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Crisis of confidence in vaccination and the role of social media

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ABSTRACT

Introduction: The aim of this paper is to review the current situation of vaccine hesitancy, with emphasis on children with neurological disorders, and to present the role social media plays in this situation.
Methods: A literature review using the following search words was performed: vaccine* OR immune* AND hesitancy OR confidence AND social media.
Results: The search retrieved 277 results; 17 duplicates and 234 irrelevant articles were excluded. 43 articles were fully analyzed.
Conclusions: An increasing number of parents are becoming vaccine hesitant. Their motives are complex and nuanced and involve factors related to vaccine safety and efficiency, perceived personal risks and benefits, socio-demographic and psychological characteristics. Attitudes toward vaccination differ in adolescents from their parents. In children with neurological disorders, factors involved in vaccination decision included physicians' knowledge of neurological diseases and parents' concerns that vaccination would exacerbate the chronic disorder. Unfortunately, the current pandemic is associated with an increase in vaccine hesitancy and brought forward unique determinants. The social media platforms can be a tool for the anti-vaccine movement to spread misinformation, but it can also be valued as a way for promoting health and pro-vaccine information.

1. Introduction

Vaccination is considered one of the greatest achievements of medicine, responsible for a significant decrease in disease, disability, and death over the last century. Due to immunization, smallpox was eradicated worldwide and poliomyelitis was eliminated in all countries except Pakistan and Afghanistan [1,2]. However, vaccines became victims of their own success. Because immunization is a very effective and safe measure, many parents and clinicians have not seen the effects of vaccine-preventable diseases and they underestimate their harm.

Questioning the need and safety of vaccines, an increasing number of parents are requesting alternative immunization schedules, postponing or even refusing vaccination. This behavior, termed vaccine hesitancy [3], poses a real challenge to the medical system. It has a direct impact on vaccine uptake, with many countries worldwide struggling to keep an optimal level of immunization needed for herd immunity, and some of them facing upsurge of outbreaks, such as measles in Italy and Romania [4]. Latest reports from the United Nations International Children's Emergency Fund (UNICEF) [5] and the World Health Organization (WHO) [6] showed that in the last years the global vaccination coverage has stalled at 86% and, given the current vaccination rate, it is estimated that the prospect for a child born this year to be fully vaccinated by the time they will be 5 years old is less than 20% [5,6]. Vaccine hesitancy is not a new phenomenon, it existed since the first inoculation against smallpox done by Edward Jenner in 1796, and changed in time, in relation to economic, social, cultural, religious and technological factors. Because of the challenges it poses, vaccine hesitancy was named by WHO as one of the top 10 public health threats in 2019 [7].

Nowadays, information about immunization can be easily obtained from sources such as the Internet and social media platforms. These platforms allow individuals to create content and

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share it globally, without editorial supervision, leading to the widespread of misinformation regarding vaccination and fueling vaccine hesitancy. However, the Internet and social media can be valuable tools in helping physicians, institutions and governments in disseminating health information and restore parents' confidence in vaccines.

The aim of this paper is to search the available literature regarding the current situation of vaccine hesitancy, with emphasis on children with neurological disorders, to present a brief analysis of vaccine hesitancy determinants and the role social media plays in this situation.

2. Material and methods

The authors performed a literature review in June 2021 without time limits in PubMed and the Cochrane Database. A search was performed using the search words: vaccine* OR immune* AND hesitancy OR confidence AND social media. Another search was performed using the key words: vaccine hesitancy AND neurological disorders OR epilepsy OR Dravet syndrome OR encephalopathy OR COVID-19. The reason for using "Dravet syndrome" and "encephalopathy" as search words was the well-known association in some cases of Dravet syndrome with vaccination-proximate seizures, a particular situation that allows for vaccine hesitancy to be explored. After duplication removal, the articles were selected by title and abstracts. Articles referring to the following were excluded: efficacy and safety trials, pre-clinical trials, cost-effectiveness or cost-benefit studies, commentaries, letters, conference abstracts. To identify additional records, the reference lists of the retrieved articles were screened and important information from the WHO, UNICEF and the Centers for Disease Control and Prevention (CDC) websites were further included. The remaining articles were then fully analyzed.

3. Results and discussion

The literature search identified 277 results. 17 duplicates and 234 irrelevant articles were excluded. 26 articles that focused on the subject of the paper remained. 14 articles were added from the bibliography of selected articles and from other sources (WHO, UNICEF, CDC). Three original articles related to COVID-19 were added. The final review included 43 articles. The details of PRISMA (The Preferred Reporting Items for Systematic Reviews and Meta-Analysis) search and selection process are presented in Fig. 1.

3.1. Vaccine hesitancy

3.1.1. Definition

In 2014, the WHO formed within its Strategic Advisory Group of Experts (SAGE) on Immunization a working group on vaccine hesitancy, in order to better understand the causes that led to vaccine refusal or deferral. They defined vaccine hesitancy as a "delay in acceptance or refusal of vaccination despite availability of vaccination services" [8]. Vaccine hesitancy is a spectrum, as confirmed in several studies [9–11].

In their review, Leask et al. [12] divided parental attitudes toward vaccination into five categories:

- unquestioning acceptor;
- cautious acceptor: these parents have minor concerns regarding vaccines, but they accept them;
- the hesitant: these parents have significant concerns regarding vaccines, they usually accept them;
- late or selective vaccinator: these parents choose to delay or accept only selected vaccines;
- refuser: these parents refuse all vaccines.

In a simplified manner, SAGE considered that vaccine hesitancy "occurs on the continuum between high vaccine demand and complete vaccine refusal" [8]. In order to identify and compare vaccine hesitancy in different world settings, SAGE developed in 2015 a 10-item scale [13], which was later modified, adapted and improved [14].

3.1.2. Determinants of vaccine hesitancy

In the last four years, an important number of papers evaluating the factors that determine vaccine hesitancy in different populations were published, with some of the available evidence being summarized in systematic reviews [3,12,15–19]. These reviews are heterogeneous, with different objectives, search strategies and results, but the main conclusion that can be drawn from all of them is that vaccine hesitancy is multi-factorial, vaccine-specific and it varies according to social, cultural, and economic context.

SAGE developed a conceptual model to encompass the determinants of vaccine hesitancy, known as "the 3 Cs" [8]:

- Confidence: defined as trust in the effectiveness and safety of vaccines and trust in the healthcare system.
- Complacency: related to the perceived risk of disease; when concern for a vaccine-preventable disease grows, vaccines are easily accepted and vaccination uptake improves; similarly, when concern for a certain vaccine-preventable disease decreases, the uptake diminishes as the parents do not perceive the need for vaccination.
- Convenience: it refers to physical availability, accessibility, cost, ability to understand (language and health literacy) and quality of immunization service.

Parental concerns represent a major contributor to vaccine hesitancy [9–11,20–24]. The most prevalent ones are listed in Table 1. Despite the abundance of evidence-based data that support the safety of currently recommended vaccines and disprove these arguments, for example the association between vaccines and multiple sclerosis [25,26] or autism [27,28], immune system weakening by multiple vaccines [29], or neurodevelopmental delays related to vaccination [30], misinformation persists and it is used by the anti-vaccine movement.

Furthermore, when these arguments are promoted by public figures, they add even more confusion and skepticism to the controversy surrounding immunization. Probably the best-known case was that of Wakefield and his colleagues, who published a paper regarding the association of the MMR vaccine with autism spectrum disorder, in The Lancet in 1998 [31]. The paper was later retracted and the association of vaccines with autism was disproved, but the sensationalist media reports led to a significant decrease of confidence in vaccines and subsequently to a decrease in vaccine uptake that caused occasional outbreaks of measles [32,33]. In addition, a number of vaccine hesitant public figures have openly expressed their concerns regarding immunizations with a direct negative impact on people's confidence in vaccines.

Healthcare professionals play a key role in parental immunization decision [23]. In a survey assessing parents' information sources regarding vaccines, 80% of the responders stated that the most important source of information was a child's doctor or nurse [23]. Consequently, healthcare professionals' attitude and knowledge about vaccination reflects on their intention to recommend vaccines and on parental immunization decision for their children [34–36]. In general, healthcare professionals are supporters of immunization, yet some are vaccine hesitant [37–39]. In a survey evaluating healthcare workers' perception of vaccination, 37% of

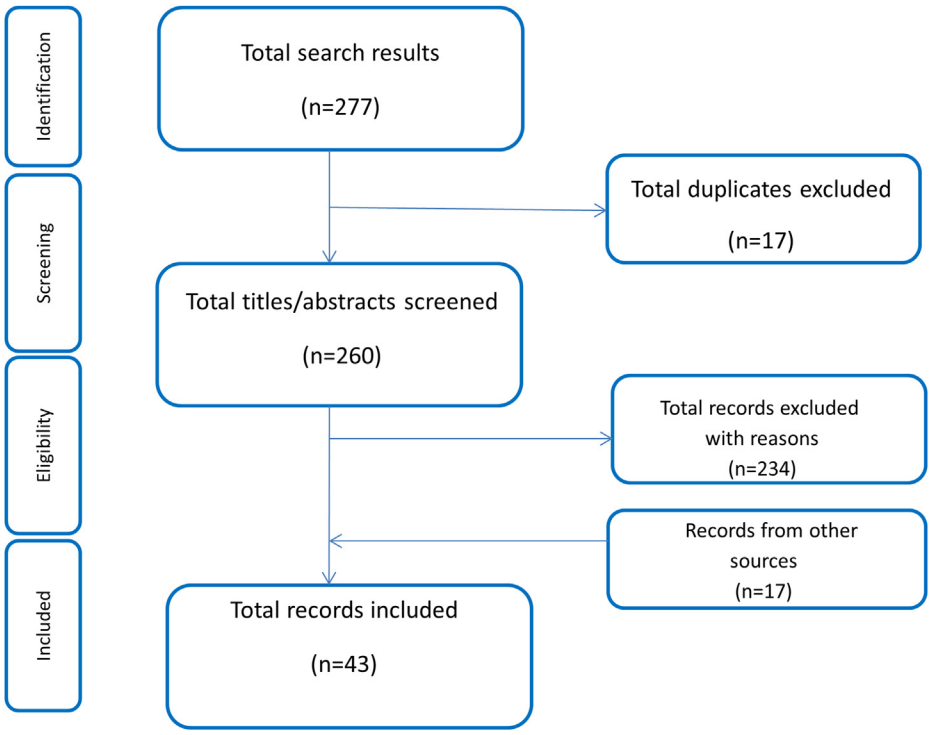

Fig. 1. Articles selection (PRISMA chart).

Table 1
Common parental concerns regarding vaccination.

Vaccine side-effects
Vaccine effectiveness
Development of autism
Development of neurological disorders
Vaccine additives (thimerosal, aluminum, formaldehyde)
A high number and timing of vaccines
Pain during administration
The disease is more “natural” than the vaccine
The vaccine-preventable disease is not serious
Insufficient research before licensure
Lack of trust in the healthcare system
Lack of trust in government health authorities
Lack of trust in pharmaceutical companies
Religious reasons
Freedom of choice

them considered that children received too many vaccines and 36% thought that a healthy way of living could eliminate the need for vaccination [40]. A qualitative multi-center study performed in four European countries (Croatia, France, Greece, Romania) that assessed concerns healthcare workers might have regarding vaccines showed that overall they have a high level of confidence in vaccination, but there were also concerns about side-effects, effectiveness, need for vaccination (especially for newer vaccines such as the human papillomavirus (HPV) vaccine) and mistrust of health authorities, with a few doctors being completely against vaccination [39]. This study also proved that factors influencing vaccine hesitancy differed according to cultural, socio-economic and political context. While in Romania and Greece the most common concern was about safety of vaccination (“HPV vaccines can lead to tumors and autism”, “'it's well known that there are vaccines that have been banned in other countries (e.g., anti-hepatitis), precisely because they were proven to cause multiple sclerosis”), this factor was not as prevalent among healthcare providers in France and Croatia. Concerns regarding low vaccine effectiveness were particularly common in Greece; moreover many participants from Greece and also Romania considered there might be too many vaccines or given to children at a very young age, with some doctors from Greece following alternative vaccination plans. Another determinant of vaccine hesitancy discussed in this study was trust in health institutions or government. Healthcare providers from Croatia, France and Romania expressed high trust in the government, doctors, health authorities, research and vaccination. In contrast, mistrust was extremely common in Greece, particularly towards pharmaceutical companies, which they considered had financial gains and were not completely transparent about side effects. The authors considered that this difference in trust was influenced by the political and economic crisis situation in Greece [39].

Another study that addressed the connection between vaccine hesitancy and trust in health authorities, this time assessed in parents, revealed that parents who decided not to immunize their children have a greater distrust of the government and healthcare system compared to those who chose to vaccinate [20]. Those that refused were more likely to choose an “alternative lifestyle”, with alternative education and healthcare, such as homeopathy, herbalism, chiropractics [20,24]. This could also be valid for healthcare providers; in one study, 2 out of 7 doctors that were completely against vaccination mentioned they had a preference for homeopathy and natural remedies [39]. Many of the anti-vaccine movement leaders are alternative practitioners, who are against conventional medicine and have financial gains from selling “natural remedies” [41]. Distrust in health institutions was also associated with an increased number of parents who sought vaccination exemptions, from various reasons, medical, religious or philosophical [19,41].

As stated in the beginning of this subchapter, the factors involved in vaccine hesitancy are numerous and nuanced; each of

them needs to be addressed strategically in order to counter vaccine hesitancy.

3.1.2.1. Determinants of vaccine hesitancy in adolescents. According to WHO, more than 5000 adolescents and young adults died daily in 2019, many from preventable or treatable causes. Diarrhea, lower respiratory tract infections and meningitis are among the top five causes of adolescent deaths in African low- and middle-income countries [42].

There are several vaccines recommended for this age category (children aged 10–19 years), such as the HPV vaccine or booster vaccines for hepatitis B, diphtheria, tetanus and pertussis [43,44]. Unfortunately, vaccine uptake in adolescents remains low compared to younger children [45]. This might be explained by the fact that immunization rates in children are strongly correlated to parental decision, while adolescents want to play an active role in vaccination-related decisions and their attitudes regarding vaccination are independent and different from those of their parents [46].

Important factors involved in adolescent vaccination uptake discussed in the literature were education and lack of information regarding vaccination [47]. It was found that adolescents have less confidence in vaccines and are more concerned about their side effects, compared to adults [46]. A European survey conducted in 2017 in France, United Kingdom, Poland, Germany, Italy and Sweden assessed adolescents' knowledge about vaccines and meningitis [48]. The results showed that the highest rate of vaccine hesitancy was among French adolescents where 41% of participants considered vaccines to be dangerous. While 93% of adolescents from Italy and United Kingdom had heard of meningitis, in Sweden only 38% were aware of the existence of this disease. Only a third of participants were vaccinated against meningitis [48].

Other common determinants of vaccine hesitancy in adolescents were represented by missed vaccination opportunities at well or sick visits, lack of adequate healthcare provider resources (financial, vaccine storage, patient-tracking platforms for example), parental attitudes and education [47].

Because determinants of vaccine hesitancy differ in adolescents compared to their parents, different tools are needed to address this issue in this age category.

3.1.2.2. Determinants of vaccine hesitancy in children with neurological disorders. The immunization status of children with neurological disorders has not received sufficient attention, this being reflected in the scarcity of publications on this topic. A few papers the search retrieved on this subject revealed that vaccination rate among children with epilepsy and other chronic neurological diseases was significantly lower than in healthy children [49–56]. Only one study showed similar vaccination coverage between children with chronic neurological disorders and the population of healthy children, but most of the patients were incompletely immunized [57]. Children with neurological disorders are at increased risk of complications from infectious diseases, especially influenza and pneumococcal infections [58,59]. Moreover, any vaccine-preventable disease poses additional risk in case it results in hospital admission, on account of exposure to hospital pathogens or multiple medications. Therefore, immunization of this special group of patients is salient.

In children with neurological disorders, reasons that led to vaccine refusal or deferral were similar to those described in the healthy population, but were obviously influenced by the existence of a chronic condition. This was illustrated by the fact that many of the children in the study population had received immunization that was scheduled before the time of their diagnosis [51,52].

Parents, as well as healthcare workers had concerns regarding vaccination. Two studies, one performed in China [52] and the other in Japan [50], evaluated vaccine-hesitancy in healthcare professionals through surveys. Both of them revealed that an important contributor to vaccine hesitancy was misinformation and insufficient knowledge primary care physicians had regarding neurological disorders. Responders considered factors such as interval since the last seizure, seizure frequency, and electroencephalogram findings essential in their decision to administer vaccines to their patients. In one study, only 12.3% of responders considered it were safe to vaccinate patients with abnormal electroencephalogram, even though the patients were seizure-free for 3 years [52]. Other reasons for vaccination refusal provided were: chronic wheezing, unstable body temperature, and very low bodyweight [50]. All these motives were not supported by scientific data; moreover, a recent study showed that vaccination does not increase the risk of seizures in children with epilepsy [60].

Guidelines specific to each country also played a role in vaccine deferral. In Japan, for patients thought to be at high-risk for febrile seizures, a 2–3 months observation period after the last seizure was recommended before immunization [50]. In the Chinese pharmacopeia, "one suffering from encephalopathy, uncontrolled epilepsy, or other progressive neurological diseases" was listed as a contraindication for all immunization [61]. In the United States, the contraindication referred only to "persons who experienced encephalopathy within 7 days after administration of a previous dose of pertussis-containing vaccine not attributable to another identifiable cause" [62].

A particular situation was that of children diagnosed with Dravet syndrome. Because in up to 50% of Dravet cases vaccination was followed by the first seizure [63], parents were concerned regarding subsequent vaccination. In a survey conducted in 2018 by the Dravet Syndrome European Federation on vaccination in Dravet syndrome [64] that involved 319 responders from 16 countries in Europe, parents reported that in 39% of the cases the first seizure was related to vaccination. Of the total responders, 23% refused further vaccinations after the first seizure, 39% continued vaccination according to the schedule, 16% deferred vaccination and 22% received a partial vaccination schedule. Although specific reasons for this behavior were not assessed in the study, it could be hypothesized that they were mainly related to the fear that the vaccines would exacerbate the chronic disorder.

In their study evaluating the socio-demographic influences on immunization of children with chronic neurological disorders, Okoro and colleagues showed that maternal education correlates with the level of immunization in their children; also, father's professional status played a determinant role in vaccine uptake [56].

Children with neurological disorders are frequently referred to the neurologist to advise regarding immunization. It can be further speculated that in this special category of patients, other causes for vaccine hesitancy are parental belief that vaccines contributed or determined their child's disorder, frequent hospitalization that delay scheduled immunization, lack of specific guidelines, limited time for vaccination appointments.

All original articles regarding the determinants of vaccine hesitancy included in the review are presented as a table in the supplementary material.

3.1.3. The role of social media on vaccine hesitancy

In time, the relationship between patient and doctor has shifted from a paternalistic model, in which the medical decisions were made by the physician, to a shared decision model, in which the patient is an active participant in decisions regarding their health. This empowerment was sustained by the widespread adoption of the Internet, with many people seeking medical information online

[65,66]. While social media platforms play an important role in promoting public health, they also allow for the spread of misinformation. On social media platforms, any individual, frequently under the cover of anonymity, can create and spread health-related content, without an editorial or medical supervision [67,68]. Furthermore, by the way they are created social media platforms allow users to form communities sharing the same ideology. As a result, misinformation regarding vaccination is widely and rapidly spread, contributing to vaccine hesitancy. Studying the diffusion dynamic of true and false news distributed on Twitter between 2006 and 2007, Vosoughi and colleagues [69] found that "falsehood diffused significantly farther, faster, deeper, and more broadly than the truth in all categories of information". True information took about six times as long to reach 1,500 people as it did for false information to reach the same number of people. Furthermore, false news diffused significantly more broadly and it was retweeted by more unique users than true news [69].

A systematic review of 79 studies, that examined the quality of health information available on 5941 publicly accessible websites and 1329 web pages, concluded that 70% of the online information was of poor quality [70].

Several studies analyzing the vaccine content on different social platforms revealed that anti-vaccine information was better represented than that supporting vaccination [71,72]. 65% of 87 YouTube videos analyzed in 2017 showed anti-vaccine views; 36.8% provided no scientific data and only 5.6% were created by governmental institutions [73]. On Twitter, between 2010 and 2016, anti-vaccine tweets were four times more frequently re-tweeted than neutral ones [74].

Another aspect that needs to be taken into account is that usually parents who refuse or have doubts regarding immunizations are more likely to share their experience on social media, rather than those with positive attitudes toward vaccination. The so-called "mommy blogs" share persuasive narratives about their children experiencing serious disorders shortly after vaccination, erroneously blaming the vaccines. This misinformation reaches an enormous number of people who use the Internet [75]. In addition, anti-vaccine lobbyists and public figures, who usually have large fan bases online, use social media platforms to share anti-vaccines messages [76].

Available evidence demonstrated that exposure to anti-vaccine websites, even as short as five to 10 min, negatively influences parents' decision to vaccinate their children [77,78]. Furthermore, some individuals are more vulnerable to messages spread through social media, including older persons, those with intellectual disability, lower literacy, and lower digital literacy skills [68].

3.1.3.1. The role of social media on vaccine hesitancy in adolescents. One survey conducted in Australia that evaluated teenagers' sources of health information revealed that adolescents spent a median 2 hours per day on social media [79]. Regarding their sources of information, 85% reported they felt comfortable using the Internet to access sexual health information, followed by a doctor (81%), school (73%) and the mainstream media (67%). A smaller percentage stated they felt comfortable using social media as a health resource: Facebook (52%), applications (apps) (51%), SMS (44%) and Twitter (36%). Similar results were reported in adolescents form the United States (US), despite the fact that most of them (55%) named their parents as an important source of information, followed by health classes in school (32%) and a doctor or nurse (29%) [80]. 12% of the participants in the survey played health-related games and 21% of them had downloaded a health-related app, even though almost half of them had never used that app. Among the participants who searched for health information online, one third said they had changed their behavior because of the information found [80].

Compared to adults, adolescents sought health and vaccine-related information on social media platforms more frequently [81], but they had difficulties in selecting quality information sources [82].

In order to be effective, immunization strategies intended for adolescents should address all the particularities regarding the ways teenagers use social media.

3.1.3.2. The role of social media on vaccine hesitancy in children with neurological disorders. The Internet is an important source of information for parents of children diagnosed with a neurological disorder. Many social platforms offer the possibility to form online communities for patients with a specific disease, in which information is easily disseminated. According to a study performed in 2014 that evaluated the quality of information available on the Internet to parents of children with epilepsy, 23.8% of websites were low quality, reliability was poor in 26% of the websites and 70% of them were biased [83]. However, this study did not evaluate the scientific quality of the websites.

3.2. Opportunities social media offers in promoting immunization

A few papers analyzing strategic interventions to promote immunization were published.

Glanz and colleagues published in 2017 the results of a randomized controlled trial, in which parents were referred to information about vaccines on a social media platform or website or given standard information from their physician [84]. The study included 888 pregnant women that were randomly assigned to three arms: one included women that were exposed to a Web site with vaccine information and interactive social media components, the second arm included women that were exposed to a Web site with vaccine information and the third arm included women exposed to usual care. Usual care meant that vaccine information was provided to parents at well-child visits. Immunization status was assessed in participants' infants from birth to age 200 days. The women assigned to the interactive social media arm were more likely to immunize their children on schedule than those assigned to usual care; there was no significant difference in the vaccination status and timing of vaccination between the second and third arm of the study. The authors concluded that interactive informational interventions administered through social media platforms can improve vaccine acceptance. Furthermore, information regarding immunization seems to be effective when presented to parents before the birth of their children [84]. Using a similar population study and intervention, the authors measured changes in parental immunization attitudes over time by baseline degree of vaccination hesitancy [85]. Participants in the first and second arm showed significant improvements in attitudes regarding vaccination benefits compared to those in the third arm of the study. Moreover, participants in the first and second arm showed a significant decrease of concerns regarding immunization than those in usual care. There was no effect among participants that were not vaccine-hesitant at baseline [85]. Both studies showed that using social media and interactive websites to administer information was more effective in promoting immunization than standard methods (information given at well child visits of informative leaflets). Because information presented to parents before birth proved to be effective in improving attitudes regarding immunization for their infants, birthing and parental classes for parents should also include interactive education classes regarding vaccination. All materials, written, visual or audio should be translated into a number of suitable languages.

Gamification, meaning "the use of game design elements in non-game contexts" is increasingly being used as a tool for health promotion [86]. Montagni and colleagues [86] have recently

Table 2
Examples of websites that promote health education.

Provider	Web address	Content
the Global Disaster Preparedness Center	https://preparecenter.org/toolkit/kidskit/	Videos for children regarding the COVID-19 pandemic
Cincinnati Children's	https://www.cincinnatichildrens.org/patients/coronavirus-information/videos-for-kids-parents	Videos for parents and children regarding the COVID-19 pandemic
UNICEF	https://www.unicef.org/jamaica/documents/activity-book-talking-about-covid-19-kids	A guide to speak to children about the COVID-19 pandemic
The Columbia University	http://goaskalice.columbia.edu/	Answers to health-related questions for adolescents
Center for Disease Control	https://www.cdc.gov/healthyschools/bam/teachers.htm	Health-related classroom resources for teachers

performed a scoping review in order to identify and evaluate the effectiveness of gamified digital tools used in promoting vaccination. All 7 studies included in the review reported positive effects of gamified tools on attitudes toward vaccination, with an important increase in vaccine-acceptance rate, increased literacy and knowledge about vaccination. Health professionals are thus encouraged to use game-based features in their practice to promote vaccination [86]. Willis and colleagues developed a taxonomy of communication to improve vaccines-related dialogue [87]. In respect to this taxonomy, a game that can efficiently improve healthcare information should include challenges, a reward system, a fun and user-friendly interface, avatars, the possibility of team-playing, immediate success and questionnaires [86]. Some of the games developed in accordance to these criteria have been highlighted by WHO as innovative methods of engaging the public in health education [88]. Table 2 lists several websites that promote health education.

As previously discussed in this paper, physicians were still the main source of information for parents; therefore, in order to counteract vaccine hesitancy, they should be actively engaged in promoting immunization through personal social media such as Twitter or Facebook. To be effective, the communication should be interactive, sensitive, in a lay language, adequate to the parents' health literacy and presenting information that is tailored to the parents' concerns [89,90]. Because interactive interventions proved to be more efficient than the traditional ones (information given at well child visits and informative leaflets), physicians could organize question and answer panel discussions using social media platforms to inform parents and address their concerns regarding immunization. It is recommended that personal stories are used, also reports of disease outbreaks and visual images for a bigger impact [91]. For example, in Romania, a number of doctors and members of the community have successfully created online groups and communities that aim to improve parents' education about health and vaccines [92,93]. Furthermore, public figures including political and religious leaders that support vaccination should be co-opted in disseminating information about vaccines and share their own positive experience using various media, thus reaching out to hesitant people through sources they trust.

Healthcare institutions should increase their presence on social media and make sure they share correct, appropriate and easily accessible health information to all age categories, including adolescents [80]. Because health classes at school are an important source of information for teenagers, every school should organize and teach age-appropriate health subjects and also offer digital literacy classes.

Given the heterogeneity in people's attitudes towards vaccination, Meng and Olsen [94] proposed that medical and public health communities use market segmentation strategies to counteract vaccine hesitancy. Marketing segmentation is a marketing term that refers to dividing the targeted market into groups with similar traits such as needs, interests, age or behavior [95]. This approach allows marketers to better understand the differences in consumers' behavior and offer products that are tailored to the consumer's characteristics. This strategy can be applied in relation to vaccine hesitancy, to reveal reasons behind each segments' decision regarding vaccination and to offer targeted solutions with the aid of social media [94].

Recently, a number of social media platforms have taken measures to counteract anti-vaccination content, which included disabling of anti-vaccine advertisements or comments on anti-vaccine subjects and labeling content as misinformation when it is the case [96]. This effort should be encouraged and supported by health authorities and the community.

Social media platforms represent a tool for health authorities to monitor real-time public confidence in immunization and trends which can be used to everyone's benefit [97]. Databases that include vaccination status and schedules for each patient should be available to primary care physicians in order for them to keep tracks of the status and their upcoming vaccination.

Specific guidelines regarding vaccination in various neurological disorders need to be developed and made available to all specialists involved in the care of this special category of patients and also to parents. These guidelines should include detailed information about all vaccines available, their possible side effects, timing of vaccination and shared on dedicated social platforms. Usually, the parents of children with disabilities have a limited time for vaccination appointments; home visits and arranging appropriate transportation for these patients could improve accessibility and vaccination uptake.

3.3. *Vaccine hesitancy during COVID-19 pandemic*

The ongoing COVID-19 pandemic led to an unprecedented time for vaccines development, with two of the currently available vaccines being developed and distributed in less than a year since the start of the pandemic. Vaccination for COVID-19 is highly effective in reducing severe disease and death and it is very safe [98,99], yet a high percentage of people are still vaccine hesitant [100,101]. The COVID-19 pandemic brought forward unique factors involved in vaccine hesitancy, factors related to the fast development of the vaccines, relatively new technologies used in their development, the need for further preventive measure even after immunization, new variants of the virus, new and emerging information related to the disease and changes in health policies worldwide [102]. This resulted in a change in people's perception of the risks and negatively influenced their decision to get the vaccine. Furthermore, a myriad of misinformation, false conspiracy theories and inaccurate beliefs circulated in the media and fueled vaccine hesitancy; for example some people consider that the virus does not exist, that vaccines cause infertility, track personal data and are made from cells of aborted fetuses or believe that 5G technology directly transmits the virus and affects people's immunity [103].

Political ideology seemed to play an important role in people's

decisions regarding vaccination [104,105]. People who declared themselves democratic ideology partisans were significantly more likely to accept vaccination, those that endorsed radical parties or those who did not vote or had no political preference were significantly more likely to refuse vaccination [104]. In the US, the lowest COVID-19 vaccination rates were in Republican-leaning states, while in the democratic-leaning states the rate of fully-vaccinated people was above 50% [105].

Regarding children's vaccination against the coronavirus, in one study 70% of parents reported more hesitancy to the COVID vaccine than previous vaccinations [106]. Vaccine acceptance rates varied between 33% and 65% in different surveys [106–108]. Unfortunately, it seems that the ongoing pandemic is associated with an increase in vaccine hesitancy. This might be linked to parents' perceived risk of COVID-19 in children; because the disease tends to have a mild course in children [109], vaccination uptake diminishes as the parents do not perceive the need for vaccination. The main reasons parents gave against vaccinating their children were lack of sufficient scientific studies, concerns about side effects and possible inefficacy of the vaccine due to virus mutations [108].

As the pandemic unfolds and more information is becoming available about the disease and current and emerging vaccines and treatments, the factors involved in vaccine hesitancy will be better understood. Therefore, improved strategies to counteract it will be developed, leading to an increase in vaccination uptake.

4. Conclusions

Immunization has proven to be a very safe and effective measure to prevent infectious diseases. However, an increasing number of parents, including parents of children with neurological disorders, are vaccine hesitant. Their motives are complex and nuanced, and involve factors related to vaccine safety and efficiency, perceived personal risks and benefits, socio-demographic and psychological characteristics. Determinants of vaccine hesitancy differ in adolescents and should be differently approached. In patients with neurological disorders, an important contributor to vaccine hesitancy was primary care physicians' knowledge of neurological diseases and parents' concerns that vaccination would exacerbate the chronic disorder. Unfortunately, the current pandemic is associated with an increase in vaccine hesitancy and brought forward unique determinants. While the Internet and social media platforms are tools for the anti-vaccine movement to spread misinformation, they can also be valued as a way for health institutions to promote health and pro-vaccine information. As a future direction, more studies on vaccine hesitancy that include children with neurological disorders are required in order to assess additional determinants of vaccine hesitancy. At the same time, specific recommendation on vaccination should be established for all physicians involved in the management of this category of patients.

Declaration of competing interest

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Appendix A. Supplementary data

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