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COVID-19 Vaccines and the Male Heart: Risk or Reassurance?

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Abstract

This study aims to synthesise current evidence on the impact of COVID-19 vaccination on cardiovascular outcomes in healthy male populations. For this purpose, the researcher has mainly focused on myocarditis, pericarditis, and myocardial infarction. The review has highlighted existing literature, which includes population-based registry studies, retrospective cohort analyses, and surveillance system data from a wide range of geographical regions. The key findings indicate that there is an indication of myocarditis/pericarditis in young men post-vaccination for COVID-19, which is shown by this scoping review. It is mainly evident following the second round of mRNA vaccinations. These events are also manifested within seven days of vaccination and are more frequently associated with the

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second dose of mRNA vaccines. The Moderna (mRNA-1273) vaccine depicted a higher rate of myocarditis compared to the Pfizer-BioNTech (BNT162b2) vaccine. Moreover, the risk of myocarditis and other major cardiac complications is significantly higher following a COVID-19 infection than after vaccination. Although some case reports underscored a link between vaccination and myocardial infarction. However, large-scale studies have not established a definitive causal relationship. In conclusion, while a small risk of cardiovascular adverse events, particularly myocarditis, it is important for young males following COVID-19 vaccination. However, these risks are generally mild, self-limiting, and substantially lower than the risks posed by the SARS-CoV-2 infection itself.

INTRODUCTION

Global COVID-19 vaccination efforts represent an unprecedented public-health undertaking; vaccines were developed, authorised, and deployed at record speed and at scale, dramatically altering the pandemic's trajectory by reducing severe disease and deaths while highlighting persistent equity gaps and logistical challenges. Early global rollouts prioritised older adults and high-risk groups, and by 2024, many countries had formalised booster and age-targeted policies as part of routine COVID programs. Despite rapid scientific progress, uptake has been uneven: programme reviews show wide variation in national policies and coverage for older adults, and persistent disparities between high- and low-income countries have limited the global reach of primary series and boosters (Santangelo et al., 2024; Zheng et al., 2024).

An epidemiological analysis estimates that vaccination campaigns averted millions of deaths and saved millions of life-years from 2020-2024, with benefits concentrated in older age groups and settings with high baseline risk (Ioannidis et al., 2025). A programmatic study attributes remaining gaps to supply-chain constraints early on, unequal donor and manufacturer distribution, variable health-system capacity, vaccine hesitancy, and weakening routine immunisation services after pandemic

disruptions (Cho et al., 2024). Moreover, surveillance and modelling work emphasise that as "Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2)" has continued to evolve, adaptive strategies, including updated strain-matched boosters and targeted campaigns for vulnerable populations, remain necessary to sustain protection and reduce pressure on health systems (Zheng et al., 2024).

Vaccines have proven to be essential in reducing hospitalisations, severe illness, and deaths from COVID-19. Several studies quantify these effects. One large U.S. study of the 2023-2024 COVID-19 vaccine formulations (including monovalent vaccines matched to Omicron XBB.1.5) found that among adults ⩾18 years, vaccine effectiveness (VE) was around 30% (95% Confidence Interval (CI) 25-33%) for preventing COVID-19 associated hospitalisations, and around 48% (95% CI 40-55%) for preventing critical illness (defined as intensive care unit (ICU) admission or in-hospital death). VE was highest (about 51% versus hospitalisation, 68% vs critical illness) in the window 7-59 days post-vaccination, and waned substantially over time (Ruth Rowley et al., 2025). Another report from the U.S. gives interim estimates for the 2024-2025 vaccine dose: in immunocompetent adults ⩾65 years, VE was ≈ 45-46% (95% CI ~36-53% and ~26-60%) against hospitalisation during the first 7-119 days after disease exposure; among immunocompromised persons in that age group the VE was somewhat lower (~40%; 95% CI 21-54%). The same report notes that the vaccination programme averted approximately 68,000 hospitalisations in the 2023-24 respiratory season (Link-Gelles, 2025).

In a hospital-based cross-sectional study in Iran, among hospitalised COVID-19 patients, being fully vaccinated (including at least one booster) was associated with much lower odds of mortality (Odds Ratio (OR) ≈ 0.235, 95% CI 0.103-0.538) and ICU

admission (OR ≈ 0.252, 95% CI 0.131-0.484), and shorter hospital stays (mean ≈ 6.38 days vs ≈ 9.22 for unvaccinated) (Maleki et al., 2025). Moreover, global modelling work estimates that between 2020 and 2024, COVID-19 vaccination averted approximately 2.5 million deaths worldwide (sensitivity range 1.4-4.0 million), and saved some 15 million life-years (sensitivity range 7-24 million). These benefits were heavily weighted towards older age groups (⩾60 years) and those who were vaccinated before any infection (Ioannidis et al., 2025).

However, emerging evidence has sharpened attention on rare but consequential cardiovascular events following COVID-19 vaccination, most notably myocarditis and pericarditis in adolescent and young adult males, prompting refinements in guidance and surveillance while reaffirming that vaccine-associated risks remain small compared with the risks of SARS-CoV-2 infection. Several systematic and cohort analyses report that myocarditis after messenger ribonucleic acid (mRNA) vaccines occurs at low absolute rates but with a clear age- and sex-pattern: the highest incidence is concentrated in males aged ~12-29 years, typically after the second dose, with symptom onset most often within the first week. Vaccine-associated myocarditis is characterised as generally clinically mild (chest pain, elevated troponin, abnormal cardiac magnetic resonance imaging in some cases), with short hospital stays and low mortality in the short term, although a minority report lingering symptoms at 3-6 months that warrant longer follow-up (Deng, Van Eldik, O'Moore, Buttery, Cheung, Cox, Drake-Brockman, Dwyer, Effler, & Gold, 2025; Jain et al., 2024; Le Vu et al., 2024).

Quantitatively, large surveillance syntheses and modelling emphasise scale: myocarditis after vaccination has been estimated in the order of tens of cases per million doses in most populations (and concentrated in young males), whereas

myocarditis following SARS-CoV-2 infection is substantially more frequent; for example, a synthesis estimated about 19.7 cases per 1,000,000 vaccine doses versus roughly 2.76 cases per 1,000 infections, underscoring that infection carries higher myocarditis risk than vaccination (Buoninfante et al., 2024). Newer safety analyses supporting regulatory label updates have added finer detail: multi-institutional case series found clustering of hospitalised myocarditis cases in adolescents (median age ~16 years) with chest-pain onset a median of ~3 days post-vaccine, prompting authorities to broaden warnings while continuing to emphasise the rarity and generally favourable short-term prognosis (Prasad & Makary, 2025).

Important programmatic findings have identified modifiable risk-mitigating strategies: extending the interval between primary mRNA doses appears associated with a reduced myocarditis risk while preserving immunogenicity, informing some jurisdictions' interval recommendations for younger males (Le Vu et al., 2024). Finally, contemporary scholarship stresses balanced interpretation for policy: although myocarditis/pericarditis after mRNA vaccination is the dominant safety signal in younger males and requires transparent communication, robust population-level analyses show vaccines' net benefit in preventing hospitalisations, critical illness, and deaths from COVID-19. Ongoing priorities, therefore, are targeted surveillance of cardiac outcomes, systematic medium- and long-term follow-up of affected individuals, optimisation of dosing schedules for lower risk, and clear risk-benefit messaging to preserve public trust while protecting populations, especially adolescents and young adults (Buoninfante et al., 2024; Jain et al., 2024; Le Vu et al., 2024).

BENEFITS OF COVID-19 VACCINATION

COVID-19 vaccination has delivered profound population-level benefits, and these benefits remain the dominant public-health outcome when measured in lives saved, severe disease prevented, and downstream reductions in long-term morbidity. Global modelling that incorporates vaccine rollouts estimates that vaccination averted on the order of 2-3 million deaths and saved tens of millions of life-years, with the largest absolute gains concentrated in older age groups and in settings that achieved high early coverage; these models show that even with variant evolution, updated formulations and boosters substantially reduced mortality burdens (Link-Gelles, 2023). Another study reports that vaccines retain markedly higher protection against severe outcomes than against infection: effectiveness against COVID-19-associated hospitalisation and critical illness commonly exceeds 60-85% after primary series plus booster (with some variation by age, immune status, and circulating variant), and booster doses restore waning protection to levels that meaningfully lower ICU admissions and in-hospital death. At the individual-patient level, vaccinated persons who are hospitalised for COVID-19 have substantially lower odds of progression to invasive mechanical ventilation, multi-organ failure, and death compared with unvaccinated patients; several cohort analyses report adjusted odds reductions in mortality on the order of 40-60% for fully vaccinated versus unvaccinated hospitalised cohorts (Jillian P. Rhoads, 2021).

Beyond acute outcomes, mounting evidence indicates vaccination reduces the risk and severity of post-COVID conditions: analysis examining children and adults show fewer persistent symptoms, shorter symptom duration, and lower odds of meeting long-COVID definitions among those who completed primary vaccination and especially those who received boosters before infection, estimating vaccine-associated reductions

in long-COVID incidence in the range of ~40-70% depending on dose timing and case definitions (Yousaf et al., 2023). Country-level impact assessments further illustrate the scale: national study estimating averted cases, hospitalisations, and deaths attribute large absolute numbers of prevented severe outcomes to vaccine campaigns (for example, single-country analysis reported hundreds of thousands of severe cases and tens of thousands of deaths averted over the first two years of rollout), highlighting that vaccination programmes both reduce acute health-system strain and protect fragile health-system capacity during waves (Kayano et al., 2022). Besides, vaccines produce important indirect and societal benefits; they reduce onward transmission enough to blunt surges when coverage is high, lessen the economic and educational disruptions associated with large outbreaks, and, by decreasing population burden, allow health systems to focus resources on non-COVID care. These benefits make vaccination a cornerstone strategy for minimising both immediate and long-term harms from SARS-CoV-2 (Jillian P. Rhoads, 2021; Link-Gelles, 2023).

Due to the exploratory nature of the study, the researcher has proposed a scoping review against other types of synthesis studies. This review aims to synthesise current evidence on the impact of COVID-19 vaccination on cardiovascular outcomes in healthy male populations, with a focus on major events such as myocarditis, pericarditis, and myocardial infarction. This scoping review aims to address the following research question: What are the incidence rates, clinical outcomes, and underlying mechanisms of cardiovascular events in healthy males following COVID-19 vaccination, and how do these risks compare with background rates and infection-associated risks as reported by global surveillance systems?

METHOD

PROTOCOL

This study followed the PRISMA-ScR ("Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews") reporting guideline to ensure transparency, reproducibility, and completeness (Tricco et al., 2018).

ELIGIBILITY CRITERIA

Eligibility criteria for inclusion in this scoping review were studies published from 2019 to 2025, in peer-reviewed journals, involving human populations; studies that report on post-COVID-19 vaccination cardiac outcomes (myocarditis, pericarditis or myopericarditis), with age and sex stratification, especially young males; must present diagnostic confirmation or clinical criteria of myocarditis (e.g. imaging, biomarkers); full-text in English; observational studies, cohort or case series. Case reports with <3 patients were excluded. Studies from 2019-2025 were chosen to capture the entire period of SARS-CoV-2 emergence, vaccine development and deployment, and evolving knowledge about cardiovascular outcomes, ensuring the inclusion of both early safety data and later evidence as vaccination programs matured and variants emerged.

INFORMATION SOURCES

Information sources included comprehensive electronic searches conducted across major medical and scientific databases to ensure coverage of relevant literature. Databases used were "PubMed, Scopus, Web of Science, Cochrane Library, and Google Scholar", focusing on studies published from 2019 onwards. These sources are widely recognised for their rigorous indexing of biomedical and public health research and provide access to observational studies, clinical reports, and systematic reviews related

to medical (Sebo & Sebo, 2025). Reference lists of included articles were also screened to capture additional eligible studies not retrieved through the initial database searches.

SEARCH

The search strategy involved using Google Scholar with filters for studies published from 2019 onwards, focused on human subjects and in English, employing keywords like "mRNA COVID-19 vaccine myocarditis incidence", "pericarditis after vaccination risk in young males", "cardiac adverse effects following COVID-19 vaccination", "vaccine myocarditis versus infection myocarditis", "interdose interval and vaccine side effects". The search screened titles and abstracts for relevance, followed by full-text review, and extracted age- and sex-stratified data, diagnostic criteria, and outcome severity.

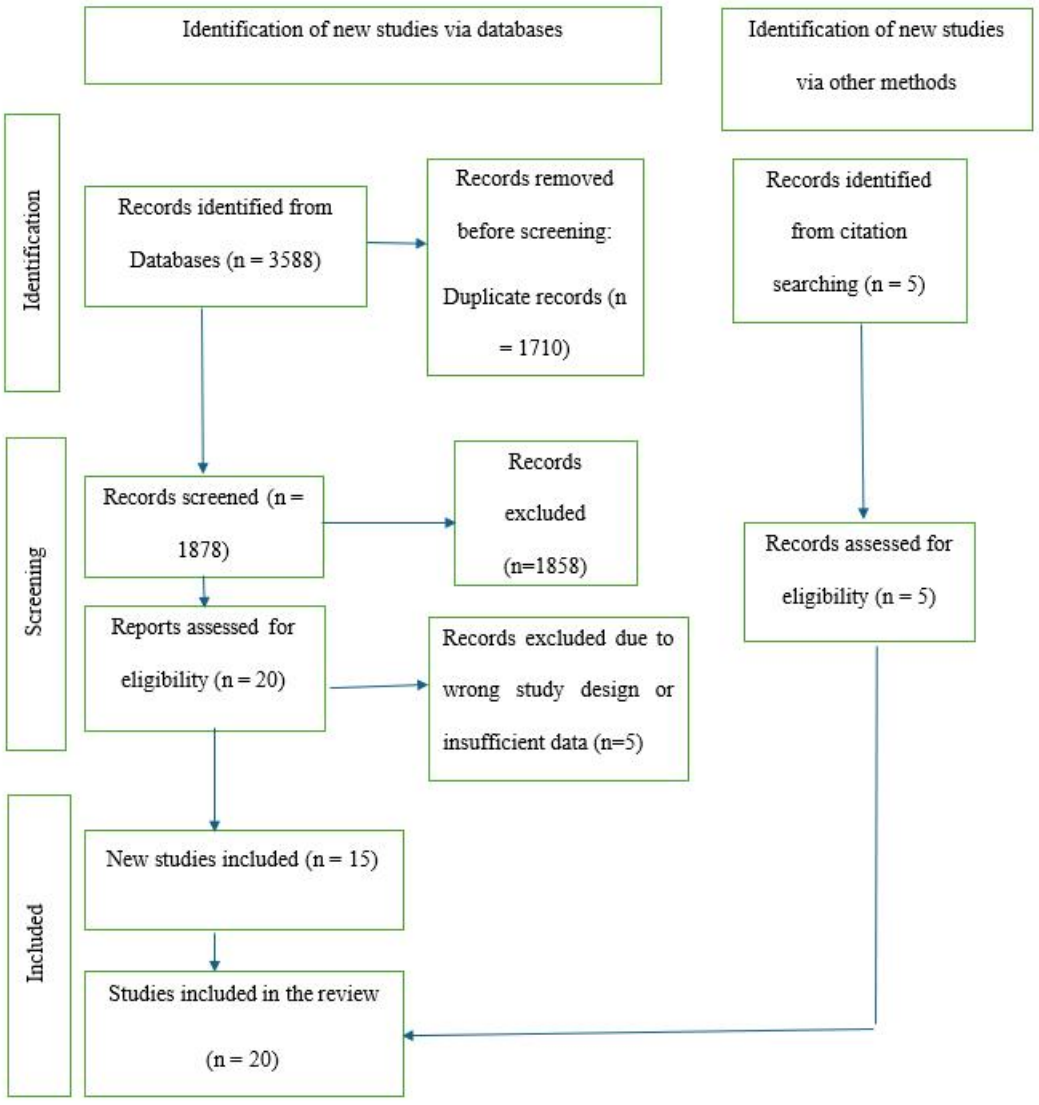
SELECTION OF SOURCES OF EVIDENCE

The selection of sources of evidence was carried out in a structured process to ensure relevance and quality. Titles and abstracts retrieved from searches were first screened against predefined eligibility criteria, including publication from 2019 onwards, English language, human participants, and a focus on cardiovascular outcomes following COVID-19 vaccination. After initial screening, full texts of potentially relevant studies were assessed in detail. Duplicates and articles lacking sufficient methodological rigour or outcome reporting were excluded. This systematic approach ensured that only high-quality and relevant evidence was included in the review.

A total of 3588 records were initially identified from the selected sources of information. After removing 1710 duplicates, 1878 articles were screened by title and abstract for relevance. From these, 20 full-text articles were assessed in detail, and 5 were excluded for not meeting eligibility criteria. Ultimately, fifteen studies were included from the databases, while five additional studies were identified through

manual searching, resulting in a total of twenty articles that were incorporated into the final review. The following figure shows the PRISMA flow diagram for the selection of articles:

FIGURE 1: PRISMA FLOW DIAGRAM FOR ARTICLES SELECTION



Source: Researcher-Generated

DATA CHARTING PROCESS AND DATA ITEMS

Data charting was conducted using an Excel spreadsheet to systematically extract key information from included studies. The data items in charted fields include publication year, country, sample sizes, age groups, vaccine type and dose number, incidence rate per vaccine dose, and clinical implications. The spreadsheet also recorded any comparative risk information (vaccination vs infection) and mechanical insights (immune, hormonal, genetic).

SYNTHESIS OF RESULTS

A thematic analysis-based synthesis was chosen to organise and interpret findings because it allows for the identification and grouping of recurring patterns, concepts, and themes across studies with varied designs (Ahmed et al., 2025). This method facilitated a deep understanding of complex phenomena like vaccine-associated cardiac risks, captures perspectives on incidence, severity, timing, diagnostics, and recovery, and presents results narratively along with tables or figures for clarity and comparability in scoping reviews.

RESULTS

CHARACTERISTICS AND RESULTS OF THE SOURCES OF EVIDENCE

The twenty included studies provide a comprehensive overview of cardiovascular outcomes following COVID-19 vaccination in male populations, spanning diverse geographical settings, methodological approaches, and vaccine types. Geographically, the United States accounted for the largest share, with studies including a retrospective military case series (Montgomery et al., 2021), VAERS-based descriptive surveillance (Oster et al., 2022), and large-scale cohort analyses (Mabila et al., 2023). Israel contributed multiple influential studies, such as a retrospective cohort study (Witberg et

al., 2021), and smaller multicentre case series (Butbul Aviel et al., 2022). From Europe, the Nordic countries provided population-based registry studies (Husby et al., 2021; Hviid et al., 2024; Karlstad et al., 2022), while the UK contributed a self-controlled case series (Bozkurt et al., 2021; Stowe et al., 2023). Other contributions included Spain (Elizalde et al., 2024), Poland (Florek & Sokolski, 2024), Canada (McDonald et al., 2024) and Australia (Deng, Van Eldik, O'Moore, Buttery, Cheung, Cox, Drake-Brockman, Dwyer, Effler, Gold, et al., 2025). Broader perspectives were offered by systematic reviews and meta-analyses (Knudsen & Prasad, 2023; Ling et al., 2022).

Study designs varied considerably, reflecting the different lenses applied to capture rare cardiovascular outcomes. Cohort studies were most prominent, leveraging health records and vaccination registries to estimate risk (Elizalde et al., 2024; Husby et al., 2021; Hviid et al., 2024; Karlstad et al., 2022; Mabila et al., 2023; Stowe et al., 2023). Case series offered valuable clinical descriptions, often involving young males presenting with myocarditis (Butbul Aviel et al., 2022; Chelala et al., 2021; Montgomery et al., 2021). Self-controlled case series in the UK (Bozkurt et al., 2021; Stowe et al., 2023) reduced confounding by comparing risk within the same individuals over time. Surveillance-based descriptive and follow-up studies (Kracalik et al., 2022; Oster et al., 2022; Stowe et al., 2023) highlighted broader population trends, while narrative reviews and expert consensus pieces (Florek & Sokolski, 2024; Heidecker et al., 2022; McDonald et al., 2024) synthesised global evidence and clinical guidance.

Sample sizes ranged widely, from small case series of fewer than 25 patients (Butbul Aviel et al., 2022; Montgomery et al., 2021) to massive registry-linked analyses encompassing millions of vaccinated males (Karlstad et al., 2022; Mabila et al., 2023; Stowe et al., 2023). The most frequently studied demographic was adolescent and

young adult males aged 12-29 years, identified consistently as the group at greatest risk of myocarditis and pericarditis. However, several studies included broader age distributions extending into adulthood (Elizalde et al., 2024; Hviid et al., 2024; Mabila et al., 2023; Stowe et al., 2023), allowing exploration of age gradients.

In terms of vaccine types, the overwhelming majority of studies evaluated mRNA vaccines, specifically BNT162b2 (Pfizer-BioNTech) and mRNA-1273 (Moderna). Fewer studies included adenoviral vector vaccines such as ChAdOx1-S (Oxford–AstraZeneca) or Ad26.COV2.S (Janssen) (Karlstad et al., 2022; Patone et al., 2022; Stowe et al., 2023). Importantly, registry-based comparisons consistently demonstrated higher rates of myocarditis following Moderna compared with Pfizer, particularly in younger males. Overall, the included evidence base is both diverse and complementary, combining detailed clinical case data with large-scale registry estimates and global syntheses. This breadth provides a strong foundation for understanding vaccine-related cardiovascular risks in male populations, particularly in younger cohorts where signals are most evident. The following table presents the characteristics of the studies:

TABLE 1: CHARACTERISTICS OF INCLUDED STUDIES

"Author/Year	Country/Region	Study Design	Sample size (males, age range)		Vaccine Type (mRNA/viral vector)
			(Males)	Age Group	
(Montgomery et al., 2021)	US	Retrospective case series	23 male patients	20–51 years	mRNA-1273 (Moderna) and BNT162b2 (Pfizer-BioNTech)
(Witberg et	Israel	Retrospective	51/54	Persons	mRNA vaccine:

al., 2021)		cohort study		aged ⩾ 16 years	BNT162b2 (Pfizer-BioNTech) only
(Oster et al., 2022)	US	Descriptive study	1334 males	Persons aged ⩾12 years	mRNA vaccines (BNT162b2 [Pfizer-BioNTech] and mRNA-1273 [Moderna])
(Karlstad et al., 2022)	Nordic countries: Denmark, Finland, Norway, Sweden	Population-based cohort studies in 4 countries	Among 23,122,522 residents 49.8% male)	Males 16-24 years	mRNA vaccines: BNT162b2 (Pfizer-BioNTech) and mRNA-1273 (Moderna); also inclusion of AZD1222 (AstraZeneca)
(Husby et al., 2021)	Denmark	Population-based cohort studies in 4 countries	196 (73%) males	12-39 years	Both mRNA vaccines: BNT162b2 (Pfizer-BioNTech) and mRNA-1273 (Moderna)
(Bozkurt et al., 2021)	US	Review study	not specified	12-39 years	mRNA vaccines (Pfizer-BioNTech BNT162b2 and Moderna mRNA-1273) only.

(Patone et al., 2022)	England	self-controlled case series study	not specified	⩾13 years	Adenovirus vaccine ChAdOx1 (Oxford–AstraZeneca) and mRNA vaccines BNT162b2 (Pfizer-BioNTech) and mRNA-1273 (Moderna).
(Kracalik et al., 2022)	US	Follow-up surveillance study via surveys	457/519 (88%) male	12-29 years	mRNA vaccines
(Chelala et al., 2021)	US	Retrospective case series	52 males	16-19 years	mRNA vaccines
(Ling et al., 2022)	Global	Systematic review + meta-analysis	n/a	⩾30 years	COVID-19 vaccines of both mRNA and non-mRNA types are included; non-COVID-19 vaccines include smallpox, influenza, etc.
(Heidecker et al., 2022)	Global	Expert clinical consensus	n/a	n/a	mRNA COVID-19 vaccines (BNT162b2, mRNA-1273)

		document			
(Hviid et al., 2024)	Nordic countries	Cohort study	992,950 males	12-39 years	mRNA vaccines: BNT162b2 (Pfizer-BioNTech) and mRNA-1273 (Moderna)
(Elizalde et al., 2024)	Spain	Retrospective cohort study	18/20 males	All ages (children 5-11, adolescents 12-17, adults ⩾18)	mRNA COVID-19 vaccines (Pfizer-BioNTech BNT162b2, Moderna mRNA-1273)
(Mabila et al., 2023)	US	Cohort study	800080 males	<20 to 45+ years	mRNA
(Butbul Aviel et al., 2022)	Israel	Multicentre retrospective case series	9 males	16-21 years	mRNA vaccine: Pfizer-BioNTech BNT162b2
(Knudsen & Prasad, 2023)	Global	Systematic review	Among the included studies, a total 1,625/1,991 were male	under 40 years	mRNA vaccines (BNT162b2 and mRNA-1273) included; Ad26.COVS1 (Janssen)
(Florek &	Poland	Narrative	n/a	under ~30-	mRNA-based

Sokolski, 2024)		review		40 years	vaccines; mRNA-1273 (Moderna)
(Stowe et al., 2023)	England, UK	Self-controlled case series (SCCS)	25717812 males	⩾ 12 years old; with detailed stratification, especially 16-39 years (especially 16-24), where risk is highest; also ⩾40 years for infection risk.	mRNA vaccines (BNT162b2 / Pfizer-BioNTech, and mRNA-1273 / Moderna); also includes ChAdOx1-S (adenovirus-vectored) for comparison.
(Deng, Van Eldik, O'Moore, Buttery, Cheung, Cox, Drake-Brockman, Dwyer, Effler, Gold, et al.,	Australia	Prospective follow-up (cohort	418/552	Median age 22 years (IQR 17-33, full range 5-76 years)	mRNA vaccines: Pfizer-BioNTech (BNT162b2) and Moderna (mRNA-1273)

2025)					
(McDonald et al., 2024)	Canada	Brief review	n/a	12-29 years	mRNA vaccines only (Pfizer-BioNTech, Moderna)"

Source: Researcher-Generated

REPORTED CARDIOVASCULAR RISKS AFTER VACCINATION

The included studies consistently identified myocarditis and pericarditis as the principal cardiovascular risks associated with COVID-19 vaccination in males, particularly among adolescents and young adults. Across settings, the highest incidence rates were observed within the first week following vaccination, with clustering around two to four days after administration of the second dose of an mRNA vaccine. This temporal relationship was highlighted in several clinical case series and large registry studies, confirming a reproducible pattern across populations. Small-scale investigations provided some of the earliest signals of risk. Montgomery et al. (2021) described 23 male military personnel in the United States, with 20 of these cases emerging after the second vaccine dose, typically within four days. Similarly, Chelala et al. (2021) documented a small series of young men, all of whom developed myocarditis within four days of the second dose. Though limited in size, these reports were important in defining the characteristic onset period and reinforcing the association with the second dose.

Large retrospective cohorts and registry-based analyses provided more robust incidence estimates. Witberg et al. (2021) calculated an overall myocarditis incidence of 2.13 per 100,000 among vaccine recipients, rising to 10.69 per 100,000 in males aged 16–29 years. Karlstad et al. (2022) demonstrated striking differences between vaccines:

adjusted incidence rate ratios (IRRs) were 5.3 for Pfizer and 13.8 for Moderna in males aged 16–24 years, corresponding to excess risks of 4–28 per 100,000. Husby et al. (2021) reinforced these findings, reporting absolute rates of 1.4 per 100,000 for Pfizer and 4.2 per 100,000 for Moderna in 12–39-year-old males. These consistent signals suggest that Moderna carries a higher relative risk of myocarditis in younger males compared to Pfizer.

Pharmacovigilance and surveillance studies further underscored these trends. Oster et al. (2022), analysing over 350 million mRNA vaccine doses reported to VAERS, identified 1,626 confirmed cases, with 82% occurring after the second dose and most within two days. CDC estimates, summarised by Bozkurt et al. (2021), placed the risk at around 12.6 cases per million doses in 12–39 year-olds, again concentrated after the second dose. Similar observations emerged from European pharmacovigilance data, with Stowe et al. (2023) reporting a relative incidence as high as 56.5 for Moderna within six days of the second dose in young males. Emerging evidence on booster doses indicates that while the risk remains present, the magnitude may be attenuated compared to second doses. Patone et al. (2022) identified elevated IRRs after first, second, and booster doses, with the strongest associations in younger men. Hviid et al. (2024) reported booster-related risk increases, particularly for Moderna, where the IRR approached 8.9. Deng, Van Eldik, O'Moore, Buttery, Cheung, Cox, Drake-Brockman, Dwyer, Effler, Gold, et al. (2025) provided further evidence, finding that 9% of myocarditis cases occurred after a third dose, compared to 70% after the second dose.

Despite variation in incidence rates across studies, several patterns were consistent. First, myocarditis risk was rare but clearly elevated above baseline in young males, particularly after the second dose of an mRNA vaccine. Second, the temporal

association was tight, with most cases occurring within one week, supporting a plausible causal link. Third, vaccine type influenced risk magnitude, with Moderna consistently associated with higher rates than Pfizer. Finally, while booster doses were not risk-free, the overall risk appeared lower than after the second dose, though confidence intervals in these estimates were often wide due to smaller case numbers. Overall, the synthesis of evidence points to a distinct epidemiological profile of vaccine-associated myocarditis: a rare adverse event, disproportionately affecting young males, most commonly after the second dose of an mRNA vaccine, with Moderna carrying a higher relative risk. These findings establish a clear, though quantitatively limited, cardiovascular risk that must be interpreted in the context of vaccine benefits. The following table presents the incidence of cardiovascular events after COVID-19 vaccination in males:

TABLE 2: INCIDENCE OF CARDIOVASCULAR EVENTS AFTER COVID-19 VACCINATION IN MALES

"Study (Author, Year)	Incidence / Temporal Pattern	Vaccine(s)	Dose Most Affected
(Montgomery et al., 2021)	20/23 cases after 2nd dose; onset 12–96h; all recovered	Pfizer, Moderna	2nd
(Witberg et al., 2021)	2.13/100k overall; 10.69/100k in males 16–29; clustered after 2nd dose	Pfizer	1st & 2nd
(Oster et al., 2022)	1,626 VAERS-confirmed	Pfizer,	2nd

	cases; median onset 2 days; 82% post-2nd dose	Moderna	
(Karlstad et al., 2022)	IRR 5.3 (Pfizer), 13.8 (Moderna) in males 16–24; 4–28/100k excess events	Pfizer, Moderna, AstraZeneca	2nd
(Husby et al., 2021)	Rates: 1.4/100k (Pfizer), 4.2/100k (Moderna); mainly young males	Pfizer, Moderna	2nd
(Bozkurt et al., 2021)	CDC est. ~12.6/million doses (ages 12–39); onset 2–3 days post-dose	Pfizer, Moderna	2nd
(Patone et al., 2022)	IRR: 1.5 (dose 1), 1.6 (dose 2), 1.7 (booster); highest in young men	Pfizer, Moderna, AstraZeneca	1st, 2nd, booster
(Kracalik et al., 2022)	81% recovered at 90 days; some persistent abnormalities	mRNA	n/a
(Chelala et al., 2021)	All 5 cases within 4 days post-2nd dose; small series	mRNA	2nd
(Ling et al., 2022)	Pooled incidence: ~33/million; higher in	mRNA & non-mRNA	2nd

	<30 yrs, after 2nd dose		
(Heidecker et al., 2022)	Summarized: rare, mostly mild, onset a few days post-2nd dose	Pfizer, Moderna	2nd
(Hviid et al., 2024)	Booster IRR ↑ in males 12–39 (Pfizer ~2.1, Moderna ~8.9)	Pfizer, Moderna	Booster
(Elizalde et al., 2024)	Incidence: ~5/100k overall; 10/100k in males 12–17; onset ~6 days	Pfizer, Moderna	2nd
(Mabila et al., 2023)	PASC is associated with a higher myocarditis risk (OR ~5.9)	mRNA	n/a
(Butbul Aviel et al., 2022)	All vaccine cases after 2nd dose; mild course vs PIMS myocarditis	Pfizer	2nd
(Knudsen & Prasad, 2023)	8–39/100k in young males after 2nd dose; booster data limited	Pfizer, Moderna, Janssen	2nd
(Florek & Sokolski, 2024)	Incidence: ~19.7/million vaccine vs 2.76/1000 infection; onset 3–4 days	Moderna	2nd
(Stowe et al., 2023)	RI up to 56.5 for Moderna (16–39 yrs, 0–6	Pfizer, Moderna,	1st, 2nd, booster

	days post-2nd dose)	AstraZeneca	
(Deng, Van Eldik, O'Moore, Buttery, Cheung, Cox, Drake-Brockman, Dwyer, Effler, Gold, et al., 2025)	Rates: 1.2/100k (Pfizer), 1.4/100k (Moderna); 70% after 2nd, 9% booster	Pfizer, Moderna	2nd, booster
(McDonald et al., 2024)	Rare: >105m doses, few reports; onset 2–7 days; highest after 2nd dose	Pfizer, Moderna	2nd"

Source: Researcher-Generated

MYOCARDITIS AND PERICARDITIS

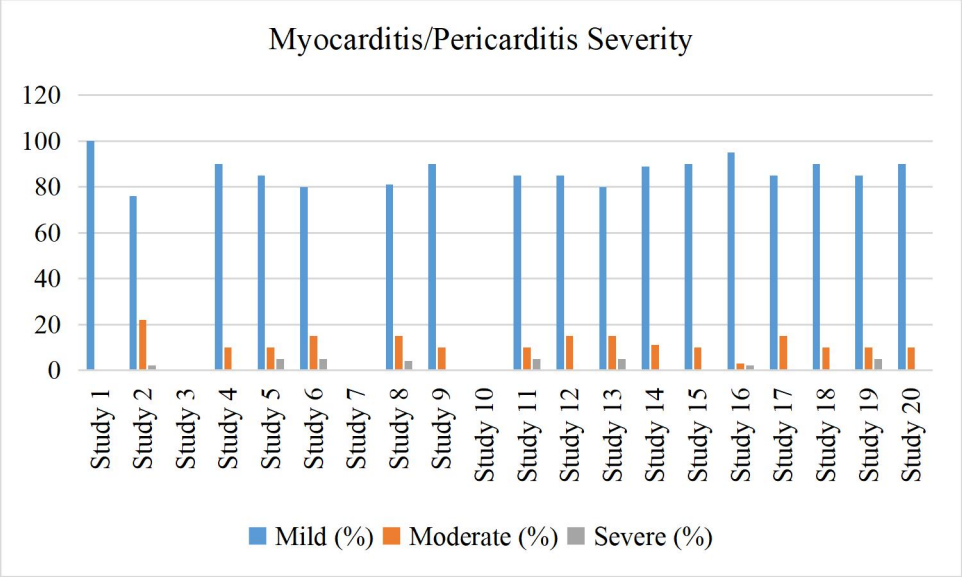
The clinical course of vaccine-associated myocarditis and pericarditis in males was generally mild to moderate, with a favourable prognosis in the vast majority of cases. Across multiple case series and registry studies, the predominant presenting symptom was acute chest pain, often accompanied by elevated cardiac troponin, ST-segment changes on ECG, and characteristic findings on cardiac MRI (Butbul Aviel et al., 2022; Chelala et al., 2021; Montgomery et al., 2021). Median onset was typically within a week post-vaccination, and most patients required short hospital stays of three to five days, during which supportive management was sufficient for recovery.

Severity varied but remained low overall. In (Witberg et al., 2021), 76% of cases were mild and only one progressed to cardiogenic shock, while Montgomery et al. (2021) reported all military patients recovered or were recovering at discharge. Larger follow-ups indicated that although most patients regained normal cardiac function, a subset demonstrated persistent imaging abnormalities. Kracalik et al. (2022) noted that at 90 days, 81% were fully recovered, though 13% still showed MRI evidence of late

gadolinium enhancement and oedema. Similarly, Chelala et al. (2021) observed persistent MRI changes in two of five patients despite clinical stability. Longer-term data remain limited but suggest generally positive outcomes. Deng, Van Eldik, O'Moore, Buttery, Cheung, Cox, Drake-Brockman, Dwyer, Effler, Gold, et al. (2025) found ongoing symptoms in up to 60% of patients at three to six months, declining to 35% by 12–18 months. Importantly, mortality was exceedingly rare: no study identified consistent vaccine-related deaths, and severe complications such as heart failure were far less common compared to myocarditis linked to SARS-CoV-2 infection (Florek & Sokolski, 2024; Hviid et al., 2024; Knudsen & Prasad, 2023).

Overall, myocarditis and pericarditis following vaccination in males typically followed a benign trajectory, with most patients recovering quickly, though some showed residual abnormalities requiring longer monitoring. As illustrated in Figure 2, the severity profile shows that the vast majority of post-vaccination myocarditis and pericarditis cases in males were mild and self-limiting, with complete recovery expected. Long-term outcome data remain limited, but available follow-ups suggest good prognosis. These findings underscore that while myocarditis is a clear signal, its clinical course is generally reassuring compared to other cardiovascular complications. The following is the myocarditis and pericarditis severity graph:

FIGURE 2: MYOCARDITIS & PERICARDITIS SEVERITY GRAPH



Source: Researcher-Generated

MYOCARDIAL INFARCTION AND OTHER MAJOR EVENTS

While myocarditis and pericarditis dominated the cardiovascular safety signal in males following COVID-19 vaccination, evidence regarding myocardial infarction (MI) and other major cardiac events was sparse. Across most case series and cohort investigations, no vaccine-associated myocardial infarction was reported (Florek & Sokolski, 2024; Knudsen & Prasad, 2023; Montgomery et al., 2021; Witberg et al., 2021). In (Montgomery et al., 2021), additional diagnostic testing excluded ischemic injury, and Witberg et al. (2021) similarly found no evidence of infarction among affected young males. These findings were consistent with other observational and registry-based studies that focused primarily on myocarditis and myopericarditis and did not identify MI as a vaccine-related outcome (Husby et al., 2021; Karlstad et al., 2022; Patone et al., 2022).

This absence of signal is clinically relevant, as it distinguishes vaccine-related myocarditis, characteristically inflammatory, with preserved coronary anatomy, from ischemic myocardial injury. It also underscores the importance of differential diagnosis in post-vaccination chest pain presentations, where exclusion of ischemia remains critical but rarely confirmed as the underlying mechanism.

Other cardiac outcomes were less frequently investigated but occasionally highlighted. Mabila et al. (2023) reported increased odds of broader cardiac diagnoses, including syncope, tachycardia, atrial fibrillation, and heart failure, within the context of post-acute sequelae of COVID-19 (PASC), though these findings reflected infection-related rather than vaccine-specific associations. Similarly, registry data occasionally noted arrhythmias or palpitations as accompanying symptoms in myocarditis cases, but these were generally transient and not linked to structural heart disease (Kracalik et al., 2022; Stowe et al., 2023). Taken together, current evidence indicates that myocardial infarction is not a consistent or validated outcome of COVID-19 vaccination in male populations. The predominant cardiovascular risk remains myocarditis and pericarditis, particularly after mRNA vaccines, whereas ischemic events and other arrhythmias appear either absent or too infrequent to establish a causal association.

POPULATION-LEVEL SURVEILLANCE DATA

Population-level surveillance systems have been critical in characterising the epidemiology of myocarditis and pericarditis following COVID-19 vaccination in males. These systems, spanning both passive and active reporting structures, provide complementary insights into the scale and distribution of adverse cardiac events. In the United States, the Vaccine Adverse Event Reporting System (VAERS) served as the primary passive surveillance tool, capturing more than 1,600 confirmed cases of

myocarditis after mRNA vaccination, with the highest reporting rates among adolescent and young adult males following the second dose (Oster et al., 2022). The Defense Health Agency's active surveillance of military personnel provided further validation, documenting clustered cases in otherwise healthy young men within days of vaccination (Montgomery et al., 2021).

Across Europe, EudraVigilance and the UK's Yellow Card scheme offered similar passive data, confirming myocarditis as a rare but disproportionately male-predominant adverse event. These findings were supported by active registry linkages in Denmark and across the Nordic countries, which quantified absolute incidence rates and demonstrated higher risks associated with Moderna compared to Pfizer (Husby et al., 2021; Karlstad et al., 2022). In the UK, NHS England's linked health records enabled self-controlled case series analyses, showing elevated incidence ratios across doses and reinforcing temporal associations (Bozkurt et al., 2021; Stowe et al., 2023).

Outside Europe and the US, hospital-based and mixed systems provided additional perspectives. Spanish hospital records (La Paz) and Canadian MYCOVACC surveillance offered both active and passive monitoring (Elizalde et al., 2024), while Australia's Therapeutic Goods Administration collected spontaneous reports consistent with international trends (Deng, Van Eldik, O'Moore, Buttery, Cheung, Cox, Drake-Brockman, Dwyer, Effler, Gold, et al., 2025). Aggregated global data further confirmed myocarditis signals across regions, though heterogeneity in reporting practices complicated direct comparisons. Overall, population-level surveillance demonstrates the strength of triangulating evidence: passive systems detect early signals, while active linked registries provide reliable incidence estimates. Together, they affirm that myocarditis risk is concentrated in young males, predominantly after second mRNA

vaccine doses, with Moderna posing comparatively higher risk. The following table presents the population-level surveillance systems reporting myocarditis/pericarditis after COVID-19 vaccination:

TABLE 3: POPULATION-LEVEL SURVEILLANCE SYSTEMS REPORTING MYOCARDITIS/PERICARDITIS AFTER COVID-19 VACCINATION

"Surveillance System / Registry	Country / Region	Type
VAERS (Vaccine Adverse Event Reporting System)	USA	Passive
Defense Health Agency (DoD surveillance)	USA (Military)	Active + Passive (VAERS linked)
EudraVigilance	Europe (EMA)	Passive
Yellow Card Scheme (MHRA)	United Kingdom	Passive
National Danish Vaccination & Hospital Registries	Denmark	Active
Nordic National Registries	Denmark, Finland, Norway, Sweden	Active
NHS England Records	United Kingdom	Active + Linked
La Paz Hospital Records	Spain (regional)	Active (Hospital-based)
TGA (Therapeutic Goods Administration) Adverse Event Reports	Australia	Passive
Canadian MYCOVACC Surveillance & AE Reports	Canada	Active + Passive
Aggregated Global Data	Multi-country	Mixed"

Source: Researcher-Generated

COMPARATIVE RISK ASSESSMENT AND MECHANISTIC INSIGHTS

Comparative evidence across cohorts and surveillance systems shows a consistent pattern: myocarditis risk after vaccination is real but uncommon, concentrated in young males, and typically smaller in magnitude than the risk after SARS-CoV-2 infection. Multiple registry analyses and reviews reported that infection-associated myocarditis exceeds vaccine-associated myocarditis on an absolute and relative basis, and several studies (e.g., large national registries) explicitly placed vaccine risk in this benefit–risk context (Elizalde et al., 2024; Florek & Sokolski, 2024; Heidecker et al., 2022; Husby et al., 2021; Hviid et al., 2024).

Within vaccine platforms, a clear signal emerges: mRNA-1273 (Moderna) is repeatedly associated with higher myocarditis rates than BNT162b2 (Pfizer) in younger males, and risk is higher after the second (priming) dose than after the first. Booster doses appear to confer some risk but generally lower or more variable than the second dose, while longer dosing intervals have been suggested (from observational comparisons) to reduce risk, though interval effects are incompletely quantified. Thus, risk ordering in most analyses is: SARS-CoV-2 infection >> (Moderna, dose-2) > (Pfizer, dose-2) > dose-1 $\approx$ booster (context dependent) (Elizalde et al., 2024; Florek & Sokolski, 2024; Heidecker et al., 2022; Husby et al., 2021; Hviid et al., 2024).

Mechanistically, no single definitive pathway has been proven. Hypotheses most frequently offered include immune-mediated inflammation (including molecular mimicry or cross-reactive spike-directed responses), hypersensitivity to vaccine components (mRNA or lipid nanoparticles), and innate/adaptive cytokine activation. Biological explanations for male predominance emphasise hormonal influences (testosterone enhancing pro-inflammatory responses) and possible but poorly defined

genetic susceptibility. A few case reports noted autoantibody or immune-cell perturbations, but controlled mechanistic data are sparse (Heidecker et al., 2022; Mabila et al., 2023; Montgomery et al., 2021; Witberg et al., 2021).

As illustrated in Figure 3, contextualising these risks against infection outcomes remains crucial: myocarditis post-vaccination is generally mild, whereas infection-related events are more frequent and severe. The following figure represents the comparative risk of myocarditis:

FIGURE 3: COMPARATIVE RISK OF MYOCARDITIS (VACCINE VS INFECTION, DOSE, TYPE)

Vaccine / Exposure	1st Dose	2nd Dose	Booster
Pfizer (BNT162b2)	1 (low)	2–3 (moderate-high)	2 (moderate, lower than 2nd dose)
Moderna (mRNA-1273)	2 (moderate)	3–4 (high to very high, esp. young males <40)	2–3 (moderate-high, lower than 2nd dose due to half dose)
Infection (COVID-19)	3–4 (high-very high, ~200 per 100k vs ~5 per 100k for vaccine)	–	–

Source: Researcher-Generated

DISCUSSION

KNOWLEDGE GAPS AND FUTURE DIRECTIONS

A consistent indication of myocarditis/pericarditis in young men post-vaccination for COVID-19 is shown by this scoping review, especially following the second round of mRNA vaccinations. Ever since then, there have been, however, several lapses in

knowledge. First, most of the sources provide evidence of high-income countries, including the United States, Israel, and Nordic countries (Butbul Aviel et al., 2022; Chelala et al., 2021; Husby et al., 2021; Hviid et al., 2024; Knudsen & Prasad, 2023; Montgomery et al., 2021; Oster et al., 2022; Witberg et al., 2021). There is little data from low- and middle-income countries where non-mRNA platforms, including Sinovac and Sputnik V, are widely used, and there is limited information on data received to date (Knudsen & Prasad, 2023; Ling et al., 2022; McDonald et al., 2024; Montgomery et al., 2021). However, there is a relative dearth of data regarding long-term outcomes. The question remains whether there is a possibility of ongoing myocardial scarring, arrhythmia, or low cardiac output in the years to come.

Future cohort studies with a long timeline should ensure that the prognosis is entirely described. Third, developing a mechanistic understanding is in its stages of development. Immune activation, molecular mimicry, and testosterone-stimulated inflammation fall under the question of hypotheses that should be proven through immunological and genetic studies (Montgomery et al., 2021; Witberg et al., 2021). Other research in the future ought to examine the explanation of why males, especially those aged 12-29 years, are most likely to succumb to the disease and whether risk is mediated by genetic polymorphisms or by hormonal profiles. Lastly, although surveillance tools like VAERS (Butbul Aviel et al., 2022; Deng, Van Eldik, O'Moore, Buttery, Cheung, Cox, Drake-Brockman, Dwyer, Effler, Gold, et al., 2025; Oster et al., 2022) and EudraVigilance Kracalik et al. (2022) have proved beneficial in detecting the signal, the mechanism is based on passive reporting, which creates the bias of underreporting. Increased active surveillance infrastructures and definition of cases on a global level will enhance risk assessment and make cross-country comparisons more accurate.

CLINICAL IMPLICATIONS AND RISK MITIGATION

Irrespective of the recognised risks, the available evidence indicates strongly that the positive outcomes of the vaccination exceed the negative consequences even in young males. Comparative studies (Bozkurt et al., 2021; Patone et al., 2022) always indicate that complex myocarditis poses greater risks post-COVID-19 infection compared to vaccination, and other cardiovascular risks, including thrombotic and arrhythmic risks, are more extensive with infection. The clinicians are thus suggested to go on the recommendation to vaccinate but pay close attention to the post-vaccine cardiac events. The evidence available can be used to inform risk mitigation strategies. To begin with, vaccinating Confederate males who are determined to be in favour of Pfizer rather than Moderna might be justified, as such an effect has been repeatedly revealed to be associated with Moderna (Florek & Sokolski, 2024; Husby et al., 2021; Karlstad et al., 2022). Second, there seems to be a decrease in myocarditis risk with an increase in the interval between doses, which indicates that studying dosing schedules and adopting them may result in an increased safety level without significant changes in protection (Heidecker et al., 2022). Third, there must be effective communication with patients and their families: clinicians must remind the patients that the vast majority of such cases are mild and treatable and much less dangerous than the infection itself.

Regarding the perspective of public health, it is highly important to further invest in the real-time surveillance and registry linkages (Elizalde et al., 2024). The long-term follow-up data of reported cases of myocarditis will be addressed through active follow-up of the selected cases, leaving the data gap presently unavailable at this time (Butbul Aviel et al., 2022). The future studies should also consider how the biomarkers could be used to identify the at-risk individuals before vaccination so that they may prevent the

risk individually through the help of tailored strategies. To conclude, vaccine-related myocarditis is a rarity to be found but a reproducible phenomenon in young men and is, in general, a mild disease that may be managed, and overall, the risk-benefit calculus of the issue leans heavily in favour of the former. Activities such as continuous surveillance, mechanical studies, and communicating risks would play an essential part in fine-tuning male-specific vaccine safety.

CONCLUSION

This scoping review identified a total of 20 studies that analysed cardiovascular outcomes in males after COVID-19 vaccination. The results are consistent that even though myocarditis and pericarditis have been identified as higher-than-anticipated occurrences in young men, particularly immediately following the second dose of mRNA vaccinations, altogether, these disorders continue to result in mild cases and self-resolve, with a positive trend in short-term recovery. Serious complications, cardiac infarction, and arrhythmias were infrequently identifiable as a result of immunisation, and most of the other reported events were indicative of incidence in the background population. Notably, comparative studies prove that the threat of myocarditis and other cardiovascular complications is much higher after COVID-19 infection than after vaccination. This highlights that vaccines still cause a net protection effect in men populations, including those most vulnerable to myocarditis signals. Additionally, there is emerging evidence that risk can be reduced with the help of such strategies as preferential use of Pfizer over Moderna among young men and extended dosing intervals.

Although these findings exist, there are significant knowledge gaps in all aspects of the long-term prognosis, the biological processes of male dysbenefit, and the safety and

effectiveness of various vaccines in the low- and middle-income background. Subsequent studies must focus on prospective follow-up and mechanistic studies to improve clinical guidance. In general, COVID-19 vaccines continue to be one of the foundations of the population's health, and in the male population, the cardiac risks are not common enough, and the impact on preventing severe infection is overwhelming.

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