Claims

1. An immunogenic composition comprising an mRNA encoding a hemagglutinin protein-HA protein of one or more influenza virus strains.

2. The immunogenic composition of claim 1, wherein the HA protein of the one or more influenza strains is selected from influenza A virus HA proteins and influenza B virus HA proteins;

preferably, the HA protein of the one or more influenza strains is one or more selected from 1)-6):

1) a HA protein of an A/Wisconsin/588/2019(H1N1)pdm09-like virus;

2) a HA protein of an A/Darwin/6/2021(H3N2)-like virus;

3) a HA protein of a B/Austria/1359417/2021-like virus (B/Victoria lineage);

4) a HA protein of a B/Phuket/3073/2013-like virus (B/Yamagata lineage);

5) a HA protein of an A/Wisconsin/67/2022(H1N1)pdm09-like virus; or

6) a HA protein of an A/Massachusetts/18/2022(H3N2)-like virus.

3. The immunogenic composition of claim 1 or 2, further comprising an mRNA encoding a neuraminidase-NA protein of one or more influenza virus strains;

preferably, the NA protein of the one or more influenza virus strains is selected from influenza A virus NA proteins and influenza B virus NA proteins.

4. The immunogenic composition of claim 3, wherein the NA protein of the one or more influenza virus strains is selected from a NA protein of a B/Austria/1359417/2021-like virus (B/Victoria lineage);

preferably, the HA protein of the one or more influenza virus strains comprises four HA proteins selected from 1)-4), or three HA proteins selected from 1)-3), or four HA proteins selected from 3)-6), or three HA proteins selected from 3), 5), and 6):

1) a HA protein of an A/Wisconsin/588/2019(H1N1)pdm09-like virus;

2) a HA protein of an A/Darwin/6/2021(H3N2)-like virus;

3) a HA protein of a B/Austria/1359417/2021-like virus (B/Victoria lineage);

4) a HA protein of a B/Phuket/3073/2013-like virus (B/Yamagata lineage);

5) a HA protein of an A/Wisconsin/67/2022(H1N1)pdm09-like virus; or

6) a HA protein of an A/Massachusetts/18/2022(H3N2)-like virus; and

the NA protein is selected from a NA protein of a B/Austria/1359417/2021-like virus (B/Victoria lineage).

5. The immunogenic composition of claim 3, wherein the HA protein of the one or more influenza virus strains comprises four HA proteins selected from 1)-4), or three HA proteins selected from 1)-3), or four HA proteins selected from 3)-6), or three HA proteins selected from 3), 5), and 6):

1) a HA protein of an A/Wisconsin/588/2019(H1N1)pdm09-like virus;

2) a HA protein of an A/Darwin/6/2021(H3N2)-like virus;

3) a HA protein of a B/Austria/1359417/2021-like virus (B/Victoria lineage);

4) a HA protein of a B/Phuket/3073/2013-like virus (B/Yamagata lineage);

5) a HA protein of an A/Wisconsin/67/2022(H1N1)pdm09-like virus; or

6) a HA protein of an A/Massachusetts/18/2022(H3N2)-like virus.

6. The immunogenic composition of claim 2 or 4 or 5, wherein the HA protein of the one or more influenza virus strains is one or more selected from HA proteins having amino acid sequences as shown in SEQ ID NOs:1-6; and

preferably, the HA protein comprises four HA proteins having amino acid sequences as shown in SEQ ID NOs: 1-4, or three HA proteins having amino acid sequences as shown in SEQ ID NOs: 1-3, or four HA proteins having amino acid sequences as shown in SEQ ID NOs: 3-6, or three HA proteins having amino acid sequences as shown in SEQ ID NO: 3, SEQ ID NO: 5, and SEQ ID NO: 6.

7. The immunogenic composition of claim 4, wherein the amino acid sequence of the NA protein

of the influenza strain is as shown in SEQ ID NO: 7.

8. The immunogenic composition of any one of claims 1-7, wherein each of the mRNA comprises, from 5' to 3', a capping structure, a 5'-UTR, an open reading frame, a 3'-UTR, and a polyA tail.

9. The immunogenic composition of claim 8, wherein the 5'-UTR comprises a 5'-UTR derived from a 17β-hydroxysteroid dehydrogenase 4 (HSD17B4) gene or a homolog, fragment, or variant thereof, and preferably, the 5'-UTR comprises a sequence as shown in SEQ ID NO: 15;

wherein the 3'-UTR comprises a 3'-UTR derived from an albumin ALB gene or a homolog, fragment, or variant thereof, preferably, the 3'-UTR comprises a sequence as shown in SEQ ID NO: 16; and/or

wherein the polyA tail is between 100 and 150 nucleotides in length.

10. The immunogenic composition of any one of claims 1-9, wherein the mRNA encoding the HA protein of the one or more influenza virus strains is one or more selected from mRNAs having sequences as shown in SEQ ID NOs: 8-13; and

preferably, the mRNA comprises four mRNAs having sequences as shown in SEQ ID NOs: 8-11, or three mRNAs having sequences as shown in SEQ ID NOs: 8-10, or four mRNAs having sequences as shown in SEQ ID NOs: 10-13, or three mRNAs having sequences as shown in SEQ ID NO: 10, SEQ ID NO: 12, and SEQ ID NO: 13.

11. The immunogenic composition of any one of claims 1-10, wherein a sequence of the mRNA encoding the NA protein of the influenza virus strain, is SEQ ID NO: 14.

12. The immunogenic composition of any one of claims 1-11, wherein one or more uridine triphosphates in the mRNA are each independently replaced with pseudouridine triphosphate, 2-thiouridine triphosphate, 5-methyluridine triphosphate, N1-methylpseudouridine triphosphate, or 5-ethynyluridine triphosphate, and/or one or more cytidine triphosphates are replaced with 5-methylcytidine triphosphates, and/or one or more adenosine triphosphates are replaced with N6-

methyladenosine triphosphates; and

preferably, one or more uridine triphosphates in the mRNA are each independently replaced with pseudouridine triphosphate, 1-methyl-pseudouridine triphosphate, or 5-ethynyluridine triphosphate, and/or one or more cytidine triphosphates are replaced with 5-methylcytidine triphosphate.

13. The immunogenic composition of any one of claims 1-12, wherein the mRNA is encapsulated in a carrier material.

14. The immunogenic composition of claim 13, wherein the carrier material is selected from lipid nanoparticles-LNPs, protamine, polymeric materials, and inorganic nanoparticles.

15. The immunogenic composition of any one of claims 1-14, wherein the molar concentration of each of the mRNAs in the immunogenic composition is no more than three times the molar concentration of any other of the mRNAs; and

preferably, the molar concentration of each of the mRNAs is substantially the same.

16. The immunogenic composition of claim 15, wherein the immunogenic composition comprises mRNAs encoding four HA proteins selected from 1)-4), or three HA proteins selected from 1)-3), or four HA proteins selected from 3)-6), or three HA proteins selected from 3), 5), and 6):

1) a HA protein of an A/Wisconsin/588/2019(H1N1)pdm09-like virus;

2) a HA protein of an A/Darwin/6/2021(H3N2)-like virus;

3) a HA protein of a B/Austria/1359417/2021-like virus (B/Victoria lineage);

4) a HA protein of a B/Phuket/3073/2013-like virus (B/Yamagata lineage);

5) a HA protein of an A/Wisconsin/67/2022(H1N1)pdm09-like virus; or

6) a HA protein of an A/Massachusetts/18/2022(H3N2)-like virus;

preferably, when the immunogenic composition comprises four mRNAs, the molar ratio of the mRNAs is 1-3:1-3:1-3:1-3, and preferably 1:1:1:1.

17. The immunogenic composition of claim 16, wherein the immunogenic composition comprises mRNAs encoding four HA proteins selected from 1)-4), or three HA proteins selected from 1)-3), or four HA proteins selected from 3)-6), or three HA proteins selected from 3), 5), and 6), and an mRNA encoding the NA protein selected from 7):

1) a HA protein of an A/Wisconsin/588/2019(H1N1)pdm09-like virus;

2) a HA protein of an A/Darwin/6/2021(H3N2)-like virus;

3) a HA protein of a B/Austria/1359417/2021-like virus (B/Victoria lineage);

4) a HA protein of a B/Phuket/3073/2013-like virus (B/Yamagata lineage);

5) a HA protein of an A/Wisconsin/67/2022(H1N1)pdm09-like virus; and

6) a HA protein of an A/Massachusetts/18/2022(H3N2)-like virus; or

7) a NA protein of a B/Austria/1359417/2021-like virus (B/Victoria lineage); and

preferably, when the immunogenic composition comprises four mRNAs, the molar ratio of the mRNAs is 1-3:1-3:1-3:1-3, and preferably 1:1:1:1.

18. The immunogenic composition of any one of claims 1-17, wherein the immunogenic composition further comprises an adjuvant;

preferably , wherein the adjuvant is any one or more selected from aluminum adjuvants, MF59, AS03, AS04, thermoreversible oil-in-water emulsions, ISA51, Freund's adjuvant, IL-12, CpG motifs, and mannose; and

preferably, the aluminum adjuvant is any one or more selected from aluminum hydroxide, aluminum phosphate, aluminum sulfate, or alum.

19. The immunogenic composition of any one of claims 1-18 for use in preventing and/or treating a disease or a condition associated with influenza virus infection;

preferably, wherein the disease or the condition is a disease or a condition associated with influenza A virus and/or influenza B virus infection.

20. A method for preventing and/or treating a disease or a condition associated with influenza virus infection, comprising:

administrating the immunogenic composition of any one of claims 1-18 to a subject suffering from the disease or the condition associated with influenza virus infection.;

preferably, wherein the disease or the condition is a disease or a condition associated with influenza A virus and/or influenza B virus infection.