Cytomegalovirus seroprevalence among blood donors: a systematic review and meta-analysis

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Abstract
Background: Screening for cytomegalovirus (CMV)-specific antibodies is not routine in some settings. Thus, transfusion of blood products poses risks for susceptible individuals.

Objectives: To investigate the global pooled CMV seroprevalence among volunteer blood donors.

Methods: This systematic review and meta-analysis was performed according to PRISMA guidelines. The databases searched included Embase, Google Scholar, Medline, PubMed, Web of Science, and Cochrane Library. Data were extracted independently and analyzed using STATA version 11.

Results: The global seroprevalence of CMV IgG, CMV IgM, and both CMV IgM and IgG was 83.16% (95% confidence interval [CI]: 78.55–87.77%, \(I^2 = 99.5\%\)), 13.77% (95% CI: 11.59–15.95%, \(I^2 = 98.8\%\)), and 23.78% (95% CI: 10.50–37.06%, \(I^2 = 98.7\%\)), respectively.

Conclusion: The global seroprevalence of CMV was high among blood donors. Therefore, regular CMV screening should be conducted to identify CMV-seronegative blood donors.

Keywords
Blood donor, cytomegalovirus, seroprevalence, systematic review, immunoglobulin M, immunoglobulin G

Date received: 23 February 2021; accepted: 2 July 2021
Background

Blood transfusion is a lifesaving component of many therapeutic interventions. However, transmission of infectious diseases is a major challenge in transfusion services worldwide. Cytomegalovirus (CMV), also known as human herpesvirus 5, is a large virus that infects humans. CMV is a highly cell-associated virus and normally causes asymptomatic infections in immunocompetent individuals. Transmission of the virus can occur vertically or horizontally through contact with virus-containing body fluids including blood. An important route of infection for high-risk groups is transfusion of blood products from latently infected donors (transfusion-transmitted [TT]-CMV). Transfusion of contaminated blood products can result in primary infection in CMV-seronegative recipients or re-infection by a new CMV strain in CMV-seropositive recipients. TT-CMV was first described by Kääriäinen and co-workers in 1966. TT-CMV infections have traditionally been explained by transfer of latently infected white blood cells (WBCs). The incidence of TT-CMV infection was reported to be as high as 13% to 37% in immunocompromised patients. Thus, the prevention of TT-CMV has become an important priority, especially in high-risk groups.

CMV is a complex pathogen with distinct pathobiology. CMV is one of the most common opportunistic pathogens in immunocompromised patients. These patients have high risks of complications following primary CMV infection, re-infection, and reactivation of latent virus. The presence of anti-CMV immunoglobulin G (IgG) indicates a previous infection by CMV, while presence of anti-CMV IgM reflects new infection, acute infection, or re-activation of CMV. Donor IgM positivity is associated with higher risk of TT-CMV because of higher CMV DNA loads in both whole blood and plasma samples.

CMV infection causes significant morbidity and mortality in immunocompromised patients who receive contaminated blood products. Because CMV can cause severe illness and death in these patients, spread of the virus through blood products should be actively prevented. Studies have demonstrated a high prevalence of CMV infection among various groups, including blood donors. The risk of CMV transmission through blood products can be limited by improved selection of donors. However, the high prevalence of CMV seropositivity in the donor populations of many countries represents a significant problem: increasing demand for CMV-free blood products may be difficult to meet if CMV-seropositive donors are excluded. In addition, use of CMV-seronegative blood cannot completely eliminate the risk of TT-CMV because of the possibility of window period donations. Leukoreduction (LR) of blood products is a common method used to decrease the risk of TT-CMV. Because latent CMV infection is restricted to small numbers of WBCs, removal of these cells significantly decreases the risk of TT-CMV. Although LR is very effective in removing leukocyte-associated CMV, it cannot remove free CMV in plasma. As a result, newly infected blood donors could transmit CMV despite effective LR. Persistence of CMV DNA following WBC removal explains rare TT-CMV in recipients of LR blood components. In the era of universal LR of blood products, screening for CMV-negative blood products is thought to be unnecessary for hematopoietic stem cell transplantation because no cases of TT-CMV have been detected in some studies. LR blood products from donors with active CMV infection have very low infectivity.
CMV-seronegative products can result in TT-CMV during the window period between infection and positive results of antibody screening tests 6 to 8 weeks later. LR blood products can result in TT-CMV because of incomplete removal of WBCs in a small proportion of units. Therefore, both LR and CMV-seronegative units have low residual risks of TT-CMV. Interestingly, the few centers without dual inventories have a relatively high prevalence of CMV seropositive blood donors within their regional populations. Some countries use both CMV-seronegative and LR products for neonatal, intrauterine, and pregnancy-associated transfusion. Other countries use CMV-seronegative and LR products for all high-risk groups, while others use LR products alone.5,24,25

CMV seroprevalence varies significantly (from 40–100%) in different parts of the world.26 The aim of this systematic review and meta-analysis was to estimate the pooled prevalence of CMV among blood donors worldwide.

**Methods**

**Study setting and design**

This systematic review and meta-analysis was conducted in a global setting. The study was designed according to the PRISMA-P 2015 Guidelines.27

**Search strategy**

We searched Embase, PubMed, Google Scholar, Medline, Web of Science, and Cochrane Library for articles published before 18 January 2021. The search terms were “Prevalence” OR “seroprevalence” OR “frequency” AND “CMV” OR “cytomegalovirus” OR “anti-cytomegalovirus antibody” AND “blood donors” OR “volunteer blood donors”.

**Study selection and eligibility criteria**

Studies were eligible if they met the following criteria: (1) peer-reviewed original articles in English; (2) cross-sectional and cohort studies reporting prevalence of CMV among blood donors; (3) publication between 1 January 2000 and 18 January 2021. Case reports, case-control studies, and editorial articles were excluded. Published articles reporting CMV seroconversion and incidence rates among blood donors were also excluded.

**Data extraction**

Two authors (TA and SG) screened references and retrieved articles according to the eligibility criteria. The selected papers were scrutinized and discrepancies between reviewers were resolved by discussion and consensus. Additionally, the reference lists of original and review articles were checked in detail to identify additional relevant studies that were not obtained via database searching. For all included studies, the following information was extracted: name of the first author, year of publication, country, study year, sample size, diagnostic methods used, mean age, and type of blood donor.

**Study quality assessment**

The Newcastle–Ottawa Scale (modified for prevalence studies) was used for methodological quality assessment.28

**Meta-analysis**

For every included study, point prevalence and 95% CI were calculated. A random-effects model was applied to assess the effects of heterogeneity among selected studies. I² values of 25%, 50%, and 75% were considered to reflect low, moderate, and high heterogeneity, respectively.29 Forest plots were used to summarize the effect sizes and 95% CIs for all studies.
A subgroup analysis was conducted to identify potential sources of heterogeneity among included studies. Funnel plots and Egger’s test were used to investigate potential publication bias. All statistical analyses were performed using STATA version 11.0 (StataCorp, College Station, TX, USA).

Results
A total of 1420 articles were retrieved by literature searching. Among these articles, 310 were excluded after duplicate removal, 1036 were irrelevant to the aim of this study, and 18 did not meet the eligibility criteria. Forty-three studies were included in the meta-analysis (Figure 1).

Study characteristics
Twenty studies were conducted in Africa, 21 in Asia, and two in South America. The countries with the largest number of studies were Nigeria (10 studies) and Iraq (5 studies). Thirty-seven studies used enzyme linked immunosorbent assay (ELISA) to assess anti-CMV antibody titers (IgM and IgG), two studies used enzyme immunoassay, one study used a microparticle enzyme immunoassay, one study used latex particle agglutination, one study used chemiluminescence, and the one used a chromatographic immunoassay. The number of blood donors ranged from 75 in Sudan to 2400 in Japan. The mean age of donors ranged from 19 years to 45 years. Thirty-three studies examined volunteer blood donors, four studies examined healthy male donors, two studies examined blood bags, one study examined family replacement donors, one study examined volunteer blood donors and family replacement donors, one study examined medical staff and volunteer donors, and one study examined regular donors (Table 1).

CMV seroprevalence among blood donors
Thirty-eight articles estimated the prevalence of anti-CMV IgG among blood donors. Among these studies, the highest

Figure 1. Flow chart of study selection for the systematic review and meta-analysis of the prevalence of anti-CMV antibodies among blood donors.
Table 1. Characteristics of included studies.

| Author and year of Publication | Country | Study year | Study design | Sample size | Population | Method | Mean age (years) | IgG (%) | IgM (%) | IgM and IgG (%) | Study quality |
|--------------------------------|---------|------------|--------------|-------------|------------|--------|-----------------|---------|---------|-----------------|---------------|
| Adjei et al. 2006             | Ghana   | 2004       | NR 264       | Volunteer donors | ELISA     |        | 32.1            | 93.2    |         |                 | Good          |
| Jobier et al. 2018            | Sudan   | 2017       | NR 90        | Volunteer donors | ELISA     |        | NA 85.5         | 42.22   |         |                 | Satisfactory  |
| Akinbami et al. 2009          | Nigeria | 2006       | Cross-sectional 122 | Volunteer donors | ELISA     | 31.3±8.7 | 96 19.5        |         |         |                 | Good          |
| Bawa et al. 2019              | Nigeria | 2013–2014  | Cross-sectional 345 | Volunteer donors | ELISA     | NR     | 96.2 2.6        |         |         |                 | Very good     |
| Bleibo et al. 2019            | Libya   | NR NR 200  | Volunteer donors | ELISA     | NR 80.5 | 39  | Good          |         |         |                 | Good          |
| Bolarinwa et al. 2014         | Nigeria | 2013       | Cross-sectional 184 | Volunteer donors | ELISA     | 26.8±6.5 | 97.4 52.6 | 52.6 | Satisfactory |               |
| Oladipo et al. 2014           | Nigeria | 2012       | NR 93        | Family replacement | ELISA     | 45±2.3 | 25.8 28        |         |         |                 | Satisfactory  |
| Gawad et al. 2016             | Egypt   | 2010       | Cross-sectional 88 | Volunteer donors | ELISA     | 30.8±8.6 | 96.6        |         |         |                 | Good          |
| Gwarzo et al. 2017            | Nigeria | 2012       | Cross-sectional 250 | Volunteer donors | ELISA     | 32.25±8.8 | 4.4        |         |         |                 | Very good     |
| Ibrahim et al. 2014           | Sudan   | 2011       | Cross-sectional 75 | Donors and medical staff | ELISA | 32.67 | 9.52 8.84 | Satisfactory |               |
| Ibrahim et al. 2015           | Sudan   | 2015       | Cross-sectional 90 | Volunteer donors | ELISA     | 26.7(18-50) | 92.1 13.3 | 93.3 | Good          |               |
| Njeru et al. 2009             | Kenya   | NR NR 400  | Volunteer donors | ELISA | 42.4 | 3.6 | Very good     |         |         |                 |               |
| Ojide et al. 2011             | Nigeria | 2010       | NR 192       | Volunteer donors | ELISA     | 32.39±7.9 | 95.8 3.1 | Satisfactory |               |
| Samuel et al. 2017            | Nigeria | 2014       | Cross-sectional 93 | Volunteer donors | ELISA     | NR 93.5 | 45.2 40.9 | Satisfactory |               |
| Pennap et al. 2016            | Nigeria | NR NR 208  | Volunteer donors | ELISA | 74  |         |         |         |                 | Satisfactory  |
| Kafi et al. 2009              | Sudan   | 2003       | NR 150       | Volunteer donors | ELISA     | 19 | 10.1 | Very good     |         |         |                 |               |
| Tebuka et al. 2019            | Tanzania | 2017    | Cross-sectional 228 | Volunteer donors | ELISA     | 30.3±8.37 | 94.4 4.0 | Satisfactory |               |
| Teka et al. 2018              | Ethiopia | 2016   | Cross-sectional 605 | Volunteer donors | ELISA | 39±21 | 4.82 57.9 | Satisfactory |               |
| Udomah et al. 2016            | Nigeria | NR NR 290  | Volunteer donors | Chromatography | MEIA | 34.17±7.1 | 95.1 3.8 | Satisfactory |               |
| Yusuf et al. 2018             | Nigeria | 2017       | Cross-sectional 185 | Volunteer donors | ELISA | 29.3 | 97.6 | Satisfactory |               |
| Ahmed et al. 2016             | Iraq     | 2014       | NR 370       | Volunteer donors | ELISA | 29.1 | 96.6 5.5 | Satisfactory |               |
| Ahmed et al. 2006             | Malaysia | NR NR 172 | Regular blood donors | ELISA | 52.38 | 9.52 8.84 | Satisfactory |               |
| Al-sabri et al. 2017          | Yemen   | NR NR 235  | Volunteer donors | ELISA | 28.2±7.22 | 87.9 | Satisfactory |               |
| Amarapal et al. 2001          | Thailand | 1998  | NR 441       | Volunteer donors | ELISA | 33.3±8.73 | 10 | Satisfactory |               |
| Chaudhari et al. 2009         | India   | NR NR 431  | Volunteer donors | EIA | 31.25 | 98.6 0.05 | Satisfactory |               |
| Dabbagh 2010                  | Iraq     | 2007–2008  | NR 90        | Healthy male | ELISA | 55 | 0.4 | Good          |         |         |                 |               |
| Das et al. 2014               | India   | 2011–2012  | Cross-sectional 2100 | Volunteer and family replacement | ELISA | 31.25 | 98.6 0.05 | Good |         |                 |               |
| Delfan-Beiranvand et al. 2012  | Iran     | NR NR 270  | Healthy male | ELISA | 30.55±9.2 | 94.9 0.44 | Good |         |                 |               |
| Furui et al. 2013             | Japan    | NR NR 2400 | Volunteer donors | EIA | 76.6 |         | Satisfactory |               |
| Henry et al. 2016             | India    | NR NR 453  | Volunteer donors | Chemiluminescence | 30.55±9.2 | 94.9 0.44 | Good |         |                 |               |

(continued)
prevalence of anti-CMV IgG antibodies was 99.2% among 1008 blood donors from Iran in 2009.63 The lowest prevalence of anti-CMV IgG antibodies was 4.82% among 290 blood donors in Nigeria.47 The estimated global pooled prevalence of anti-CMV IgG among blood donors was 83.16% (95% CI: 78.55%–87.77%, I² = 99.5%) (Figure 2).

Twenty-eight articles estimated the prevalence of anti-CMV IgM among blood donors. The global pooled prevalence of anti-CMV IgM among blood donors using a random effects model was 13.77% (95% CI: 11.59%–15.95%, I² = 98.8%). The highest prevalence of anti-CMV IgM was 85% among healthy blood donors in Iran (Figure 3) (Figure 4).66

Four studies estimated the prevalence of both anti-CMV IgG and IgM among blood donors. The global pooled prevalence of both CMV IgM and IgG among blood donors using a random effects model was 23.78% (95% CI: 10.50%–37.06%, I² = 98.7%) (Figure 5).

Subgroup analysis by region and method of detection

The pooled prevalence of anti-CMV IgG in Africa, Asia, and South America was 82.64% (95% CI 67.47%–97.81%), 82.75% (95% CI 78.20%–87.30%), and 99.23% (95% CI 83.90%–100.56%), respectively. The pooled prevalence of anti-CMV IgM in Africa, Asia, and South America was 22.52% (95% CI 15.89%–29.16%), 8.06% (95% CI 5.70%–10.43%), and 59.00% (95% CI 52.54%–65.48%), respectively. The pooled prevalence of anti-CMV IgG and IgM CMV measured by ELISA was higher compared with other methods of detection (Table 2).

Publication bias

Potential publication bias among the included studies were assessed statistically.
and graphically using Egger’s test and funnel plots, respectively. Funnel plots of the prevalence of both anti-CMV IgG (Figure 6) and IgM (Figure 7) were non-symmetrical, suggesting the presence of publication bias. Egger’s test also indicated publication bias in both anti-CMV IgG ($P < 0.001$) and IgM ($P < 0.001$).

**Discussion**

The presence of anti-CMV antibodies (IgM and IgG) among blood donors is a sign of potentially infectious virus in transfused blood products. According to this systematic review and meta-analysis, the global prevalence of anti-CMV IgG and IgM among blood donors was 83.16% (95% CI: 78.55%–87.77%, $I^2 = 99.5%$) and 13.77% (11.59%–15.95%, $I^2 = 98.8%$), respectively. The global prevalence of both anti-CMV IgM and IgG among blood donors was 23.78% (95% CI: 10.50%–37.06%, $I^2 = 98.7%$). The high prevalence of anti-CMV IgG identified in this meta-analysis reflects the fact that CMV infection is endemic in different parts of the world. However, the pooled prevalence estimated in the current study was lower than another worldwide estimate.
## Figure 3. Forest plot of the prevalence of anti-CMV IgM among blood donors.

| Author, year of Publication | E(R) (95% CI) | % Weight |
|-----------------------------|---------------|----------|
| Jobier et al 2018            | 42.22 (32.02, 52.42) | 2.12     |
| Akrifi et al 2009            | 19.50 (12.47, 26.53) | 2.80     |
| Bawa et al 2019              | 2.50 (0.92, 4.28)    | 3.86     |
| Bekrio et al 2019            | 11.00 (5.24, 45.78)  | 3.98     |
| Boletineau et al 2014        | 52.60 (45.30, 59.81) | 2.70     |
| Gower et al 2014             | 19.00 (20.02, 35.08) | 3.25     |
| Gweer et al 2017             | 4.40 (1.86, 6.94)    | 3.75     |
| IBRAHM et al 2015            | 13.30 (5.28, 93.32)  | 2.80     |
| Jin et al 2009               | 3.90 (1.77, 5.43)    | 3.84     |
| Gjikd et al 2011             | 2.10 (0.55, 5.55)    | 3.70     |
| Samuel et al 2017            | 45.20 (50.05, 55.32) | 2.13     |
| Tufia et al 2018             | 10.10 (0.19, 14.01)  | 3.50     |
| Teks et al 2018              | 4.00 (2.44, 5.65)    | 3.87     |
| Ahmed et al 2016             | 3.90 (1.85, 5.75)    | 3.83     |
| Al-Safi et al 2017            | 5.50 (2.99, 8.41)    | 3.69     |
| Dobaghi et al 2010           | 10.00 (3.89, 19.20)  | 2.99     |
| Dene et al 2014              | 0.05 (-0.05, 0.15)   | 3.95     |
| Heny et al 2016              | 0.44 (-0.17, 1.05)   | 3.93     |
| Karid 2012                   | 3.00 (-0.24, 6.34)   | 2.61     |
| Mahmood et al 2014           | 3.40 (0.71, 6.09)    | 3.72     |
| Mabung 2009                  | 7.00 (3.97, 11.03)   | 3.50     |
| Mehr et al 2004              | 2.50 (1.10, 3.90)    | 3.90     |
| Namhata et al 2019           | 1.48 (0.39, 2.57)    | 3.91     |
| Ashour et al 2014             | 1.30 (0.83, 2.37)    | 3.93     |
| Shaheen et al 2020           | 4.00 (0.92, 7.14)    | 3.65     |
| Zia et al 2013                | 85.00 (50.05, 120.00)| 2.28     |
| Datta-Basuvard et al 2012     | 0.60 (-0.35, 1.55)   | 3.93     |
| Arora et al 2001              | 0.83 (0.78, 12.26)   | 3.71     |
| Umer et al 2016               | 57.90 (52.22, 63.59) | 3.11     |
| Overall (I-squared = 98.8%, p = 0.000) | 13.77 (11.50, 15.95) | 100.00  |

NOTE: Weights are from random effects analysis.

## Figure 4. Estimated global CMV seroprevalence among blood donors.
of among blood and organ donors (86% seroprevalence). The prevalence of anti-CMV IgG among blood donors varies according to local infection rates in the general population as well as the socioeconomic characteristics of the blood donors. The high seroprevalence of IgG indicates frequent past exposure to CMV. Low socioeconomic status is associated with increased exposure to CMV because of factors such as large household size, crowding, child care practices, and sexual practices. We found that 14.8% of blood donors were positive for anti-CMV IgM, indicating the presence of recent acute CMV infection. This type of infection could be either primary or recurrent. Because of the sensitivity of detection assays, IgM may be detectable both prior to the appearance of IgG and shortly after IgG seroconversion, and remains positive for several months.

In this study, the prevalence of anti-CMV IgG in Africa, Asia, and South America was 82.64% (95% CI: 67.47%–97.81%), 82.75% (95% CI: 78.20%–87.30%), and 99.23% (95% CI: 83.90%–100.56%), respectively. The prevalence of anti-CMV IgM was 22.52% (95% CI: 15.89%–29.16%), 8.06% (95% CI: 5.70%–10.43%), and 59.00% (95% CI: 52.54%–65.48%) in Africa, Asia, and South America, respectively. CMV

Figure 5. Forest plot of the prevalence of anti-CMV IgM and IgG among blood donors.
seroprevalence varies geographically across the world. A systematic review and meta-analysis conducted in Iran by Shaiegan et al. showed that the prevalence of anti-CMV IgG and IgM was 92% (95% CI: 90%–94%) and 2.6% (95% CI: 1.7%–3.6%), respectively. Another single center study conducted in Nigeria by Gwarzo et al. showed that the prevalence of anti-CMV IgG and IgM was 92% (95% CI: 90%–94%) and 2.6% (95% CI: 1.7%–3.6%), respectively. Another single center study conducted in Nigeria by Gwarzo et al. showed that the prevalence of

### Table 2. Prevalence of anti-CMV antibodies among blood donors.

| Characteristic               | No. of studies | Sample size | Prevalence (95% CI)   | $I^2$ (%) | P-value |
|-----------------------------|----------------|-------------|-----------------------|-----------|---------|
| CMV IgG                     |                |             |                       |           |         |
| **Region**                  |                |             |                       |           |         |
| Africa                      | 18             | 3881        | 82.64% (67.47–97.81%) | 99.8      | <0.001  |
| Asia                        | 18             | 9388        | 82.75% (78.20–87.30%) | 99.3      | <0.001  |
| America                     | 2              | 1681        | 99.23% (83.90–100.56%)| 97.2      | <0.001  |
| Global                      | 38             | 14743       | 83.16% (78.55–87.77%) | 99.5      | <0.001  |
| **Method of anti-CMV antibody detection** | | | | | |
| ELISA                       | 32             | 10847       | 85.34% (82.44–88.24%) | 98.6      | <0.001  |
| Others                      | 6              | 3896        | 75.51% (47.87–103.15%)| 99.9      | <0.001  |
| CMV IgM                     |                |             |                       |           |         |
| **Region**                  |                |             |                       |           |         |
| Africa                      | 14             | 3389        | 22.52% (15.89–29.16%) | 98.4      | <0.001  |
| Asia                        | 15             | 6878        | 8.06% (5.70–10.43%)   | 98.9      | <0.001  |
| Global                      | 29             | 10267       | 13.77% (11.59–15.95%) | 98.8      | <0.001  |
| **Method of anti-CMV antibody detection** | | | | | |
| ELISA                       | 26             | 9419        | 13.41% (10.97–15.85%) | 98.7      | <0.001  |
| Others                      | 2              | 558         | 1.87% (−1.55–5.30%)   | 79.0      | 0.029   |

CMV, cytomegalovirus; CI, confidence interval; ELISA, enzyme-linked immunosorbent assay.

**Figure 6.** Funnel plot of the prevalence of anti-CMV IgG among blood donors in the included studies.
showed that the prevalence of anti-CMV IgG was 100% among blood donors.

The prevalence of anti-CMV IgG among blood donors observed using ELISA and rapid kits was 85.34% (95% CI: 82.44%–88.24%) and 75.51% (95% CI: 47.87%–103.15%), respectively. The prevalence of anti-CMV IgM among blood donors observed using ELISA and rapid kits was 13.41% (95% CI: 10.97%–15.85%) and 1.87% (95% CI: −1.55% to 5.30%), respectively. We found that the prevalence of anti-CMV IgG and IgM among blood donors was higher using ELISA compared with rapid kits. This might be because rapid screening kits are associated with more false negative results compared with ELISA.74 Moreover, a study conducted by Chameera et al.75 showed that rapid kits had lower sensitivity and negative predictive values compared with ELISA.

LR of cellular blood products and/or selection of CMV-seronegative donors are measures used to reduce the risk of TT-CMV. The risk of TT-CMV is closely associated with transfer of leukocytes from infected donors to the recipient.76 However, because of the window period between CMV infection and seroconversion, apparently seronegative donors with transient viremia may be able to transfer CMV.77 CMV-seropositive blood donors are CMV carriers and latently infected cells may be present in their blood that can be reactivated after transfusion and thus may be infectious.76 Blood donations from newly CMV IgG-positive donors should have the highest risks of TT-CMV because they contain the highest levels of CMV DNA and early anti-CMV antibodies cannot neutralize the virus.70 However, because of the high rate of CMV seropositivity in different parts of the world and the need for screening of large numbers of blood donations, use of exclusively CMV-seronegative blood is not practical.78 Use of pathogen-inactivated blood products is another strategy to reduce the risk of TT-CMV and many other infections.5

**Figure 7.** Funnel plot of the prevalence of anti-CMV IgM among blood donors in the included studies.
The findings of this systematic review and meta-analysis should be considered in the context of some important limitations. Heterogeneity was observed in all analyses, including subgroup analyses. High heterogeneity may have arisen from inclusion of studies only in the English language. We also did not explore potential risk factors associated with presence of anti-CMV IgG and IgM among blood donors because this information was not available in most of the included studies.

Conclusion and recommendations

This study revealed that CMV seroprevalence was high among blood donors globally. CMV seropositivity among blood donors is a challenge for safe blood transfusion and can lead to high mortality and morbidity in high-risk transfusion recipients. Therefore, routine CMV screening should be performed to identify CMV-seronegative blood donors.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgement

We would like to acknowledge the authors of the studies included in this systematic review and meta-analysis.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author contributions

TA and SG were involved in the literature search, statistical analysis, study quality assessment, and manuscript drafting, review, and final approval. Both authors critically revised the paper and agree to be accountable for all aspects of the work.

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