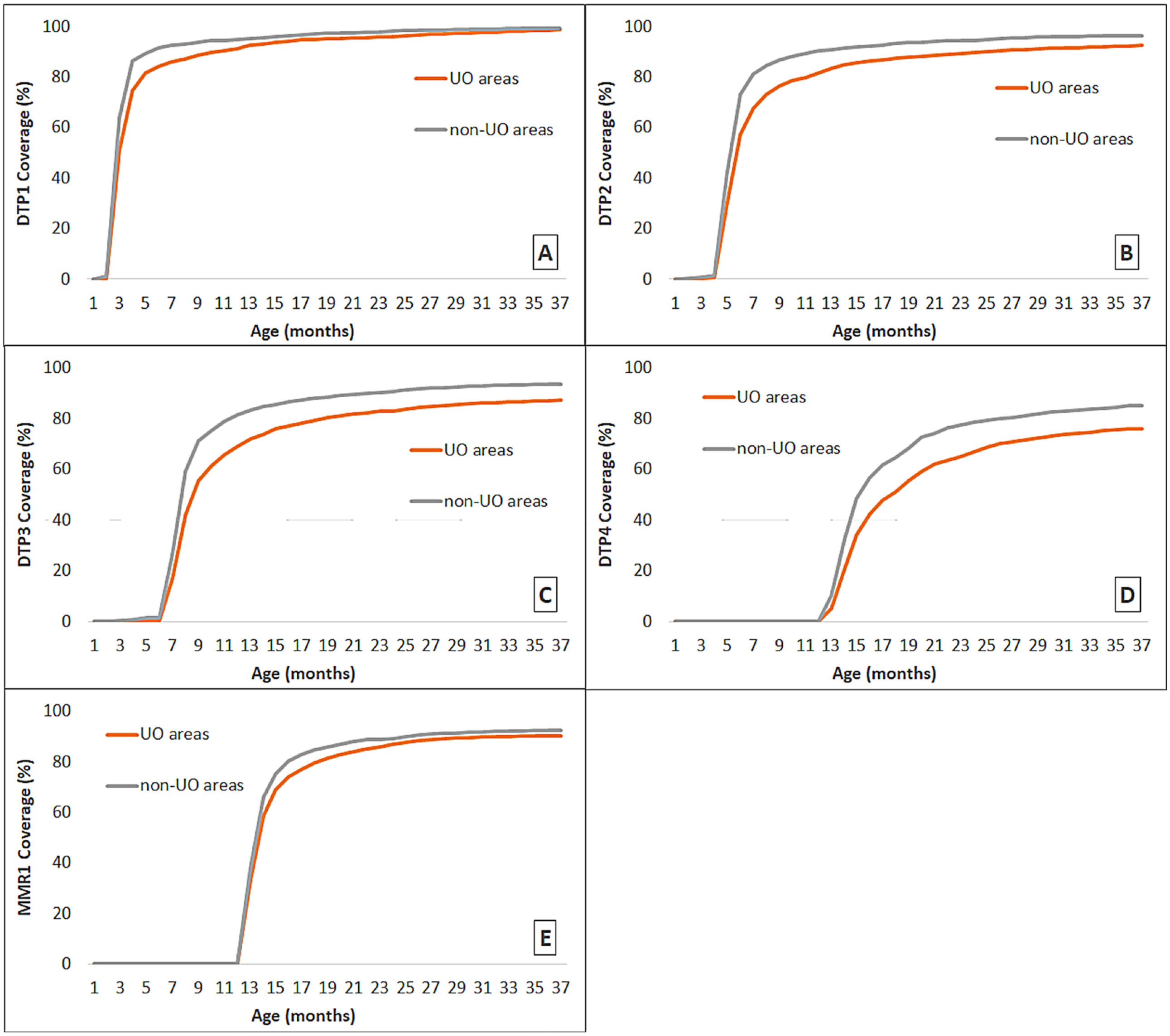

Fig. 4 Vaccine coverage among children born 2017–2022 for DTP1 (**A**) DTP2 (**B**) DTP3 (**C**) DTP4 (**D**) and MMRV1 (**E**) in Safed UO and non UO neighborhoods

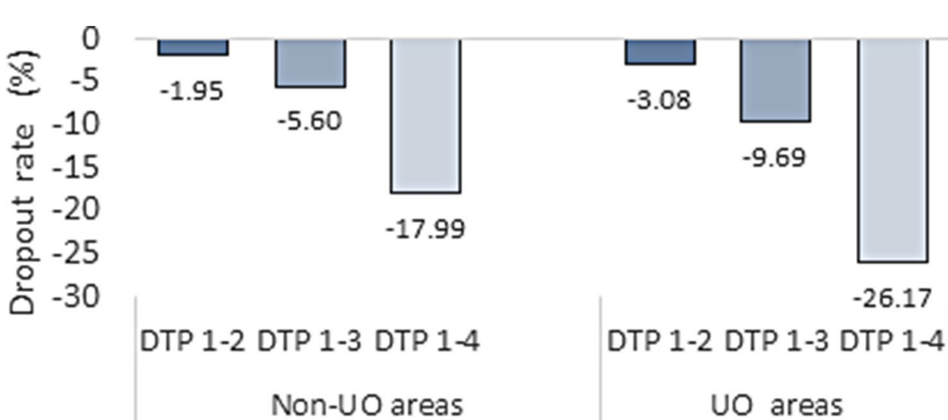

Fig. 5 DTP 1–2, 1–3 and 1–4 dropout rates among 24 month-old children living in UO and non UO areas

between UO and non-UOareas for MMRV1 but not DTP4 indicates that vaccination behavior in the community may be specific to each vaccine, highlighting the need to examine barriers and enablers at the individual vaccine level, not just overall. One possible reason we suggest for the higher MMRV1 vaccination rate and smaller differences between UO and non UO areas for MMRV1 is the outbreaks of mumps and measles in previous years, which have raised awareness of these diseases' in the UO community and changed their perceived seriousness, compared to the diseases included in the DTP vaccine, which have had no large outbreak in recent years. This suggestion however is a simple observation and would need to be substantiated by data to be validated. It remains to be seen whether the 2023 pertussis outbreak in Israel, predominantly affecting the UO population, will change perceived seriousness of the disease and by extension vaccine coverage. This should be further examined through quantitative and qualitative studies.

This difference between MMRV and DTP also suggests that the barriers to vaccination are not primarily due to outright refusal of vaccination. This is supported by the fact that there is almost no difference in DTP1 coverage between UO and non-UO areas, while the disparities become significant by DTP4. A parent completely opposed to vaccination would likely not administer the first DTP dose, therefore indicating that other obstacles arise and prevent the completion of all four doses. Again, qualitative studies in this population will help better understand these nuances.

One limitation of the study is the relatively high resolution of the data we received from the Ministry of Health. The lowest available resolution was statistical areas, which are not homogeneous, making the classification of an area as UO or non-UO general and imprecise. As noted above, there is heterogeneity among voters of the Shas party, as some non-UO individuals also vote for it. Therefore, it is possible that parts of the population we classified as UO are not entirely UO. This potential misclassification may lead to an underestimation of the actual differences between UO and non-UO populations, suggesting that the real disparities may be greater than those observed in our analysis. In addition to the heterogeneity of Shas voters, there is an UO minority that votes for non-UO parties [20], which our index does not account for. Despite these limitations, we believe that our proposed approach is sufficiently accurate to provide meaningful insights into vaccination among the UO population relevant for strategic decision making at the local and regional level. Such an approach, even if not 100% accurate, could be replicated in other parts of Israel and in contexts where voting occurs along ethnic or religious lines.

Conclusions

The current study reveals a gap between UO and non-UO areas of the city in terms of vaccination coverage, completion and timeliness, for DTP-containing more than for MMRV1 vaccines. From our comprehensive analysis of routine data linked to voting data, we can infer that barriers to vaccination among the UO in Safed cannot be attributed solely to vaccine hesitancy, but likely represent a complex interaction between logistics, confidence, literacy and perception of health and illness, in a wider context of overall low coverage and socio-economic deprivation. Our approach can be replicated in other contexts, both other UO population and other minority groups, to generate insights into vaccination in minority groups. Further research should examine additional variables that account for socioeconomic status (SES) and other contextual factors that may influence vaccination behaviors both within and in interaction with the Ultra-Orthodox (UO) population. Incorporating methods such as stratified ecological comparisons or sensitivity analyses could help disentangle the specific effects of SES and other structural determinants, while also identifying subgroup-specific factors—such as community norms, institutional trust, or access barriers—that may differentially shape vaccine uptake in distinct segments of the UO community. Such studies should be completed by qualitative studies to complete a complex picture of vaccination behaviour in our population. The combination of quantitative coverage studies and qualitative insights can inform future interventions addressing the need of hyperlocal populations with a unique combination of barriers to vaccination.Intervention programs implemented during measles outbreaks in the UO community in Jerusalem included recruiting rabbis for a pro-vaccination campaign, collaborating with local community health organizations, and extending the operating hours of vaccination clinics [14, 16, 40]. The implementation of these strategies during the measles outbreaks in 2003, 2004 [16], and 2018 proved to be highly effective. In 2018, these interventions led to an increase in the vaccination rate within the ultra-Orthodox community in Jerusalem from 76 to 96% within 30 weeks [16]. Involving the community in Co-creating and co-delivering such immunization interventions has also been suggested as a way to address hyperlocal barriers to immunization in UO communities [41] and warrants rigorous evaluation to be used more widely in UO and other minority populations.

Abbreviations

UO	The Ultra-Orthodox Jewish population
MMRV	Measles, Mumps, and Rubella containing vaccines
DTP	Diphtheria, Tetanus, and Pertussis containing vaccines
MCV	Measles containing vaccines
WHO	The world health organization
VPD	Vaccine-preventable diseases

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Not applicable.

Author contributions
ME and SS conceptualised the study. AY and ME conducted the statistical analysis. AY drafted the manuscript. AY, SS and ME gave comments and revised the manuscript.

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Data availability
All data generated or analysed during this study are included in this published article. According to Ministry of heath regulations, the authors lose access to the raw dataset upon finalization of the analysis and therefore all available data is presented in the paper.

Declarations

Ethics approval and consent to participate
The Ethics Committee of the Bar Ilan University, Faculty of Medicine, approved the study, approval number: 11-2021. We also received approval from the Helsinki Committee of the Ministry of Health in Israel for accessing the data, approval number: MOH-076-2022. The data is based on the anonymized vaccine registry obtained from the Ministry of Health, and individual consent is not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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