Carbapenem-resistance conferring gene variants in *K. pneumoniae* recovered from clinical samples in Africa: Systematic Review and Meta-analysis

Supplementary files

List of tables and figures

S1 Table: searching strings and searched studies using Pub Med, Science direct and Scopus for searching studies

String	Mesh terms	No
PubMed	**((((((((((prevalence) OR (epidemiology)) AND (carbapenemase)) OR (carbapenemase producing genes)) OR (BlaOXA)) OR (BlaNDM)) OR (BlaVIM)) OR (BlaKPC)) OR (BlaIMP)) AND (*Klebsiella Pneumoniae*)) OR (Enterobacteriaceae)) AND (Africa)** Filters: **from 2010/1/1 - 2023/12/30** ((((((("epidemiology"[MeSH Subheading] OR "epidemiology"[All Fields] OR "prevalence"[All Fields] OR "prevalence"[MeSH Terms] OR "prevalance"[All Fields] OR "prevalences"[All Fields] OR "prevalence s"[All Fields] OR "prevalent"[All Fields] OR "prevalently"[All Fields] OR "prevalents"[All Fields] OR ("epidemiologies"[All Fields] OR "epidemiology"[MeSH Subheading] OR "epidemiology"[All Fields] OR "epidemiology"[MeSH Terms] OR "epidemiology s"[All Fields])) AND ("carbapenemase"[Supplementary Concept] OR "carbapenemase"[All Fields] OR "carbapenemases"[All Fields])) OR (("carbapenemase"[Supplementary Concept] OR "carbapenemase"[All Fields] OR "carbapenemases"[All Fields]) AND ("produce"[All Fields] OR "produced"[All Fields] OR "producent"[All Fields] OR "producer"[All Fields] OR "producer s"[All Fields] OR "producers"[All Fields] OR "produces"[All Fields] OR "producible"[All Fields] OR "producing"[All Fields]) AND ("gene s"[All Fields] OR "genes"[MeSH Terms] OR "genes"[All Fields])) OR "BlaOXA"[All Fields] OR "BlaNDM"[All Fields] OR "BlaVIM"[All Fields] OR "BlaKPC"[All Fields] OR "BlaIMP"[All Fields]) AND ("*klebsiella pneumoniae*"[MeSH Terms] OR ("klebsiella"[All Fields] AND "pneumoniae"[All Fields]) OR "*klebsiella pneumoniae*"[All Fields])) OR ("enterobacteriacea"[All Fields] OR "enterobacteriaceae"[MeSH Terms] OR "enterobacteriaceae"[All Fields])) AND ("africa"[MeSH Terms] OR "africa"[All Fields] OR "africa s"[All Fields] OR "africas"[All Fields])) AND (2010/1/1:2023/12/30[pdat])	3,937
Science direct	prevalence AND carbapenemase genes OR BlaOXA OR BlaNDM OR BlaVIM OR BlaKPC OR BlaIMP AND *Klebsiella Pneumoniae* AND Africa	4017
Scopus	prevalence* AND carbapenemase-gene* OR blaoxa* OR blandm* OR blaimp* OR blakpc* OR blavim* AND klebsiella AND pneumoniae* OR enterobacteriaceae* AND africa AND PUBYEAR > 2009 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE , "ar")) AND(LIMIT-TO (LANGUAGE , "English"))	713

S2 Table: Quality appraisal result of included studies for Prevalence of carbapenem-resistance conferring gene variants in *K. pneumoniae* clinical isolates in Africa. Using Joanna Briggs Institute (JBI) quality appraisal checklist for prevalence studies (1).

Author	Year	1) Was the sample frame appropriate?	2) Were study participants sampled in appropriate way?	3) Was the sample size adequate?	4) Were the study subjects and the setting described in detail?	5) Was the data analysis conducted with sufficient coverage of the identified sample?	6) Were valid methods used for the identification of the condition?	7) Was they measure in a standard, reliable way for all participants?	8) Was there appropriate statistical analysis?	9) Was the response rate adequate, and if not, was the low response rate managed appropriately?	Quality score
Tekele *et al (2)*	2021	YES	YES	No	YES	YES	YES	YES	YES	NI	7/9
Kumwenda *et al* (3)	2019	YES	YES	No	YES	YES	YES	YES	YES	YES	8/9
Turugurwa *et al (4)*	2019	YES	YES	No	YES	YES	YES	YES	YES	YES	8/9
El-Domany *et al (5)*	2021	YES	YES	No	YES	YES	YES	YES	YES	YES	8/9
Gandor *et al* (6)	2022	YES	YES	No	YES	YES	YES	YES	YES	YES	8/9
Martha *et al* (7)	2014	YES	YES	YES	YES	YES	YES	YES	YES	YES	9/9
Mohamed (8)	2023	YES	YES	No	YES	YES	YES	YES	YES	NI	7/9
Odewale *et al (9)*	2023	YES	YES	No	YES	YES	YES	YES	YES	NI	7/9
Awoke *et al* (10)	2022	YES	YES	YES	YES	YES	YES	YES	YES	NI	8/9
Dwomoh *et al* (11)	2022	YES	YES	No	YES	YES	YES	YES	YES	NI	7/9
Bourafa *et al* (12)	2018	YES	No	No	YES	YES	YES	YES	YES	NI	6/9
Muraya *et al* (13)	2022	YES	YES	No	YES	YES	YES	YES	YES	NI	7/9
Taha *et al (14)*	2023	YES	YES	No	YES	YES	YES	YES	YES	NI	7/9
tawfik *et al (15)*	2020	YES	YES	No	YES	YES	YES	YES	YES	NI	7/9
Suwaiba (16)	2020	YES	YES	No	YES	YES	YES	YES	YES	YES	8/9
Okoche D *etal* (17)	2016	YES	YES	No	YES	YES	YES	YES	YES	NI	7/9
Ojo *et al* (18)	2021	YES	YES	No	YES	YES	YES	YES	YES	NI	7/9
Ghaith *et al (19)*	2019	No	YES	YES	YES	YES	YES	YES	YES	NI	7/9
Hamed *et al (20)*	2022	No	YES	No	YES	YES	YES	YES	YES	NI	6/9
Abdelaziz (21)	2022	No	YES	YES	YES	YES	YES	YES	YES	NI	7/9
Ssekatawa *et al*	2021	YES	YES	No	YES	YES	YES	YES	YES	YES	8/9

(22)											
Adam (23)	2018	YES	YES	YES	YES	YES	YES	YES	YES	NI	8/9
El-Badawy (24)	2020	YES	YES	YES	YES	YES	YES	YES	YES	NI	8/9
Daniel (25)	2017	YES	YES	YES	YES	YES	YES	YES	YES	NI	8/9
Osama et al (26)	2021	No	YES	YES	YES	YES	YES	YES	YES	NI	7/9
Kopotsa (27)	2020	No	YES	No	YES	YES	YES	YES	YES	NI	6/9
Mansour *et al* (28)	2017	YES	YES	YES	YES	YES	YES	YES	YES	YES	9/9
Vasaikar *(29)*	2017	No	YES	No	YES	YES	YES	YES	YES	YES	7/9
Perez-Palacios *et al (30)*	2023	YES	YES	YES	YES	YES	YES	YES	YES	YES	9/9
Lowe *et al* (31)	2019	YES	YES	No	YES	YES	YES	YES	YES	NI	7/9
Owusu et al (32)	2023	YES	YES	YES	YES	YES	YES	YES	YES	NI	8/9
Barguigua *et al* (33)	2015	YES	YES	YES	YES	YES	YES	YES	YES	YES	9/9
Afolayan *et al* (34)	2021	YES	YES	YES	YES	YES	No	YES	YES	NI	7/9
Kalambry *et al* (35)	2023	No	YES	No	YES	YES	YES	YES	YES	NI	7/9
Aboulela *et al* (36)	2023	No	YES	No	YES	YES	YES	YES	YES	NI	7/9
legese *et al* (37)	2022	YES	YES	YES	YES	YES	YES	YES	YES	NI	8/9
Arhoune *et al* (38)	2021	YES	YES	YES	YES	YES	YES	YES	YES	YES	9/9
Kieffer *et al* (39)	2016	No	YES	No	YES	YES	YES	YES	YES	YES	7/9
Messaoudi *et al (40)*	2019	YES	YES	YES	YES	YES	YES	YES	YES	YES	9/9
Ktari (41)	2011	YES	YES	No	YES	YES	YES	YES	YES	NI	7/9
tanfous *et al (42)*	2016	YES	YES	YES	YES	YES	YES	YES	YES	NI	8/9
Elbadawi *et al* (43)	2021	YES	YES	YES	YES	YES	YES	YES	YES	NI	8/9
Albasha *et al* (44)	2020	YES	YES	YES	YES	YES	NO	YES	YES	NI	7/9
Osman *et al* (45)	2023	2022	YES	YES	YES	YES	YES	YES	YES	YES	NI
Abdeta *et al* (46)	2021	2022	YES	YES	No	YES	YES	YES	YES	YES	NI
Zalegh *et al* (47)	2023	2018	YES	No	No	YES	YES	YES	YES	YES	NI
Sherif *et al* (48)	2021	2022	YES	YES	YES	YES	YES	YES	YES	YES	NI
KHALIFA *et al* (49)	2017	2022	YES	YES	No	YES	YES	YES	YES	YES	NI
Khaldi *et al* (50)	2022	2018	YES	No	No	YES	YES	YES	YES	YES	NI

S3 Table: Sensitivity analysis showing for carbapenemase encoding genes profile in *K. pneumoniae* isolates after deletion of one study.

```
. meta summarize, leaveoneout

  Effect-size label: Effect size
        Effect size: p
          Std. err.: se
        Study label: Nameofauthors

Leave-one-out meta-analysis summary             Number of studies =     49
Random-effects model
Method: REML
```

Omitted study	Effect size	[95% conf.	interval]	p-value
Ktari (2011)	34.263	26.180	42.346	0.000
Martha et al (2014)	33.652	25.538	41.765	0.000
Barguigua et al (2015)	34.418	26.372	42.464	0.000
Kieffer et al et al (2016)	33.784	25.663	41.905	0.000
ben tanfous etal (2016)	34.432	26.389	42.474	0.000
Okoche D etal (2016)	33.791	25.669	41.913	0.000
KHALIFA et al (2017)	34.073	25.962	42.184	0.000
Daniel (2017)	34.439	26.402	42.477	0.000
Vasaikar et al (2017)	34.550	26.545	42.555	0.000
Mansour et al (2017)	34.276	26.195	42.357	0.000
Bourafa et al (2018)	34.104	26.009	42.200	0.000
Adam (2018)	33.789	25.671	41.908	0.000
Ghaith et al (2019)	33.141	25.134	41.148	0.000
Kumwenda et al (2019)	34.336	26.271	42.401	0.000
Lowe et al 2019	33.571	25.459	41.682	0.000
Messaoudi et al(2019)	34.343	26.277	42.410	0.000
Turugurwa et al(2019)	33.960	25.853	42.068	0.000
tawfik et al(2020)	32.515	24.809	40.221	0.000
El-Badawy (2020)	33.976	25.856	42.095	0.000
Suwaiba (2020)	34.413	26.367	42.458	0.000
Kopotsa (2020)	32.571	24.831	40.311	0.000
Albasha et al (2020)	32.476	24.796	40.156	0.000
Osama et al (2021)	33.162	25.149	41.176	0.000
Sherif et al (2021)	33.895	25.779	42.012	0.000
El-Domany et al. (2021)	33.990	25.869	42.111	0.000
Tekele et al(2021)	34.350	26.289	42.410	0.000
Abdeta et al(2021)	34.482	26.454	42.509	0.000
Arhoune et al (2021)	34.325	26.255	42.395	0.000
Ojo et al (2021)	34.406	26.359	42.454	0.000
Afolayan et al (2021)	34.382	26.327	42.438	0.000
Elbadawi et al (2021)	32.928	25.001	40.854	0.000
Ssekatawa et al (2021)	33.851	25.724	41.977	0.000
Khaldi et al (2022)	34.034	25.949	42.120	0.000
Hamed et al(2022)	33.675	25.568	41.782	0.000
Abdelaziz (2022)	32.489	24.800	40.177	0.000
Gandor et al (2022)	33.573	25.464	41.682	0.000
Awoke T et al (2022)	34.118	26.011	42.225	0.000
legese et al (2022)	34.118	26.012	42.224	0.000
Dwomoh et al 2022	34.206	26.116	42.295	0.000
Muraya et al (2022)	34.509	26.490	42.527	0.000
Mohamed (2023)	33.546	25.440	41.652	0.000
Taha et al(2023)	33.571	25.462	41.679	0.000
Aboulela et al (2023)	33.947	25.827	42.068	0.000
Owusu et al (2023)	34.328	26.265	42.392	0.000
Kalambry et al (2023)	34.186	26.106	42.266	0.000
Perez-Palacios et al (2023)	33.101	25.112	41.090	0.000
Zalegh et al (2023)	33.558	25.484	41.633	0.000
Odewale et al (2023)	32.646	24.860	40.432	0.000
Osman et al (2023)	33.536	25.437	41.635	0.000
theta	33.833	25.875	41.790	0.000

.

S4 Table: Sensitivity analysis showing for Bla$_{OXA-48}$ genes in *K. pneumoniae* isolates after deletion of one study.

```
. meta summarize, leaveoneout

  Effect-size label: Effect size
        Effect size: p
          Std. err.: se
        Study label: Nameofauthors

Leave-one-out meta-analysis summary             Number of studies =     39
Random-effects model
Method: REML
```

Omitted study	Effect size	[95% conf.	interval]	p-value
Martha et al (2014)	15.248	9.724	20.772	0.000
Barguigua et al (2015)	15.298	9.786	20.810	0.000
Okoche D etal (2016)	15.188	9.652	20.725	0.000
Kieffer et al et al (2016)	15.290	9.776	20.804	0.000
Daniel (2017)	15.253	9.732	20.774	0.000
Mansour et al (2017)	15.245	9.719	20.771	0.000
Vasaikar et al (2017)	15.323	9.819	20.828	0.000
KHALIFA et al (2017)	14.753	9.211	20.295	0.000
Adam (2018)	15.161	9.622	20.700	0.000
Ghaith et al (2019)	14.568	9.068	20.068	0.000
Lowe et al (2019)	15.207	9.671	20.743	0.000
Messaoudi et al(2019)	15.310	9.802	20.819	0.000
tawfik et al(2020)	14.033	8.766	19.300	0.000
El-Badawy (2020)	15.245	9.719	20.770	0.000
Kopotsa (2020)	14.576	9.077	20.075	0.000
Albasha et al (2020)	14.879	9.328	20.430	0.000
Tekele et al(2021)	15.263	9.744	20.782	0.000
El-Domany et al. (2021)	14.917	9.356	20.478	0.000
Ssekatawa et al (2021)	15.236	9.707	20.764	0.000
Osama et al (2021)	14.853	9.302	20.403	0.000
Afolayan et al (2021)	15.168	9.627	20.709	0.000
Elbadawi et al (2021)	13.287	8.608	17.967	0.000
Sherif et al (2021)	14.481	9.018	19.944	0.000
Gandor et al (2022)	14.724	9.182	20.266	0.000
Awoke T et al (2022)	14.815	9.263	20.368	0.000
Dwomoh et al 2022	15.265	9.746	20.784	0.000
Muraya et al (2022)	15.297	9.786	20.809	0.000
Abdelaziz (2022)	13.292	8.609	17.975	0.000
legese et al (2022)	14.987	9.429	20.544	0.000
Khaldi et al (2022)	14.797	9.303	20.290	0.000
Mohamed (2023)	14.638	9.112	20.164	0.000
Odewale et al (2023)	15.075	9.522	20.629	0.000
Taha et al(2023)	15.229	9.699	20.759	0.000
Perez-Palacios et al (2023)	14.498	9.029	19.968	0.000
Owusu et al (2023)	15.231	9.706	20.755	0.000
Kalambry et al (2023)	15.090	9.560	20.620	0.000
Aboulela et al (2023)	15.060	9.507	20.612	0.000
Osman et al (2023)	14.537	9.048	20.026	0.000
Zalegh et al (2023)	15.071	9.543	20.600	0.000
theta	14.909	9.502	20.317	0.000

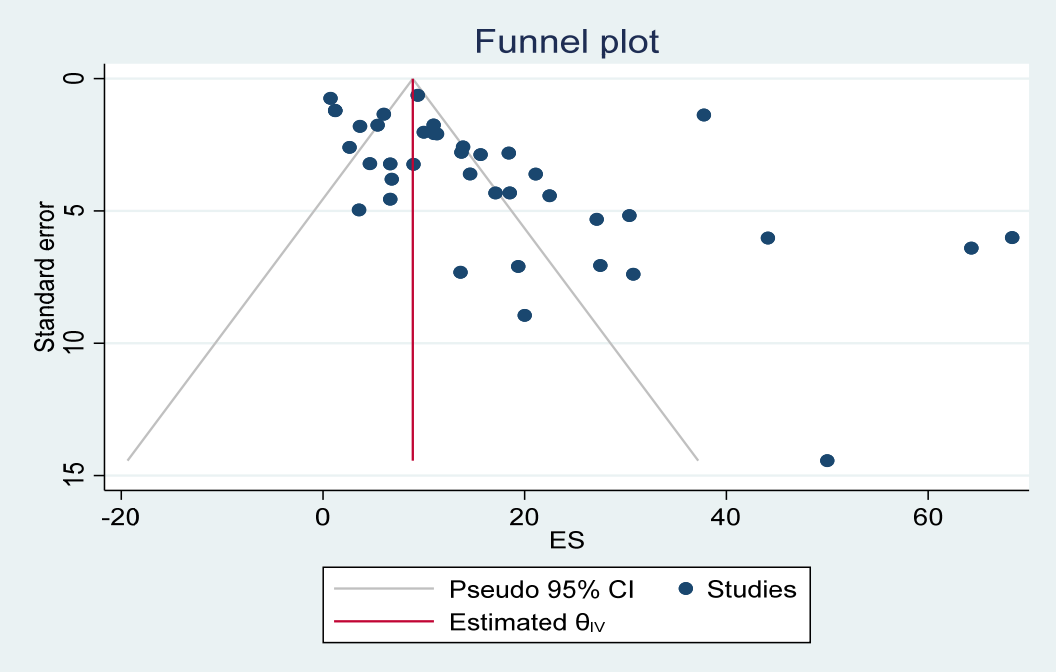
S5 Table: Sensitivity analysis showing for Bla_{NDM-1} genes in *K. pneumoniae* isolates after deletion of one study.

```
. meta summarize, random(reml) leaveoneout

  Effect-size label: Effect size
        Effect size: p
          Std. err.: se
        Study label: Nameofauthors

Leave-one-out meta-analysis summary             Number of studies =     39
Random-effects model
Method: REML
```

Omitted study	Effect size	[95% conf.	interval]	p-value
Martha et al (2014)	15.248	9.724	20.772	0.000
Barguigua et al (2015)	15.298	9.786	20.810	0.000
Okoche D etal (2016)	15.188	9.652	20.725	0.000
Kieffer et al et al (2016)	15.290	9.776	20.804	0.000
Daniel (2017)	15.253	9.732	20.774	0.000
Mansour et al (2017)	15.245	9.719	20.771	0.000
Vasaikar et al (2017)	15.323	9.819	20.828	0.000
KHALIFA et al (2017)	14.753	9.211	20.295	0.000
Adam (2018)	15.161	9.622	20.700	0.000
Ghaith et al (2019)	14.568	9.068	20.068	0.000
Lowe et al (2019)	15.207	9.671	20.743	0.000
Messaoudi et al(2019)	15.310	9.802	20.819	0.000
tawfik et al(2020)	14.033	8.766	19.300	0.000
El-Badawy (2020)	15.245	9.719	20.770	0.000
Kopotsa (2020)	14.576	9.077	20.075	0.000
Albasha et al (2020)	14.879	9.328	20.430	0.000
Tekele et al(2021)	15.263	9.744	20.782	0.000
El-Domany et al. (2021)	14.917	9.356	20.478	0.000
Ssekatawa et al (2021)	15.236	9.707	20.764	0.000
Osama et al (2021)	14.853	9.302	20.403	0.000
Afolayan et al (2021)	15.168	9.627	20.709	0.000
Elbadawi et al (2021)	13.287	8.608	17.967	0.000
Sherif et al (2021)	14.481	9.018	19.944	0.000
Gandor et al (2022)	14.724	9.182	20.266	0.000
Awoke T et al (2022)	14.815	9.263	20.368	0.000
Dwomoh et al 2022	15.265	9.746	20.784	0.000
Muraya et al (2022)	15.297	9.786	20.809	0.000
Abdelaziz (2022)	13.292	8.609	17.975	0.000
legese et al (2022)	14.987	9.429	20.544	0.000
Khaldi et al (2022)	14.797	9.303	20.290	0.000
Mohamed (2023)	14.638	9.112	20.164	0.000
Odewale et al (2023)	15.075	9.522	20.629	0.000
Taha et al(2023)	15.229	9.699	20.759	0.000
Perez-Palacios et al (2023)	14.498	9.029	19.968	0.000
Owusu et al (2023)	15.231	9.706	20.755	0.000
Kalambry et al (2023)	15.090	9.560	20.620	0.000
Aboulela et al (2023)	15.060	9.507	20.612	0.000
Osman et al (2023)	14.537	9.048	20.026	0.000
Zalegh et al (2023)	15.071	9.543	20.600	0.000
theta	14.909	9.502	20.317	0.000

```
  Model and method
               Model: Random effects
              Method: REML

.
. meta bias, egger random(reml)

  Effect-size label: Effect size
        Effect size: p
          Std. err.: se

Regression-based Egger test for small-study effects
Random-effects model
Method: REML

H0: beta1 = 0; no small-study effects
              beta1 =      0.82
      SE of beta1 =     1.434
                  z =      0.57
       Prob > |z| =    0.5670
```

S1 Figure: Egger's test showing for publication biases of the included studies for carbapenemase genes in *K. pneumoniae* clinical isolates in Africa.



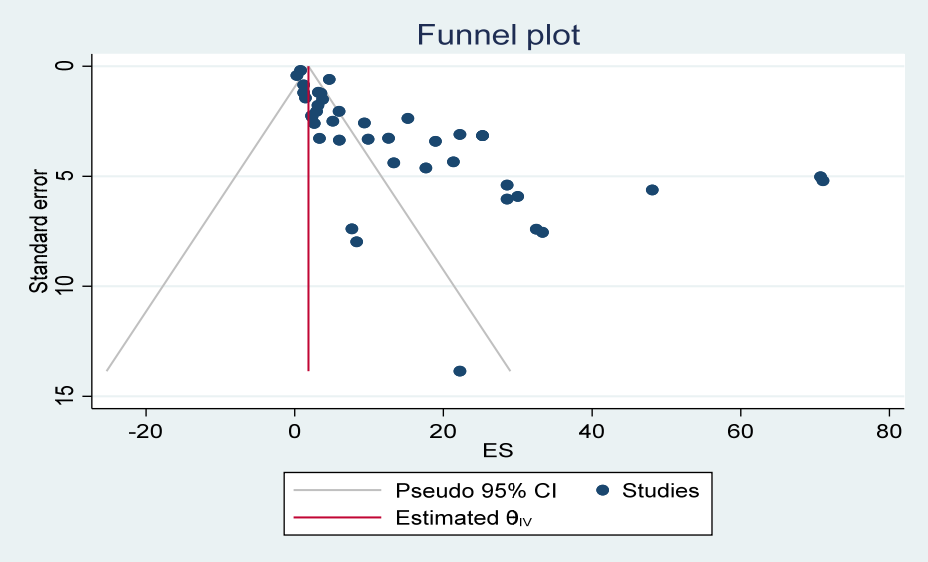
S2 Figure: Funnel plot showing publication biases of bla$_{OXA-48}$ gene in *K. pneumoniae* clinical isolates in Africa.

```
  Model and method
              Model: Random effects
             Method: REML

.
. meta bias, egger random(reml)

  Effect-size label: Effect size
        Effect size: p
          Std. err.: se

Regression-based Egger test for small-study effects
Random-effects model
Method: REML

H0: beta1 = 0; no small-study effects
              beta1 =      3.85
      SE of beta1 =     0.852
                z =      4.52
      Prob > |z| =    0.0000
```

S3 Figure: Egger's test showing for publication bias of bla$_{\text{OXA-48}}$ gene in *K. pneumoniae* clinical isolates in Africa.

```
. meta trimfill, right

  Effect-size label: ES
        Effect size: p
          Std. err.: se

Nonparametric trim-and-fill analysis of publication bias
Linear estimator, imputing on the right

Iteration                              Number of studies =     46
  Model: Random-effects                         observed =     39
 Method: REML                                   imputed =      7

Pooling
  Model: Random-effects
 Method: REML

------------------------------------------------------------------------------
             Studies |                 ES    [95% conf. interval]
---------------------+--------------------------------------------------------
            Observed |             16.964          12.169          21.759
  Observed + Imputed |             20.420          15.721          25.119
------------------------------------------------------------------------------
```

S4 Figure: Trim-and-fill analysis for the prevalence bla$_{\text{OXA-48}}$ gene in *K. pneumoniae* clinical isolates in Africa.



S5 Figure: Funnel plot showing publication biases of bla$_{NDM-1}$ gene in *K. pneumoniae* clinical isolates in Africa.

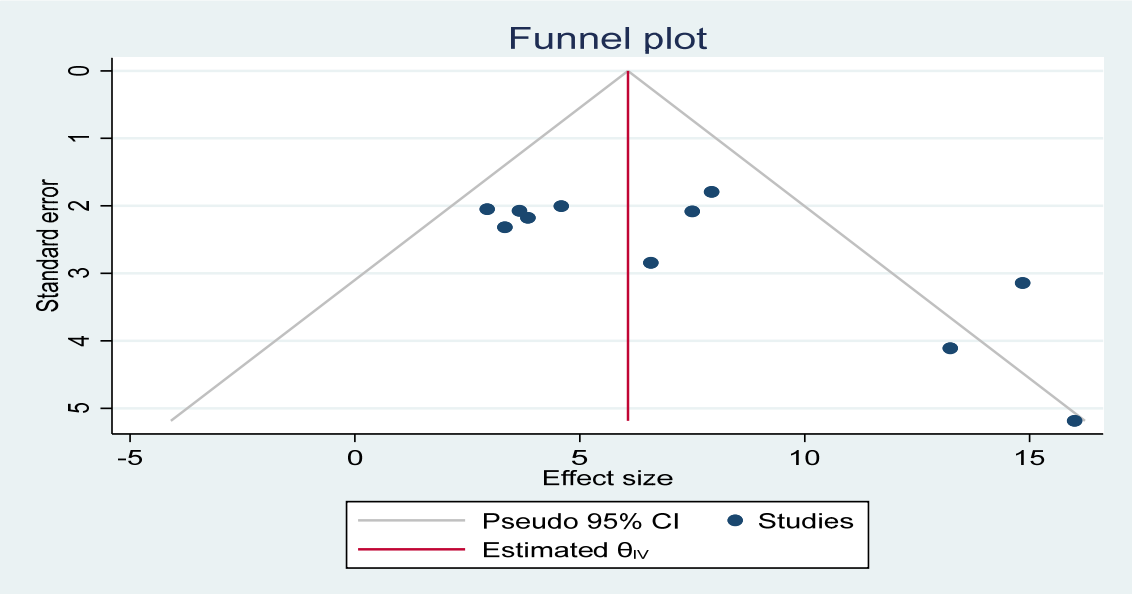
```
  Model and method
               Model: Random effects
              Method: REML

.
. meta bias, egger random(reml)

  Effect-size label: Effect size
        Effect size: p
          Std. err.: se

Regression-based Egger test for small-study effects
Random-effects model
Method: REML

H0: beta1 = 0; no small-study effects
              beta1 =       4.01
       SE of beta1 =      0.933
                 z =       4.30
        Prob > |z| =     0.0000
```

S6 Figure: Eggers test showing publication biases of bla$_{NDM-1}$ gene in *K. pneumoniae* clinical isolates in Africa.

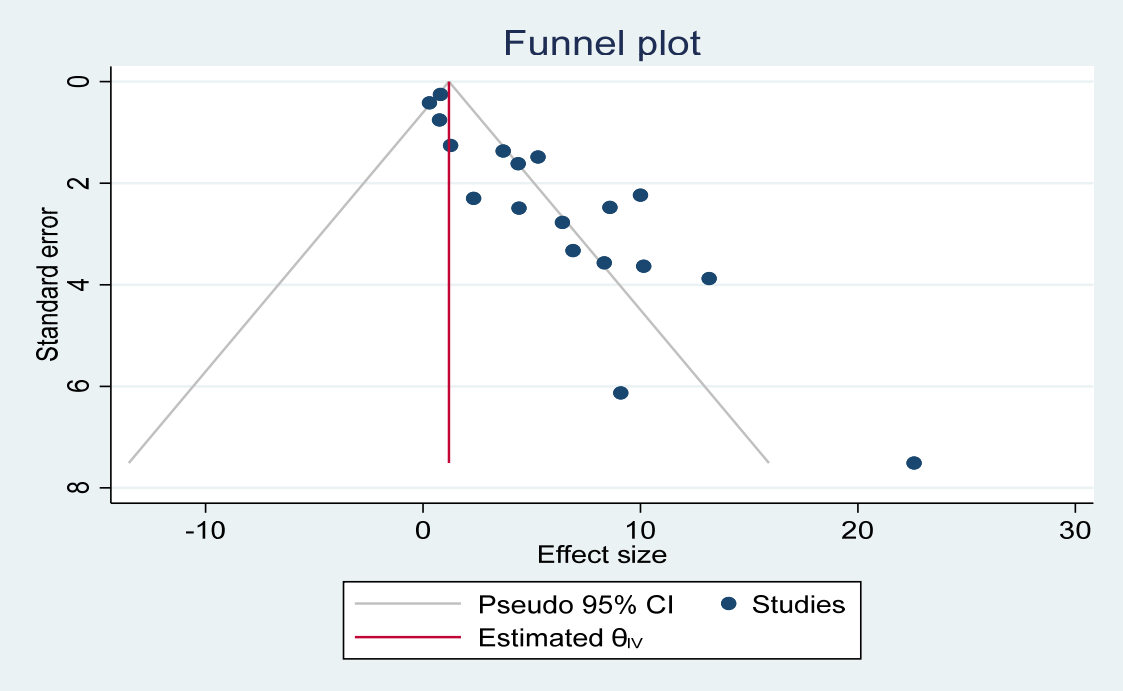
```
. meta trimfill, right

  Effect-size label: Effect size
        Effect size: p
          Std. err.: se

Nonparametric trim-and-fill analysis of publication bias
Linear estimator, imputing on the right

Iteration                              Number of studies =     49
  Model: Random-effects                       observed =     40
 Method: REML                                 imputed =      9

Pooling
  Model: Random-effects
 Method: REML
```

Studies	Effect size	[95% conf.	interval]
Observed	15.083	9.792	20.374
Observed + Imputed	19.282	14.320	24.243

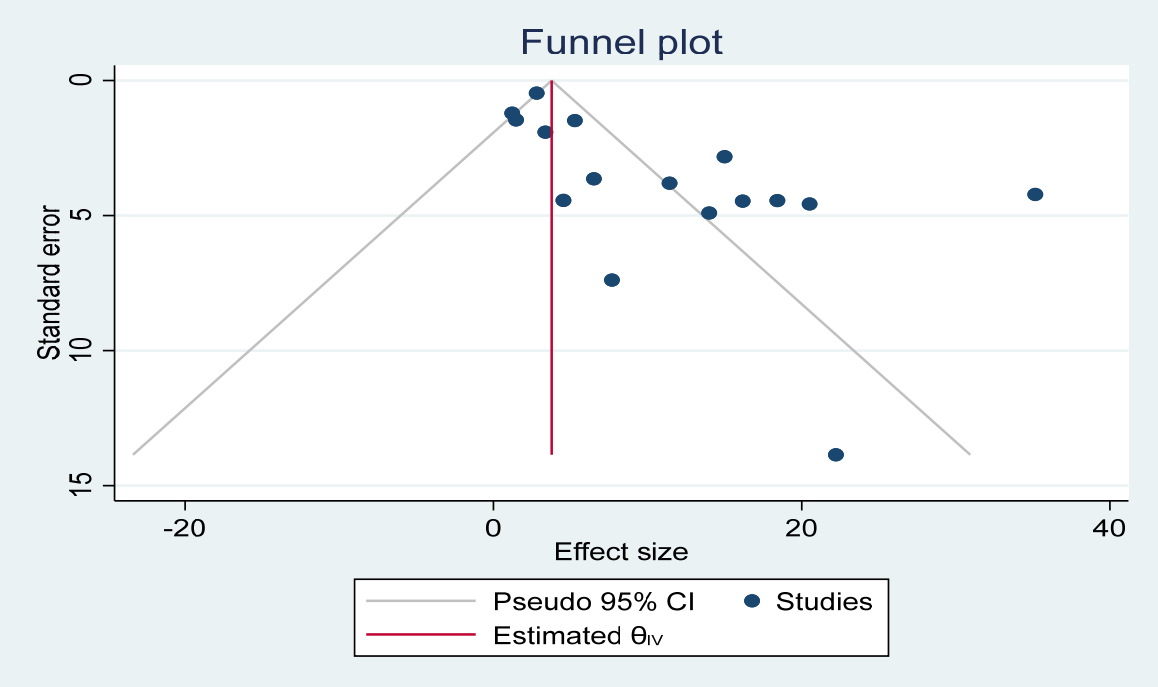
S7 Figure: Trim-and-fill analysis for the prevalence bla$_{NDM-1}$ gene in *K. pneumoniae* clinical isolates in Africa



S8 Figure: Funnel plot showing publication biases of bla$_{IMP}$ gene in *K.pneumoniae* clinical isolates in Africa.



S9 Figure: Funnel plot showing publication biases of bla_{KPC} gene in *K.pneumoniae* clinical isolates in Africa.



S10 Figure: Funnel plot showing publication biases of bla_{VIM} in *K.pneumoniae* clinical isolates in Africa.

```
  Model and method
              Model: Random effects
             Method: REML

.
. meta bias, egger random(reml)

  Effect-size label: Effect size
        Effect size: p
          Std. err.: se

Regression-based Egger test for small-study effects
Random-effects model
Method: REML

H0: beta1 = 0; no small-study effects
              beta1 =       3.78
       SE of beta1 =      1.277
                 z =       2.96
        Prob > |z| =     0.0030
```

S11 Figure: Egger's test showing for publication biases of bla_{IMP} genes in *K.pneumoniae* clinical isolates in Africa.

```
  Model and method
              Model: Random effects
             Method: REML

.
. meta bias, egger random(reml)

  Effect-size label: Effect size
        Effect size: p
          Std. err.: se

Regression-based Egger test for small-study effects
Random-effects model
Method: REML

H0: beta1 = 0; no small-study effects
              beta1 =       2.55
       SE of beta1 =      0.351
                 z =       7.25
        Prob > |z| =     0.0000
```

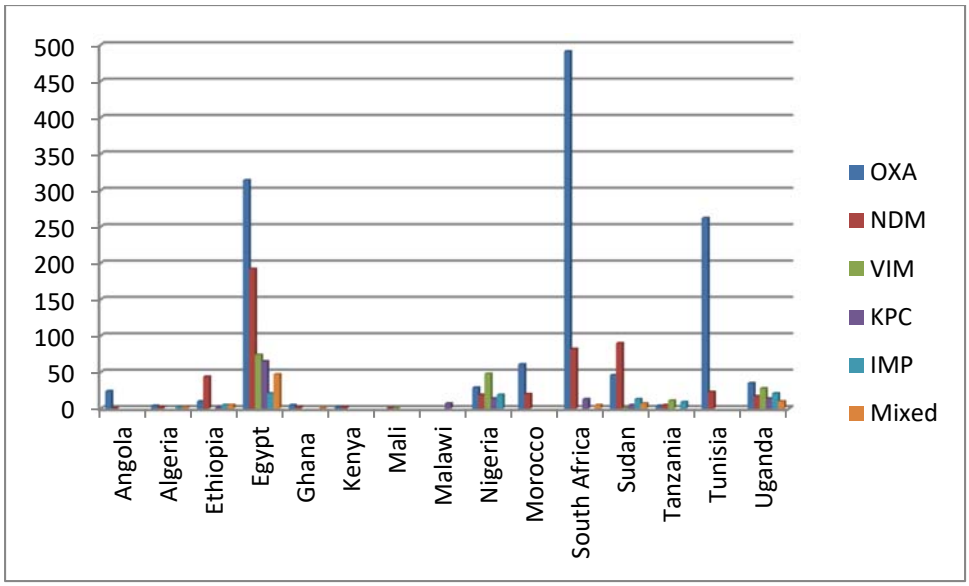
S12 Figure: Egger's test showing for publication biases of bla_{KPC} gene in *K.pneumoniae* clinical isolates in Africa.

```
   Model and method
                Model: Random effects
               Method: REML

.
. meta bias, egger random(reml)

   Effect-size label: Effect size
         Effect size: p
           Std. err.: se

Regression-based Egger test for small-study effects
Random-effects model
Method: REML

H0: beta1 = 0; no small-study effects
                beta1 =       2.26
       SE of beta1 =      0.892
                   z =       2.53
        Prob > |z| =     0.0113
```

S13 Figure: Egger's test showing for publication biases of bla$_{VIM}$ gene in *K.pneumoniae* clinical isolates in Africa.

```
. meta trimfill, left

   Effect-size label: Effect size
         Effect size: p
           Std. err.: se

Nonparametric trim-and-fill analysis of publication bias
Linear estimator, imputing on the left

Iteration                              Number of studies =      28
  Model: Random-effects                      observed =      20
 Method: REML                                imputed =       8

Pooling
  Model: Random-effects
 Method: REML

------------------------------------------------------------------------------
             Studies |      Effect size     [95% conf. interval]
---------------------+--------------------------------------------------------
            Observed |              4.401        2.732        6.071
  Observed + Imputed |              2.351        0.246        4.457
------------------------------------------------------------------------------
```

S14 Figure: Trim-and-fill analysis for the prevalence bla$_{KPC}$ gene in *K. pneumoniae* clinical isolates in Africa.



S15 Figure 15. Graph showing country wise distribution of genes encoding carbapenem resistance for *K. pneumoniae* isolate

References

1. Munn Z, Moola S, Lis K, Riitano D, C T. Systematic reviews of prevalence and incidence. In: Aromataris E, Z. M, editors. *JBI Manual for Evidence Synthesis*: JBI; 2020.
2. Tekele SG, Teklu DS, Legese MH, Weldehana DG, Belete MA, Tullu KD, et al. Multidrug-Resistant and Carbapenemase-Producing Enterobacteriaceae in Addis Ababa, Ethiopia. BioMed Research International. 2021;2021(1):9999638.
3. Kumwenda GP, Sugawara Y, Abe R, Akeda Y, Kasambara W, Chizani K, et al. First Identification and genomic characterization of multidrug-resistant carbapenemase-producing Enterobacteriaceae clinical isolates in Malawi, Africa. Journal of medical microbiology. 2019;68(12):1707-15.
4. Turugurwa J, Mwesigye J, Kassaza K, Byarugaba F, Kabanda T, Musinguzi B. Antimicrobial resistance patterns and molecular characterization of *Klebsiella pneumoniae* in clinical isolates at mbarara regional referral hospital. Advances in Infectious Diseases. 2019;9(03):197.
5. Shallie PD, Haffejee F. Systematic review and meta-analysis assessing the knowledge and use of the female condom among Nigerians. African Health Sciences. 2021;21(3):1362-74.
6. Mohamed Gandor NH, Amr GE-S, Eldin Algammal SMS, Ahmed AA. Characterization of Carbapenem-Resistant *K. Pneumoniae* Isolated from Intensive Care Units of Zagazig University Hospitals. Antibiotics (2079-6382). 2022;11(8).
7. Mushi MF, Mshana SE, Imirzalioglu C, Bwanga F. Carbapenemase genes among multidrug resistant gram negative clinical isolates from a tertiary hospital in Mwanza, Tanzania. BioMed research international. 2014;2014(1):303104.
8. Ahmed TM, Afifi SA, Ateya RM. Prevalence and Characterization of Carbapenem-Resistant *Klebsiella pneumoniae* isolated from the intensive care units of Zagazig University Hospitals. The Egyptian Journal of Hospital Medicine. 2023;92(1):5540-5.
9. Odewale G, Jibola-Shittu MY, Ojurongbe O, Olowe RA, Olowe OA. Genotypic determination of Extended Spectrum β-Lactamases and carbapenemase production in clinical isolates of *Klebsiella pneumoniae* in Southwest Nigeria. Infectious Disease Reports. 2023;15(3):339-53.
10. Awoke T, Teka B, Aseffa A, Sebre S, Seman A, Yeshitela B, et al. Detection of bla KPC and bla NDM carbapenemase genes among *Klebsiella pneumoniae* isolates in Addis Ababa, Ethiopia: Dominance of bla NDM. PLoS One. 2022;17(4):e0267657.
11. Dwomoh FP, Kotey FC, Dayie NT, Osei M-M, Amoa-Owusu F, Bannah V, et al. Phenotypic and genotypic detection of carbapenemase-producing Escherichia coli and *Klebsiella pneumoniae* in Accra, Ghana. PLoS One. 2022;17(12):e0279715.
12. Bourafa N, Chaalal W, Bakour S, Lalaoui R, Boutefnouchet N, Diene SM, et al. Molecular characterization of carbapenem-resistant Gram-negative bacilli clinical isolates in Algeria. Infection and drug resistance. 2018:735-42.
13. Muraya A, Kyany'a C, Kiyaga S, Smith HJ, Kibet C, Martin MJ, et al. Antimicrobial resistance and virulence characteristics of *Klebsiella pneumoniae* isolates in Kenya by whole-genome sequencing. Pathogens. 2022;11(5):545.
14. Taha MS, Hagras MM, Shalaby MM, Zamzam YA, Elkolaly RM, Abdelwahab MA, et al. Genotypic characterization of carbapenem-resistant *Klebsiella pneumoniae* isolated from an Egyptian University Hospital. Pathogens. 2023;12(1):121.
15. Tawfick MM, Alshareef WA, Bendary HA, Elmahalawy H, Abdulall AK. The emergence of carbapenemase bla NDM genotype among carbapenem-resistant Enterobacteriaceae isolates from

Egyptian cancer patients. European Journal of Clinical Microbiology & Infectious Diseases. 2020;39:1251-9.

16. Suwaiba M, Dadah A, Sanusi S. Prevalence of carbapenem resistant escherichia coli and *klebsiella pneumoniae* in urine samples of patients attending selected general hospitals within Kaduna Metropolis. Science World Journal. 2020;15(4):99-107.

17. Okoche D, Asiimwe BB, Katabazi FA, Kato L, Najjuka CF. Prevalence and characterization of carbapenem-resistant Enterobacteriaceae isolated from Mulago National Referral Hospital, Uganda. PloS one. 2015;10(8):e0135745.

18. Ojo AE, Adebajo SO, Fasina KA, Odejinmi B, Ojo OA, Ooladotun A, et al. Phenotypic detection of carbapenem resistant Enterobacteriaceae and characterization of *Klebsiella pneumoniae* carbapenemase (KPC) producing Klebsiella pneumonia. Microbes and Infectious Diseases. 2021;2(4):760-6.

19. Ghaith DM, Mohamed ZK, Farahat MG, Shahin WA, Mohamed HO. Colonization of intestinal microbiota with carbapenemase-producing Enterobacteriaceae in paediatric intensive care units in Cairo, Egypt. Arab Journal of Gastroenterology. 2019;20(1):19-22.

20. Hamed MO, Abdel Wahab M, Abdel Monem AA, Fathy M, Elgendy AO. Phenotypic and Genotypic Evaluation of Carbapenamase Producing *Klebsiella Pneumoniae* Isolates with Their Phylogenetic Analysis at an Egyptian University Hospital. Egyptian Journal of Medical Microbiology. 2022;31(4):25-31.

21. Abdelaziz NA. Phenotype-genotype correlations among carbapenem-resistant Enterobacterales recovered from four Egyptian hospitals with the report of SPM carbapenemase. Antimicrobial Resistance & Infection Control. 2022;11(1):13.

22. Ssekatawa K, Byarugaba DK, Nakavuma JL, Kato CD, Ejobi F, Tweyongyere R, et al. Prevalence of pathogenic *Klebsiella pneumoniae* based on PCR capsular typing harbouring carbapenemases encoding genes in Uganda tertiary hospitals. Antimicrobial Resistance & Infection Control. 2021;10:1-10.

23. Adam MA, Elhag WI. Prevalence of metallo-β-lactamase acquired genes among carbapenems susceptible and resistant Gram-negative clinical isolates using multiplex PCR, Khartoum hospitals, Khartoum Sudan. BMC infectious diseases. 2018;18:1-6.

24. El-Badawy MF, El-Far SW, Althobaiti SS, Abou-Elazm FI, Shohayeb MM. The First Egyptian report showing the co-existence of bla NDM-25, bla OXA-23, bla OXA-181, and bla GES-1 among carbapenem-resistant *K. pneumoniae* clinical isolates genotyped by BOX-PCR. Infection and drug resistance. 2020:1237-50.

25. Maina D, Revathi G, Whitelaw AC. Molecular characterization of multidrug-resistant *Klebsiella pneumoniae*and Escherichia coliharbouring extended spectrum beta-lactamases andcarbapenemases genes at a tertiary hospital, Kenya. Microbiologia Medica. 2017;32(4):132.

26. Osama D, El-Mahallawy H, Mansour MT, Hashem A, Attia AS. Molecular characterization of carbapenemase-producing *Klebsiella pneumoniae* isolated from Egyptian pediatric cancer patients including a strain with a rare gene-combination of β-lactamases. Infection and Drug Resistance. 2021:335-48.

27. Kopotsa K, Mbelle NM, Osei Sekyere J. Epigenomics, genomics, resistome, mobilome, virulome and evolutionary phylogenomics of carbapenem-resistant *Klebsiella pneumoniae* clinical strains. Microbial Genomics. 2020;6(12):e000474.

28. Mansour W, Haenni M, Saras E, Grami R, Mani Y, Khalifa ABH, et al. Outbreak of colistin-resistant carbapenemase-producing *Klebsiella pneumoniae* in Tunisia. Journal of global antimicrobial resistance. 2017;10:88-94.

29. Vasaikar S, Obi L, Morobe I, Bisi-Johnson M. Molecular characteristics and antibiotic resistance profiles of Klebsiella isolates in Mthatha, Eastern Cape province, South Africa. International journal of microbiology. 2017;2017(1):8486742.

30. Perez-Palacios P, Girlich D, Soraa N, Lamrani A, Maoulainine FMR, Bennaoui F, et al. Multidrug-resistant Enterobacterales responsible for septicaemia in a neonatal intensive care unit in Morocco. Journal of global antimicrobial resistance. 2023;33:208-17.

31. Lowe M, Kock MM, Coetzee J, Hoosien E, Peirano G, Strydom K-A, et al. *Klebsiella pneumoniae* ST307 with blaoxa-181, South Africa, 2014–2016. Emerging infectious diseases. 2019;25(4):739.

32. Owusu FA, Obeng-Nkrumah N, Gyinae E, Kodom S, Tagoe R, Tabi BKA, et al. Occurrence of carbapenemases, extended-spectrum beta-lactamases and AmpCs among beta-lactamase-producing Gram-negative bacteria from clinical sources in Accra, Ghana. Antibiotics. 2023;12(6):1016.

33. Barguigua A, Zerouali K, Katfy K, El Otmani F, Timinouni M, Elmdaghri N. Occurrence of OXA-48 and NDM-1 carbapenemase-producing *Klebsiella pneumoniae* in a Moroccan university hospital in Casablanca, Morocco. Infection, Genetics and Evolution. 2015;31:142-8.

34. Afolayan AO, Oaikhena AO, Aboderin AO, Olabisi OF, Amupitan AA, Abiri OV, et al. Clones and clusters of antimicrobial-resistant Klebsiella from southwestern Nigeria. Clinical Infectious Diseases. 2021;73(Supplement_4):S308-S15.

35. Kalambry AC, Potindji TMF, Guindo I, Kassogue A, Drame BSI, Togo S, et al. ESBL and carbapenemase-producing Enterobacteriaceae in infectious pleural effusions: current epidemiology at Hôpital du Mali. Drug Target Insights. 2023;17:92.

36. Aboulela AG, Jabbar MF, Hammouda A, Ashour MS. Assessment of Phenotypic Testing by mCIM with eCIM for Determination of the type of Carbapenemase Produced by Carbapenem-resistant Enterobacterales. Egyptian Journal of Medical Microbiology. 2023;32(1):37-46.

37. Legese MH, Asrat D, Mihret A, Hasan B, Mekasha A, Aseffa A, et al. Genomic epidemiology of Carbapenemase-producing and Colistin-resistant Enterobacteriaceae among Sepsis patients in Ethiopia: a whole-genome analysis. Antimicrobial Agents and Chemotherapy. 2022;66(8):e00534-22.

38. Arhoune B, El Fakir S, Himri S, Moutaouakkil K, El Hassouni S, Benboubker M, et al. Intense intestinal carriage and subsequent acquisition of multidrug-resistant enterobacteria in neonatal intensive care unit in Morocco. PLoS One. 2021;16(6):e0251810.

39. Kieffer N, Nordmann P, Aires-de-Sousa M, Poirel L. High prevalence of carbapenemase-producing Enterobacteriaceae among hospitalized children in Luanda, Angola. Antimicrobial agents and chemotherapy. 2016;60(10):6189-92.

40. Messaoudi A, Mansour W, Jaidane N, Chaouch C, Boujaâfar N, Bouallègue O. Epidemiology of resistance and phenotypic characterization of carbapenem resistance mechanisms in *Klebsiella pneumoniae* isolates at Sahloul University Hospital-Sousse, Tunisia. African Health Sciences. 2019;19(2):2008-20.

41. Ktari S, Mnif B, Louati F, Rekik S, Mezghani S, Mahjoubi F, et al. Spread of *Klebsiella pneumoniae* isolates producing OXA-48 β-lactamase in a Tunisian university hospital. Journal of antimicrobial chemotherapy. 2011;66(7):1644-6.

42. Ben Tanfous F, Alonso CA, Achour W, Ruiz-Ripa L, Torres C, Ben Hassen A. First description of KPC-2-producing Escherichia coli and ST15 OXA-48-positive *Klebsiella pneumoniae* in Tunisia. Microbial drug resistance. 2017;23(3):365-75.

43. Elbadawi HS, Elhag KM, Mahgoub E, Altayb HN, Ntoumi F, Elton L, et al. Detection and characterization of carbapenem resistant Gram-negative bacilli isolates recovered from hospitalized patients at Soba University Hospital, Sudan. BMC microbiology. 2021;21(1):136.

44. Albasha AM, Osman EH, Abd-Alhalim S, Alshaib EF, Al-Hassan L, Altayb HN. Detection of several carbapenems resistant and virulence genes in classical and hyper-virulent strains of *Klebsiella pneumoniae* isolated from hospitalized neonates and adults in Khartoum. BMC Research Notes. 2020;13:1-7.

45. Osman EA, Yokoyama M, Altayb HN, Cantillon D, Wille J, Seifert H, et al. Klebsiella pneumonia in Sudan: multidrug resistance, polyclonal dissemination, and virulence. Antibiotics. 2023;12(2):233.

46. Abdeta A, Bitew A, Fentaw S, Tsige E, Assefa D, Lejisa T, et al. Phenotypic characterization of carbapenem non-susceptible gram-negative bacilli isolated from clinical specimens. Plos one. 2021;16(12):e0256556.

47. Zalegh I, Chaoui L, Maaloum F, Zerouali K, Mhand RA. Prevalence of multidrug-resistant and extensively drug-resistant phenotypes of Gram-negative bacilli isolated in clinical specimens at Centre Hospitalo-Universitaire Ibn Rochd, Morocco. Pan African Medical Journal. 2023;45(1).

48. Sherif M, Palmieri M, Mirande C, El-Mahallawy H, Rashed HG, Abd-El-Reheem F, et al. Whole-genome sequencing of Egyptian multidrug-resistant *Klebsiella pneumoniae* isolates: a multi-center pilot study. European Journal of Clinical Microbiology & Infectious Diseases. 2021;40:1451-60.

49. Khalifa HO, Soliman AM, Ahmed AM, Shimamoto T, Hara T, Ikeda M, et al. High carbapenem resistance in clinical gram-negative pathogens isolated in Egypt. Microbial Drug Resistance. 2017;23(7):838-44.

50. Khaldi Z, Nayme K, Bourjilat F, Bensaci A, Timinouni M, El-Hadj-Khelil AO. Detection of ESBLs and carbapenemases among Enterobacteriaceae isolated from diabetic foot infections in Ouargla, Algeria. The Journal of Infection in Developing Countries. 2022;16(11):1732-8.