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Review article

Comparative Systematic Review and Efficacy of Various Vaccines Against SARS-COV-2

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Abstract

This review article is based on the current scenario wherein COVID-19 is dominating the world. COVID-19 has caused losses of innumerable lives while the battle to eradicate the virus is still on. The main weapon to help us overcome this pandemic is the vaccines provided to us by the research scientists. More than twelve vaccines have been introduced in the market having safety and efficacy. These vaccines will help us reduce the number of cases emerging every day and help us sustain through these difficult times. The article aims to compare and evaluate different vaccines available in the market. The vaccines compared are Covishield, Covaxin, Pfizer BioNTech, Moderna, Novavax, Janssen, Sputnik V, EpiVacCorona, CoviVac, Sino pharm, Sinovac, CanSinoBio and RBD-dimer. The review article also covers the calculation related to the efficacy of the vaccines.

Introduction to COVID-19

A new terror to this world has been named Coronavirus. From the beginning of the 20th century, these viruses have been seen. The Chicken was the first infected with virus which caused the respiratory ailments [1]. The array of hosts they infect and their types escalated over decades, each of which is linked to the emergence of respiratory diseases of unique pathological differences.

The main cause of the disease is the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV2) [2]. The disease trespasses from one individual to another by means of the respiratory route. The transmission of the disease is possible when an infected person coughs, sneezes, talks, or breathes within a range of 1.8 meters. New infection can develop when particles containing the virus are exhaled from an infected person and gets into the mouth, nose, or eyes of a non-infected person [3]. Human-to-human interaction is the most common way for SARS CoV2 virions to initiate a new infection.

Coronavirus disease 2019 (COVID-19) is said to be more infectious than influenza but less as compared to measles. It frequently proliferates in clusters, wherein infections may be traced returned to an index case or geographical location [4]. The infection can be transmitted from an infected person to others up to two days before they show symptoms. It is also possible that the infection is carried even if the patient is asymptomatic [5]. Moderate instances of the contamination convey the virus for 7-12 days and weeks or greater for excessive instances. The diploma to which the virus is infectious is uncertain, however, studies have indicated that the pharynx reaches the top viral load about 4 days after the contamination or the primary week of symptoms, and declines later.

Respiratory failure from Acute Respiratory Distress Syndrome (ARDS) is the main reason for deaths in the COVID-19 patients [6]. 39% of the overall pooled mortality rate is seen in COVID-19 patients due to ARDS. Respiratory failure includes various risk factors such as

older age, male sex, cardiovascular diseases, laboratory markers, and high viral load on admission.

Polymerase chain reaction testing is currently used for the diagnosis of COVID-19. However, because of false-negative test results, presumptive tests such as nasal swabs, clinical, laboratory and imaging findings are used to detect SARS-CoV2.

By using preventive measures, the spread of the virus can be controlled. These measures include staying at home, wearing a mask, washing hands for about 20 seconds, avoiding crowded places, avoid touching eyes, mouth and nose, maintaining respiratory hygiene [7].

Mechanism of Action of COVID-19

Firstly, the viral infection is spread through inhalation or ingestion of viral droplets as a result of sneezing, coughing, or touching which is the primary source of infection. The coronavirus genome encodes four different structural proteins [9]. It includes Nucleocapsid(N) protein, Membrane(M) protein, Spike(S) protein and Envelope(E) protein, and several non-structural proteins (nsp) as depicted in Figure 1.

In the process of transcription and translation of the viral RNA, the N protein plays a major role. The M protein is present on the surface of the virus and is known to be the central organizer in the assembly of the virus. The S protein, also present on the surface helps in attachment to the host surface receptors and causes the permeation of the virus into the host cell. The S protein contains two well-defined protein domain regions: S1 and S2 subunits, which are associated with cell recognition and the fusion of viral and cellular membranes respectively. The E protein plays an important role in membrane penetration in the host cell, virus-cell interaction, and the assembly of the virions.

The binding of the S protein takes place on the surface of the human cells, mainly present in the lungs via the Angiotensin Converting Enzyme 2 (ACE2) receptor [10]. The S protein is also broken down by the host cells through enzymes such as trypsin and furin. Hence, activation of the membrane fusion mechanism is triggered. Once the virus enters the cytoplasm through endocytosis, it proceeds with a three-step reaction for membrane fusion, involving receptor-binding and induced conformational changes in the S protein resulting in the proteolysis of the cathepsin L by intracellular proteases and further activation with the help of endosomes. The endosomes then release the virus into the cytoplasm where the uncoating of the viral nucleocapsid occurs. The single-stranded RNA is released in the cytoplasm. Replication/Transcription Complex (RTC) mediates the procedure of replication and transcription. Structural viral proteins such as M, N, S, and E are synthesized in the cytoplasm and inserted in the endoplasmic reticulum and transferred to the Endoplasmic reticulum- Golgi intermediate compartment (ERGIC) for the assembling of the new virions. The newly produced virions are transferred to the surface of the infected host cells and released through the process of endocytosis. The released virions then attack other cells and then spread the infection, whereas the host cell, which has released the virions due to the viral production stress eventually leads to cell death.

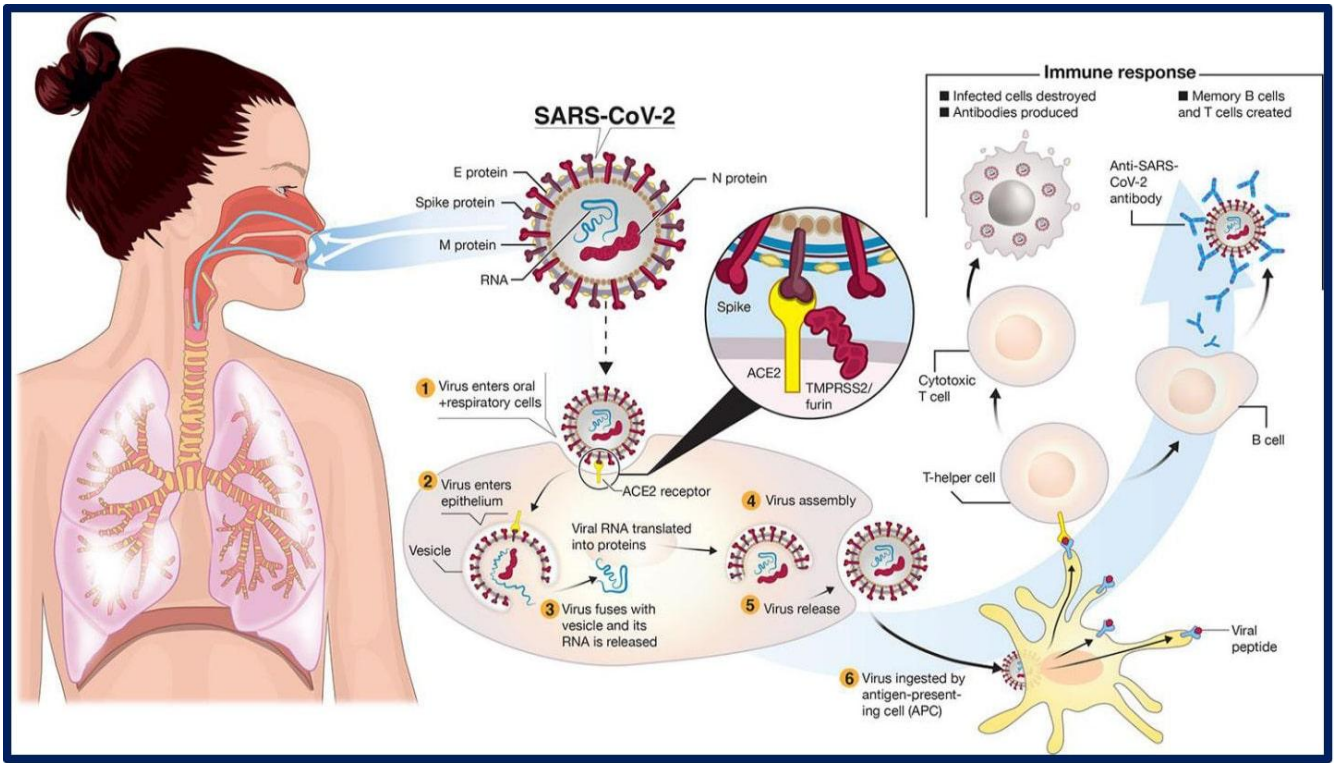

Figure 1. Mechanism of COVID-19 [8].

Immunity to COVID- 19

Immunity development to SARS-CoV2 is yet to be understood fully, but research suggests that there is a response seen through both antibody-mediated as well as cell-mediated.

Antibody-mediated immunity: Also known as humoral immunity includes immunity through helper T cells, B cells which differentiate into plasma B cells which act as an antibody to the antigen. As per research, it says that after the infection has been developed, IgM and IgG are detected in the body. IgM antibodies are at their peak at the initial stage of the infection and remain in the body for approximately 20 days and then decline gradually. Whereas IgG is to be seen at the later stage, mostly after 25 days from the onset of the infection and remains up to 120 days. Neutralizing antibodies are also found in adults which remain in the body for several months. The Maternal IgG antibodies are seen to be transferred to the child through the placenta and remain for about 8 months after infection.

Cell-mediated immunity: Immune system, which does not require any involvement of antibodies but is activated through phagocytes, antigen-specific cytotoxic T- cells, and through the release of different cytokines due to the presence of antigens is known as cell-mediated immunity. People generally develop a strong and broad T-cell response, including both CD4+ and CD8+ T-cells, and also have a memory phenotype. These cells having a half-life of about 3-5 months in recovered patients and up to 8 months after primary infection.

Vaccines

Introduction to Vaccines

The world is facing a global pandemic wherein so many people have lost their lives and many are battling against this deadly disease. COVID-19 has very serious and life-threatening effects as it spreads at such a high rate. Vaccines are required to put an end to this pandemic. Although wearing a mask, maintaining social distancing, and following all the social norms may reduce the chance of getting the virus, but that is not sufficient. It is necessary to build our immune system to help us fight against this virus, and this can be done with the help of vaccines. Many companies have been successful in doing so, and vaccines are now available to people across the globe. By getting vaccinated, the chain of the virus can be broken, and the virus won't get a host to survive, at least till herd immunity is achieved. Vaccines will help reduce cases of hospitalization and death, which is of major concern.

A biological preparation given to a person provides that person immunity against a particular infectious disease is known as a vaccine [11]. A vaccine can be differentiated as prophylactic or therapeutic. The disease-causing unit, such as the toxin, sugar, protein, or the virus, is weakened by treatment and is used for the preparation of vaccines. These components therefore, trigger an immune response and help to induce antibodies that are memorized and can decrease the effect and severity of the diseases.

Vaccination can be a very important and primary way to arrest the widespread control of any infectious disease and provide the gift of life [12]. For example, Vaccines for polio, measles, tetanus, whooping cough, etc. have saved the lives of millions.

Once a sufficient number of people are vaccinated, the chances for an outbreak of a particular disease become so low that even the ones who aren't vaccinated benefit. Eventually, a bacteria or virus simply will not have enough eligible hosts to feed on and will subsequently die out. This concept is known as "herd immunity" wherein every single individual may necessarily not be vaccinated and has helped to eradicate the disease [13].

Serious diseases can spread rapidly and can cause concern in pregnant women along with the fetus. But with the help of vaccines, we can make sure that the immunity developed will keep the mother and the baby safe. MMR vaccines have been advised on women who are expecting to conceive so that they can be away from diseases such as mumps, measles and rubella. It is likewise encouraged that pregnant ladies must take a shot of influenza and whooping cough vaccine as it guarantees immunity for each mother and fetus and effects in lesser possibilities of having the virus [14].

Monovalent vaccines are those which are effective against only one microorganism, whereas polyvalent vaccines are used to provide immunity against more than one microorganism.

Types of COVID-19 Vaccines [15]

Four major types of vaccine used are, depicted in figure 2.

1) Whole virus
2) Protein subunit
3) Viral vector
4) Nucleic acid (RNA and DNA)

1. Whole Virus Vaccine [16]

The whole virus vaccine is further subdivided into:

a) **Live attenuated vaccine:** Live attenuated vaccine virus which is disabled such that it does not carry the efficiency to cause the disease, but it can alarm the immune system [17].

Advantage

1) Well-known technology.
2) Strong immune response acquired.
3) Easy to manufacture.

Disadvantage

1) Relatively sensitive to temperature, so special attention should be given to storage.
2) Not be given to people with compromised immune systems.

3) Might trigger disease, but very rare case

b) Inactivated vaccine: Virus used in an inactivated type of vaccine undergoes physical and chemical treatment which destroys the genetic material of the virus. They cannot infect cells and replicate but can boost immune response. They are safe to use, but low response compared to live attenuated vaccines.

Advantage
1) Given to people with compromised immune systems.
2) Since no live component is present, there is no risk of the vaccine triggering the disease.
3) Relatively stable.
Disadvantage
1) Requirement of Booster shots for proper immunity against disease
Four inactivated vaccines Sinopharm BIBP COVID-19 vaccine also known as BBIBP-CorV, developed by Sinopharm's Beijing Institute of Biological Products, CoronaVac, also known as the Sinovac COVID-19 vaccine, is an inactivated virus COVID-19 vaccine developed by the Chinese company Sinovac Biotech., Covaxin India's First Indigenous COVID-19 Vaccine. Devlped by Bharat Biotech is developed in collaboration with the Indian Council of Medical Research (ICMR) - National Institute of Virology.

2. Protein Subunit

A protein is extracted from the virus which could be alive or inactivated, purified, and injected as a vaccine for the disease. For the coronavirus, most commonly, the spike protein is used. Virus-like substances work in the same manner and are safe for use as they do not contain any disease-producing components. But it requires the addition of few a chemical in order to boost immunogenicity [18].
Two protein subunit vaccines (EpiVacCorona is a COVID-19 preventive vaccine developed by the Vektor State Research Center of Virology and Biotechnology in Russia.)
Advantage
1) Noninfectious vaccine.
2) Protein subunit has a strong humoral response.
3) Strong innate Immune Response
Disadvantage
1) High risk of infection and inflammation which may result in adverse reactions.
2) Used for production of multivalent vaccine formulation.

3. Viral Vector

The gene for a pathogen protein is inserted into a different virus that can infect without causing the disease. The safe viruses are used as a transporter of the protein component which will trigger the immune response. Some reproduce in the body, but some do not reproduce. Three viral vector vaccines (Sputnik Vis an adenovirus viral vector vaccine from COVID-19 developed by Gamaleya Reearc Institute of Epidemiology and Microbiology in Russia., Oxford-AstraZeneca, sold under brand name Covishield and Vaxzevria is a viral vector for prevention of Covid-19 devloped by Oxford University & AstraZeneca, Convidecia, is a single-dose viral vector vaccine for COVID-19 developed by CanSino Biologics [19].
Advantage
1) Provide long-term gene expression.
2) Dividing and non-dividing cells can be infected.
3) Much safer vaccine.
4) Produce high immunogenicity.
Disadvantage
1) Pre-existing immunity is one of the major drawbacks.
2) Generation of the competent-replication virus may result in tumorigenesis.

4. Nucleic Acid

This type of vaccine promotes nucleic acid for coding as an antigen instead of a protein antigen or a virus expressing the protein [20].
DNA plasmid enters the nucleus and is translated to mRNA for the expression of a protein. Directly mRNA can also be injected which requires no translation, but is less stable than DNA type. Two RNA vaccines (Pfizer-BioNTech, is a COVID-19 vaccine sold under the brand name Comirnaty, is an mRNA-based COVID-19 vaccine developed by the German, Moderna COVID-19 vaccine, codenamed mRNA-1273 and sold under the brand name Spikevax, is a vaccine developed by Moderna,).

Working of vaccines

A healthy immune machine facilitates maintaining invaders far away from us. The immune system comprises of various types of cells. Harmful pathogens are defended and removed from the body because of these cells. The important thing is that the immune system recognizes the harmful substance. Vaccines aim to teach the body to recognize new diseases. Upon recognition, it stimulates the body to produce antibodies against the antigens of pathogenic diseases. It also primes immune cell response to the disease in the future. There are various methods by which the vaccines work and act as an antigen, and are as follows:

1) Sugar or protein is used to make the pathogen.
2) The virus, which is either inactivated or is dead, is used.
3) The toxic parts of the virus are made into toxoids.
4) The virus is weakened via the way of physical or chemical remedy.

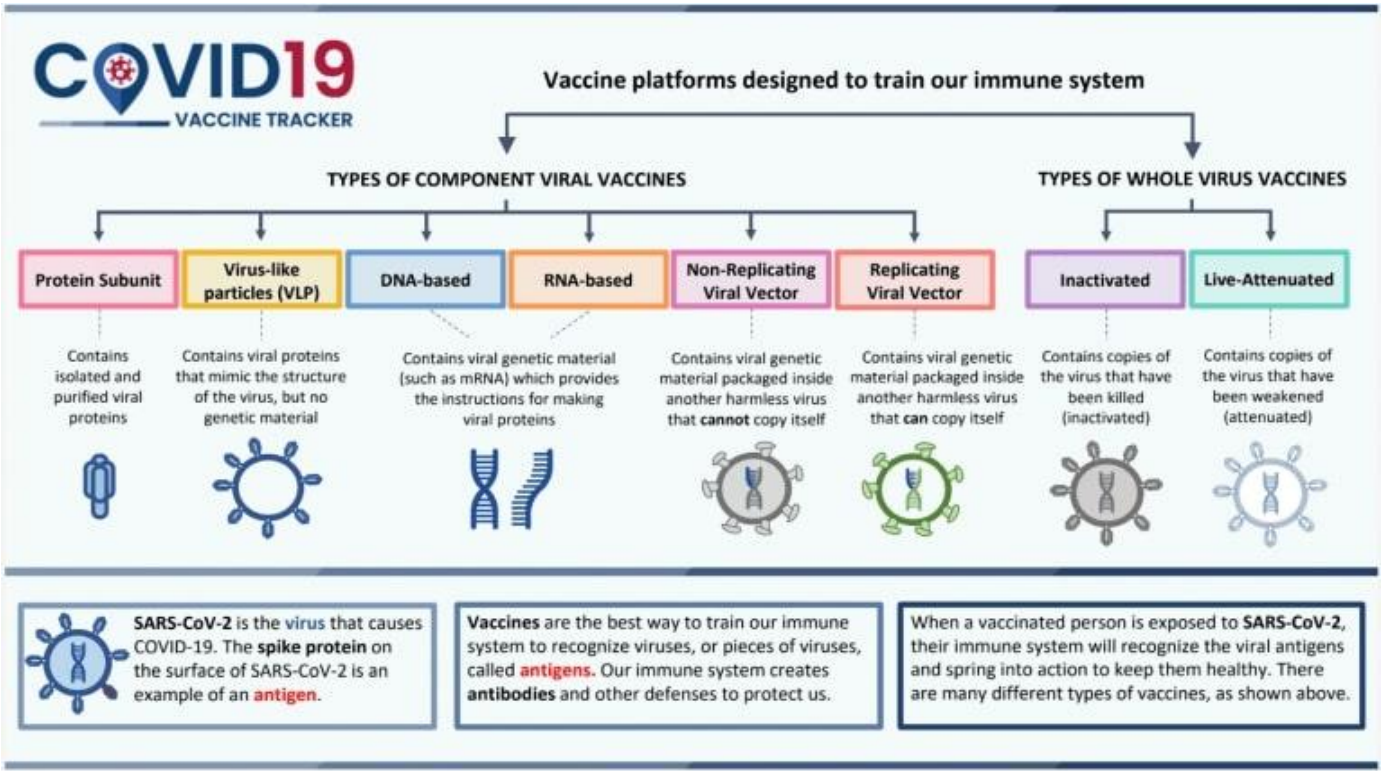

Figure 2.Types of COVID-19 Vaccine.

Injectables are the preferred route for the administration of vaccines. They are made up of two units. The antigen is the first component which includes a part of the disease which is used to warn the body about a harmful substance. Adjuvant is the second component that helps in triggering a strong immune response [20].

Different Vaccines in the Market

Calculation for the efficacy of Vaccines

The efficacy rate of vaccines is calculated through clinical trials where the vaccine is tested on a large number of people. These individuals are divided into two categories. One gets the vaccine, and the other gets a placebo. The placebo is a substance that is identical to the treatment being tested in the clinical trial but does not contain the active ingredient. Once they receive the particular treatment i.e., vaccine or the placebo the participants of the trial are allowed to live their lives while the scientists monitor whether or not the participants get infected by Covid-19. The general range of members inflamed through the sickness is noted. For example, if 40,000 participants took part in the clinical trial, from which about 200 participants were infected by the disease, these 200 participants are divided based on which group they belong to i.e., whether they belong to the vaccine group or the placebo group.

- If the participants infected in each group are equal, then the efficacy of the vaccine is said to be 0%
- If all the 200 were in the placebo group and zero people got the disease, then the vaccine would have efficacy of 100%
- If 190 participants belonged to the placebo group and 10 belonged to the vaccine group, then the vaccine would be 95% effective.

The above case means that each vaccinated person is 95% less likely to get the disease than a person without a vaccine each time they are exposed to Covid-19 [28].

PFIZER

(n= total no. Of people under the trial) (n=44,000) [22, 23].

Table 1. Calculation for the efficacy of Pfizer Vaccines.

Pfizer	No. of people under the trial	No infection with COVID-19	Infected with COVID-19
Vaccine	22,000	21,992	8
Placebo	22,000	21,838	162
Total	44,000	43,830	170

% of the vaccinated group that developed COVID-19= 8/22,000= 0.036%
% of placebo group that developed COVID-19= 162/22,000= 0.74%
Relative risk of getting COVID-19= 0.036/0.74= 0.049
Vaccine Efficacy= 1-0.049= 95.1%.

MODERNA
(n=30,000) [23].

Table 2. Calculation for the efficacy of Moderna Vaccines.

Moderna	No. of people under the trial	No infection with COVID-19	Infected with COVID-19
Vaccine	15,000	14,989	11
Placebo	15,000	14,815	185
Total	30,000	29,804	196

% of the vaccinated group that developed COVID-19 = 11/15,000 = 0.073%
% of placebo group that developed COVID-19 = 185/15,000 = 1.233%
Relative risk of getting COVID-19 = 0.073/1.233 = 0.059
Vaccine Efficacy = 1-0.059 = 94.1%.

JOHNSON & JOHNSON
(n=40,000 but data collected from 39,321 participants) [24].

Table 3. Calculation for the efficacy of Johnson & Johnson Vaccines.

Johnson & Johnson	No. of people in the trial	No infection with COVID-19	Infected with COVID-19
Vaccine	19,514	19,398	116
Placebo	19,544	19,196	348
Total	39,321	38,594	196

% of the vaccinated group that developed COVID-19 = 116/19,514 = 0.594%
% of placebo group that developed COVID-19 = 348/19,544 = 1.78%
Relative risk of getting COVID-19 = 0.594/1.78 = 0.333
Vaccine Efficacy=1-0.333 = 66.7%.

SPUTNIK V
(n=22,714) (Placebo: Vaccine=1;3) [25].

Table 4. Calculation for the efficacy of Sputnik V Vaccines.

Sputnik	No. of people in the trial	No infection with COVID-19	Infected with COVID-19
Vaccine	17,032	17,016	16
Placebo	5,682	5,620	62
Total	22,714	22,636	78

% of the vaccinated group that developed COVID-19 = 16/17,032 = 0.093%
% of placebo group that developed COVID-19 = 62/5,682 =1.091%
Relative risk of getting COVID-19 = 0.093/1.091 = 0.085
Vaccine Efficacy =1-0.085 = 91.5%.

COVAXIN (According to the first interim analysis in March 2021)
(n=25,800) [26].

Table 5. Calculation for the efficacy of Covaxin Vaccines.

Covaxin	No. of people under the trial	No infection with COVID-19	Infected with COVID-19
Vaccine	12,900	12,893	7
Placebo	12,900	12,864	36
Total	25,800	25,757	43

% of the vaccinated group that developed COVID-19 = 7/12,900 = 0.054%
% of placebo group that developed COVID-19 = 36/12,900 = 0.279%
Relative risk of getting COVID-19 = 0.054/0.279 = 0.1935
Vaccine Efficacy =1-0.193 = 80.6%

NOVAVAX
(n=about 15,000) [27].

Table 6. Calculation for the efficacy of Novavax Vaccines.

Novavax	No. of people under the trial	No infection with COVID-19	Infected with COVID-19
Vaccine	7,500	7,494	6
Placebo	7,500	7,444	56
Total	15,500	14,938	62

% of the vaccinated group that developed COVID-19 = 6/7,500 = 0.08%
% of placebo group that developed COVID-19 = 56/7,500 = 0.746%
Relative risk of getting COVID-19 = 0.08/0.746 = 0.1072
Vaccine Efficacy =1-0.1072 = 89.3%.

Comparison of different marketed COVID-19 vaccines

Table 7. Comparison of COVISHIELD & COVAXINE.

Indicators	**COVISHIELD** [29,30,31,50]	**COVAXIN** [29,30]
Name of Vaccine	AZD1222	Covaxin
Type of Vaccine	Viral Vector Vaccine	Inactivated Virus Vaccine
Primary Developers	Oxford University, AstraZeneca	Bharat Biotech, ICMR
Each Dose	5*10^10 particle/dose	6 mcg/dose
Dosing	2 doses-8 to 12 weeks apart	2 doses-4 to 6 weeks apart
Shelf life	6 months	6 months
Mode of administration	Intramuscular Injectable	Intramuscular Injectable
Efficacy	70.4%	78%
Storage	2-8^{0}C	2-8^{0}C
Targeted population	18 years and above	18 years and above
Working	ds DNA encoding for the Spike protein is protected in a safe virus. The infected cell expresses the Spike protein which leads to an immune response [32].	SARS-CoV2 is chemically inactivated (with a chemical called beta-propiolactone) so it cannot replicate but all the proteins remain intact [32].
Variants	At least one study finds it has little effect against the South African variant but appears effective against the UK and Brazilian variants.	Show significant immunogenicity against the rapidly emerging variants.
Side Effects	Injection site tenderness, injection site pain, headache, fatigue, myalgia, malaise, pyrexia, chills, arthralgia, nausea, redness, itching.[49]	Injection site pain, headache, fatigue, fever, body ache, abdominal pain, nausea, vomiting, dizziness-giddiness, tremor, sweating, cold, cough, injection site swelling
Contraindications	Hypersensitivity to the active substance or any of the excipients such as L-Histidine, L-Histidine hydrochloride monohydrate, Magnesium chloride hexahydrate, Polysorbate 80, Ethanol, Sucrose, Sodium chloride, Disodium edetate dihydrate, Water for injection.	People having a history of allergies, have a fever, have a bleeding disorder or are on a blood thinner, are immune-compromised or are on a medicine that affects the immune system, are pregnant, are breastfeeding, have received another COVID-19 vaccine, any other serious health-related issue [33].
Price	$3-$4 per dose	$4.2 per dose
Country of origin	U. K.	India

Table 8. Comparison of PFIZER BIONTECH & MODERNA.

Indicators	**PFIZER BIONTECH** [29,30,49]	**MODERNA** [29,30,37,38,50]
Name of Vaccine	BNT162b2	mRNA-1273
Type of Vaccine	Encapsulated mRNA Vaccine	Encapsulated mRNA Vaccine
Primary Developers	Pfizer, BioNTech, Fosun Pharma	Moderna, BARDA, NIAID
Each Dose	30 mcg/dose [36]	100 mcg/dose [36]
Dosing	2 doses-21 days apart	2 doses-28 days apart
Shelf life	6 months	6 months
Mode of administration	Intramuscular Injectable	Intramuscular Injectable
Efficacy	95%	94.10%
Storage	-80^{0}C	2-8^{0}C for 30 days
Targeted population	12 years and older	18 years and older
Working	mRNA encoding for the Spike protein is protected in lipid-nanoparticles (like soap bubbles). Once absorbed, the cell expresses the Spike protein resulting in an immune response [32].	mRNA encoding for the Spike protein is protected in lipid-nanoparticles (like soap bubbles). Once absorbed, the cells express the Spike protein resulting in an immune response [32].
Variants	Lab data suggest, "quite effective" against the UK variant as well as the South African and Latin American variants.	Lab data suggest, "quite effective" against the UK variant as well as the South African and Latin American variants.
Side Effects	Pain, fatigue, headache, muscle pain, chills, joint pain, fever, swelling at the injection site, nausea, malaise. [34,35]	Pain, swelling, tiredness, chills, fever, swelling of lymph nodes, headache, muscle, and joint pain, nausea, vomiting. [49]
Contraindications	Severe allergic reaction (e.g., anaphylaxis) after a previous dose of an mRNA COVID-19 vaccine or any of its components. An immediate allergic reaction of any severity to a previous dose of an mRNA COVID-19 vaccine or any of its components. (including polyethylene glycol) [50].	Should not be administered to individuals with a known history of a severe allergic reaction. (e.g., an anaphylactic reaction occur following administration of the Moderna COVID-19 Vaccine [39].
Price	$19.50 per dose	$25-$37 per dose
Country of origin	Multinational	U.S.

Table 9. Comparison of NOVAVAX&JANSSEN.

Indicators	**NOVAVAX [30]**	**JANSSEN [29,30]**
Name of Vaccine	NVX-CoV2373	JNJ-78436735
Type of Vaccine	Virus-like Particle Vaccine	Viral Vector Vaccine
Primary Developers	Novavax, Coalition for Epidemic Preparedness Innovations (CEPI)	Janssen Vaccines (Johnson & Johnson)
Each Dose	5 mcg/dose [50]	5*10^10 particles/dose [36]
Dosing	2 doses-21 days apart	1 dose
Shelf life	2 years	2 years
Mode of administration	Intramuscular Injectable	Intramuscular Injectable
Efficacy	89%	66%
Storage	2-8℃ for 3 months	2-8℃ for 3 months
Targeted population	18-59 years	18 years and older

Working	Nanoparticles are coated with synthetic spike proteins. Additional element called an adjuvant is added which allows boosting the immune reaction [32].	ds DNA encoding for the Spike protein is protected in a safe virus. The infected cell expresses the Spike protein which leads to an immune response [32].
Variants	Effective against UK and South African	Based on clinical studies in Africa, UK, and Latin America, there is evidence the vaccine is effective against the variants, although less so against the South African and Latin American strains.
Side Effects	Injection site pain, rash, headache, muscle pain, fever, nausea, vomiting, tenderness [49].	Injection site pain, rash, headaches, muscles soreness, fever, fatigue, nausea, redness, swelling, tiredness, chills [49].
Contraindications	Information, not available	Known history of a severe allergic reaction (e.g., anaphylaxis) to any component of the vaccine.[50]
Price	$16 in the US	$10 per dose
Country of origin	U.S.	The Netherlands, U.S.

Table 10. Comparison of SPUTNIK V, EPIVACCORONA & COVIVAC.

Indicators	**SPUTNIK V [29,30]**	**EpiVacCorona [29,30,40,41]**	**CoviVac [29,30,42,43]**
Name of Vaccine	Gam-COVID-Vac	EpiVacCorona	CoviVac
Type of Vaccine	Viral Vector Vaccine	Protein Subunit	Inactivated Virus based Vaccine
Primary Developers	Gamaleya Research Institute, Acellena Contract Drug Research, and Development	Federal Budgetary Research Institution, State Research Center of Virology and Biotechnology	Chumakov Centre
Each Dose	(1.0 ± 0.5) × 10^11 particles/dose	Information not found	Information not found
Dosing	2 doses-21 days apart	2 doses-21-28 days apart	2 doses-14 days apart
Shelf life	2 years	2 years	Information not found
Mode of administration	Intramuscular Injectable	Intramuscular Injectable	Intramuscular Injectable
Efficacy	91.6%	Information not found	Information not found
Storage	Store in a dark place at a temperature not exceeding -18℃	Stable in refrigerator	2-8℃
Targeted population	18 years and older	18-60 years	18-60 years
Working	ds DNA encoding for the Spike protein is protected in a safe virus. The infected cell expresses the Spike protein which leads to an immune response [32].	Vaccine relies on chemically synthesized peptide antigen of SRS-CoV-2 proteins, conjugated to a carrier protein and adsorbed on aluminum-containing adjuvant. It forms immunity due to artificially synthesized peptides	The vaccine includes spike protein on the outside of the viral envelope and genetic material on the inside. The virus has been so that its genetic material cannot infect cells or replicate but can still trigger an immune response.
Variants	Unknown. Clinical trial data was largely conducted in Russia before the emergence of major variants.	Russian scientists say it is effective against variants.	Russian researchers say that because it is based on the whole virus, it will be effective against most variants or mutations.

Side Effects	Flu-like symptoms, chills, fever, arthralgia, myalgia, asthenia, headache	Fever or chills, cough, shortness of breath, fatigue, muscle pain, headache, loss of taste or smell, soar-throat, stuffy nose, nausea, vomiting, diarrhea	No severe side effects
Contraindications	Hypersensitivity, pregnancy and period of breastfeeding, acute infectious and non-infectious diseases, exacerbation of chronic diseases	Information not found	Severe allergic reactions, pregnancy, and breastfeeding.
Price	Free in Russia and US $10 in the international market per dose	Information not found	Information not found
Country of origin	Russia	Russia	Russia

Table 11. Comparison of SINOPHARM, SINOVAC.

Indicators	**SINOPHARM [29,30,45]**	**SINOVAC [29,30,44]**
Name of Vaccine	BBIBP-CorV	CoronaVac
Type of Vaccine	Inactivated Virus Vaccine	Inactivated Virus Vaccine
Primary Developers	Beijing Institute of Biological Products; China National Pharmaceutical Group	Sinovac
Each Dose	2 mcg/dose	3 mcg/dose
Dosing	2 doses-21 days apart	2 doses-28 days apart
Shelf life	2 years	3 years
Mode of administration	Intramuscular Injectable	Intramuscular Injectable
Efficacy	79%	50%
Storage	2-8℃	2-8℃
Targeted population	18-60 years	18-59 years
Working	SARS-CoV2 is chemically inactivated (with a chemical called beta-propiolactone) so it cannot replicate but all the proteins remain intact [32].	SARS-CoV2 is chemically inactivated (with a chemical called beta-propiolactone) so it cannot replicate but all the proteins remain intact [32].
Variants	Triggers immune response against South African variant but the effect is weaker as compared to the original variant.	Unknown, although a study in Brazil demonstrated 50.4% efficacy at preventing symptomatic infections.
Side Effects	Headache, fever, muscle and joint pain, nausea, diarrhea, itchy skin, cough. Uncommon-loss of appetite, constipation, hypersensitivity. Rare-allergic reaction, drowsiness, nasal congestion, limb pain, acne, ear discomfort. Very rare-tremors, tonsillitis, gastritis, blurry vision, asthma, mouth ulcers	Increase in blood pressure, pain at the injection site, rashes, nausea, headache
Contraindications	Severe allergic reactions, pregnant and lactating women, cancer patients currently on chemotherapy	Severe allergic reactions.
Price	<$145 for 2 doses	$60 per dose
Country of origin	China	China

Table 12. Comparison of CANSINOBIO, RBD-Dimer.

Indicators	**CANSINOBIO [30,46]**	**RBD-Dimer [29,30,47,48]**
Name of Vaccine	Ad5-nCoV	ZF2001
Type of Vaccine	Viral Vector Vaccine	Protein Subunit
Primary Developers	CanSion Biologics	Anhui Zhifei Longcom Biologic Pharmacy Co. Ltd.
Each Dose	Information not found	25 mcg/dose
Dosing	1 dose	3 doses over a period of 2 months
Shelf life	2 years	Information not found
Mode of administration	Intramuscular Injectable	Intramuscular Injectable
Efficacy	65.28%	Information not found
Storage	2-8℃	Information not found
Targeted population	18 years and older	18 years and older
Working	The vaccine is a genetically engineered vaccine candidate with the replication-defense adenovirus type 5 as the vector to express SARS-CoV-2 spike protein.	The vaccine targets the receptor-binding domain (RBD) of the SARS-CoV-2 S protein which is responsible for the engagement of its cellular receptor, ACE2 and is an attractive vaccine target to induce immune responses focusing on blocking receptor binding.
Variants	Information not found	Showed neutralizing activity against the South African variants although with weaker activity than against the original virus.
Side Effects	Pain at the injection site, fever	Redness, swelling
Contraindications	Information not found	Information not found
Price	Information not found	Information not found
Country of origin	China	China

Conclusion

The article aims to get an understanding of the different vaccines available and also to get a fair idea about the similarities and differences among these vaccines. These vaccines could be categorized based on various factors such as their type or based on how they work, their route of administration, the number of doses given for a particular vaccine, the age group as to who are eligible to get the vaccine, their storage conditions, etc.

Based on the Type of Vaccine discussed earlier there are the Viral Vector type, Inactivated Virus Vaccine, the mRNA Vaccine and the Protein Subunit Vaccine. The Vaccines are further subcategorized in the following manner.

Table 13. Types of vaccine.

Type of Vaccine	**Vaccine**
Viral Vector Vaccine	Covishield, Janssen, Sputnik, CanSinoBio
Inactivated Virus Vaccine	Covaxin, CoviVac, Sino pharm, Sinovac
mRNA Vaccine	Pfizer, Moderna
Protein Subunit	Novavax, EpiVacCorona, RBD-Dimer

Based on the number of doses, these vaccines are given as a single dose, two doses, and even three doses. The vaccines are further categorized as follows.

Table 14. Dosage regimen of vaccine.

No. of doses	**Vaccine**
1 dose	Janssen, CanSinoBio
2 doses	Covishield, Covaxin, Pfizer, Moderna, Novavax, Sputnik V, EpiVacCorona, CoviVac, Sino pharm Sinovac
3 doses	RBD-Dimer

Based on age group, vaccines are given to the people. These vaccines are not given to children under a certain age group. This is because the trials conducted did not include children and hence no data has been established as to its effect on children. Vaccines are further categorized as follows.

Based on age group, vaccines are given to the people. These vaccines are not given to children under a certain age group. This is because the trials conducted did not include children and hence no data has been established as to its effect on children. Vaccines are further categorized as follows.

Table 15. Vaccines for age group.

Age group	Vaccine
12 years and older	Pfizer
18 years and older	Covishield, Covaxin, Moderna, Novavax, Janssen, Sputnik V, EpiVacCorona, CoviVac, Sino pharm, Sinovac, CanSinoBio, RBD-Dimer

Based on storage conditions, most of these vaccines can be stored at normal refrigerator conditions whereas there are a few vaccines that need deep-freeze conditions. As per these conditions' vaccines are further categorized as follows.

Table 16. Storage conditions for vaccine.

Storage Condition	Vaccine
2-8^0 C	Covishield, Covaxin, Moderna, Novavax, Janssen, EpiVacCorona, CoviVac, Sino pharm, Sinovac, CanSinoBio, RBD-Dimer
-18^0 C	Sputnik V
-80^0 C	Pfizer

Based on the route of administration, all these vaccines are Intramuscular Injections which are given in the deltoid muscle.

Hence, in this way, the similarities and differences between these vaccines can be understood.

March 2021, it's been 15 months since the first case of COVID-19 was reported in Wuhan, China, and now we have twelve or more authorized vaccines which are available to people across the globe. Covaxin, AstraZeneca (Covishield), Pfizer, Moderna, Sputnik V, Novavax, Johnson & Johnson, Sinovac, Sino pharm, CanSinoBio, CoviVac, EpiVacCorona, and still many more to come which are under clinical trials.

Although it would not be lawful to compare vaccines based on their efficacy rates but still looking at the efficacy numbers, it is often assumed that Pfizer and Moderna are better in efficacy as compared to the rest of the vaccines, but this is not the case as the trials of each is done in very different circumstances. Trials of each vaccine were done in different seasons, different epidemiological seasons, different countries, different clinical trials, and most importantly with different strains of the virus. For example, trials for Pfizer and Moderna were executed within the U.S. during the summer whereas Johnson & Johnson held their U.S. trials when there were more opportunities for participants to be exposed to infection, moreover, most of the trials took place in countries such as South Africa and Brazil where not only their case rates were high but also the virus there was different (variants). These variants have a higher chance of getting the participants infected. Even though the trials were taken in such situations, the vaccine showed a significant reduction of the infection. If the Pfizer and Moderna vaccines were tested under such conditions it is possible that their efficacy numbers would be different.

Dr. Adalja an adjunct assistant professor at the Johns Hopkins Bloomberg School of Public Health, attached to the John Hopkins Center for Global Health and is emergency medicine, critical care, and infectious disease specialist in Pittsburgh says that 'the goal of a vaccine program for COVID-19 is not necessarily to get to COVID zero but to tame this virus, defang it and the most important thing about COVID-19 vaccines is that they remove the ability of the virus to cause serious hospitalization or death.'

All of these vaccines are effective and safe. The important thing about all these vaccines is that they will protect us from hospitalization and death and this will help us end the pandemic. The answer to the question 'Which vaccine is the best?' is 'The one which is offered to you.

Conflict of Interest

There is no conflict of interest in research for the literature, writing and documenting this review article.

Authors Contribution

Ms. Simona D'Souza, Ms. Maria Alva have contributed in collecting the relevant data for this review, Ms. Sanya Lisboa and Mr. Tanmay Golekar have contributed for the doing the literature survey and Mr. Sohail Sayyed has contributed in editing the manuscript as per authors instruction and Dr. Deepak Bharati has done proof reading of the manuscript.

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