Worldwide magnitude of inguinal hernia: Systematic review and meta-analysis of population-based studies

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Abstract
This review pooled the magnitude of inguinal hernia based on the available population-based studies conducted throughout the world. We have searched for population-based articles reporting the magnitude of inguinal hernia on PubMed/Medline, EMBASE, Cochrane library and Google Scholar. Random-effect meta-analysis was carried out to pool the magnitude of inguinal hernia and its proportion between male and female subjects. To determine the presence of between-study heterogeneity, I² and Cochran's Q methods were employed. Publication bias was evaluated by the Egger test and visual examination of a funnel plot. All statistical tests were conducted by Stata version 16 software. Ten population-based studies with a total population of 51,304,093 were incorporated to pool the magnitude of inguinal hernia. The pooled prevalence of inguinal hernia was 7.7% (95% confidence interval: 6.06–9.34). Subgroup analysis showed that the highest pooled prevalence of inguinal hernia (12.72%) was observed in Asia. On the contrary, the lowest pooled prevalence emanated from America, 4.73%. The pooled prevalence of inguinal hernia in males is far higher than females. It was, respectively, 9.61% (95% confidence interval: 6.46–12.76) and 1.31% (95% confidence interval: 0.36–2.26) for males and females. The current meta-analysis revealed a higher burden of inguinal hernia. This finding glares the light that giving greater attention to inguinal hernia is required. It is recommended to identify the significant causes of inguinal hernia and design appropriate prevention as well as management strategies.

Keywords
Inguinal hernia, magnitude, prevalence, meta-analysis, systematic review

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Introduction
Inguinal hernia (IH) is a bump of an abdominal visera via the weak area of the abdominal wall in the groyne region. The protrusion may occur directly through the rear of the inguinal canal that is termed as direct IH. Contrastingly, in an indirect IH, the protruding visceral organ enters via internal inguinal ring and exists through an external inguinal ring of the inguinal canal and descends towards the scrotal sac.1 IH is a commonly reported disease condition in the world, due to this, herniorrhaphy, surgical repair of IH is among the frequently conducted surgery.2 Clinically, it is easy to diagnose IH, a simple physical examination can disclose an observable bump or an easily notable swelling on straining with an examining finger in the external inguinal ring.3 IH can occur bilaterally or on one side of the groyne region of the abdominal wall.4 It accounts for more than 75% of abdominal wall hernias with a higher lifetime risk for males (27%) than females (3%).5 It can be caused by...
congenital-related causes like persistent processes vaginalis, patient risk factors, or external factors. Some patient-related risk factors of IH are: male gender, old age, low body mass index, pre-existing abdominal wall muscle weakness, and increased intra-abdominal pressure. Even though population-based studies with representative sample sizes are lacking, many risk factors such as smoking, heavy weight lifting, as well as coughing and jumping that increase intra-abdominal pressure are associated with IH.

The existing works of literature reported the prevalence of IH differently and it is also variable in different age groups. Many published studies reporting the magnitude of IH are mainly institution-based, such studies lack generalizability to the external population. Some studies reported the magnitude of IH as low as 0.06% whereas another study reported 24.38%. Having a concise evidence regarding the pooled estimate of the magnitude of IH is helpful to give emphasis for this disease and develop appropriate management strategies. Based on our search, there is no systematic review with meta-analysis that shows the pooled prevalence of IH in the world. Therefore, the current meta-analysis is aimed to summarize the pooled prevalence of IH based on the available population-based studies conducted throughout the world. Thus, the finding of this meta-analysis could fill the knowledge gap, ‘what is the pooled prevalence of IH worldwide’.

Methods

Search strategy

This is a systematic review and meta-analysis aimed to pool the magnitude of IH based on the existing literatures. The following databases: PubMed/Medline, EMBASE, Cochrane library and Google Scholar were searched for articles reporting the prevalence of IH. The MeSH terms we used were: “inguinal hernia” OR “groin hernia” OR “abdominal hernia” AND prevalence OR incidence OR epidemiology OR magnitude. In addition, references in the selected articles were inspected to search for additional literatures. University websites were searched for additional thesis/dissertations. The literature search was completed on March 30 2022. Our search included articles written in English. The search strategy on PubMed database is as follows; (((((“inguinal hernia””) OR (“groin hernia””) OR (“abdominal hernia””)) AND prevalence)) AND (incidence)) AND (epidemiology)) AND (magnitude) Filters: English. The current systematic review was performed based on the Preferred Reporting Items for Systematic Reviews guideline.

Eligibility criteria

For this meta-analysis, articles reporting the magnitude of IH were embraced. Only population-based observational studies that reported the magnitude of IH and conducted throughout the world were reviewed. Published articles as well as thesis written in English and accessed up to March 30 2022 were summarized to get the pooled prevalence of IH. The study population considered for the current review are adult males and females. Institution-based studies, since lack representativeness of the general population, were excluded from this analysis.

Data extraction

From the manuscript, the name of authors, publication period, the place where the study is conducted, total sample size, number of IH cases, the prevalence of IH as well as a proportion of IH in males and females were extracted in an excel spreadsheet.

Outcome measurement

The outcomes of this systematic review are the overall pooled prevalence of IH and its proportion in the male and female populations. The pooled prevalence of IH was computed by dividing the total number of IH cases by the sample size and multiplying by hundred.

Assessment of article’s quality

Each article was meticulously and independently evaluated by two authors (MSA and AAT). We have used Joanna Briggs Institute’s (JBI) critical appraisal checklist for the respective study designs. The JBI’s critical appraisal tools assist in evaluating the soundness, importance and accuracy of the results of the published papers. The tools are utilized to evaluate the methodological quality, appropriateness of statistical analysis and nature of outcomes reported in research articles. Each article was evaluated out of nine and articles that scored five and above, were incorporated for the statistical analysis. Rater’s discrepancy regarding the quality of the articles and overall scoring was settled by dialogue.

Statistical data analysis

All statistical analyses were conducted using Stata version 16 software. Meta-analysis was conducted to pool the prevalence, accompanied by 95% confidence intervals (CI), of IH and its proportion between male and female subjects. The presence of heterogeneity among the included studies was determined by I² statistics and Cochran’s Q test. We used 75% I² value as a cutoff point for high heterogeneity. For the reason that heterogeneity was detected, random-effect meta-analysis, to manage it, as well as subgroup analysis, to search for the possible origin of heterogeneity was done. The presence of publication bias was explored by the Egger test.
and funnel plot drawing. Trim and fill as well as sensitivity analysis were performed. The statistical level of significance for heterogeneity and the Egger tests was $p$-value < 0.05.

**Results**

**Search results**

The first database search produced 1696 articles. In addition, by searching University websites and article references, five studies were added. One thousand six hundred thirty-one articles were banished as a consequence of redundancy, unrelated title/abstract, or the findings were not the prevalence of IH, that is outcomes mainly related to the clinical/management strategies of IH. Additional 60 articles were excluded since they were institution-based studies and their outcomes were the association between IH other cases, recurrence rate, or only incidence of IH. Finally, all 10 population-based articles subjected to quality assessment scored more than 50% in JBI’s quality evaluation checklist. The detailed process of article screening and culling is presented in Figure 1.
Characteristics of included studies

A total of 10 population-based studies that report the prevalence of IH in the general, male and female populations were incorporated in the current systematic review. A total of 51,304,093 population were utilized to calculate the prevalence of IH. Most of the studies were cross-sectional in design. The studies were conducted in Africa, America, Asia, and Europe. Table 1 presents a detailed description of the included studies.

Meta-analysis

Pooled prevalence of IH

The result of the current systematic review reported that the pooled prevalence of IH was 7.7% (95% CI: 6.06–9.34). This result is based on population-based studies, which are assumed to have appropriate representativeness of the general population. As presented in Figure 2, there was substantially high variability between included studies (heterogeneity $I^2=99.8\%$, Cochran's Q value = 3645.85, degree of freedom = 9 and $p < 0.05$).

Subgroup analysis

To search for potential sources of heterogeneity, a subgroup analysis was conducted. The analysis was performed based on the region (continent) where studies are conducted. The included studies were conducted in Africa (3), America (2), Asia (2) and Europe (3). The highest pooled prevalence of IH in the general population was observed in Asia, 12.72%. On the contrary, the lowest pooled prevalence report emanated

| Number | Author's name | Publication year | Sample size | Number of cases | Prevalence of IH | Type of study | Type of study design | Study done |
|--------|---------------|------------------|-------------|----------------|-----------------|---------------|---------------------|------------|
| 1      | Stewart et al. | 2014             | 2695        | 30             | 1.1             | Population based | Cross-sectional    | Nepal      |
| 2      | Patel et al.   | 2014             | 3645        | 188            | 5.16            | Population based | Cross-sectional    | Sierra Leone |
| 3      | Ohene-Yeboah et al. | 2016     | 803         | 105            | 13              | Population based | Cross-sectional    | Ghana      |
| 4      | Akin et al.    | 1997             | 27,408      | 885            | 3.2             | Population based | Cross-sectional    | Turkey      |
| 5      | Chendjou et al. | 2019          | 8065        | 48             | 0.59            | Population based | Cross-sectional    | Cameroon    |
| 6      | Sazhin et al.  | 2019             | 783         | 79             | 10.09           | Population based | Cross-sectional    | Russia      |
| 7      | Ruhl and Everhart | 2007       | 5316        | 500            | 9.41            | Population based | NE                  | USA         |
| 8      | Abramson et al. | 1978           | 1883        | 459            | 24.38           | Population based | NE                  | Israel      |
| 9      | Rosemar et al. | 2008             | 7495        | 1012           | 13.5            | Population based | Cohort              | Sweden      |
| 10     | Kang et al.    | 1999             | 51,246,000  | 30,791         | 0.06            | Population based | Cross-sectional    | United States |

IH: inguinal hernia; NE: not extractable.

Figure 2. Forest plot showing pooled prevalence of IH. Effect (95% CI): prevalence of IH accompanied by 95% CI. CI: confidence interval; IH: inguinal hernia.
from America, 4.73%. A high heterogeneity still exists between studies conducted in the same continent, presented in Figure 3.

In addition to the region, we also conducted subgroup analysis using the study period (year of publication), by grouping studies conducted before and after 2000. The pooled prevalence of IH was higher in studies done before 2000 (8.66%) compared to those studies conducted after 2000 (7.48). However, a high between-study variability was still observed (Figure 4).

**Pooled prevalence of IH in male and female**

Among the included studies, respectively, 8 and 4 studies for males and females reported the proportion of IH by sex. The pooled prevalence of IH in males is far higher compared with females. It was, respectively, 9.61% (95% CI: 6.46–12.76) and 1.31% (95% CI: 0.36–2.26) for males and females. Still a high heterogeneity among studies was observed, presented in Figures 5 and 6.

**Publication bias and small study effect**

To determine the effect of smaller study and the presence of publication bias, we have performed Egger’s test and funnel plot observation (Figure 7). The funnel plot was asymmetrical and the p-value of Egger’s regression test was <0.05 indicating the presence of publication bias. Sensitivity analysis as well as non-parametric trim and fill test was performed.

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**Figure 3.** Forest plot showing subgroup analysis region for the pooled prevalence of IH. Effect (95% CI): prevalence of IH accompanied by 95% CI.

CI: confidence interval; IH: inguinal hernia.
Figure 4. Forest plot showing subgroup analysis by study period for the pooled prevalence of IH. Effect (95% CI): prevalence of IH accompanied by 95% CI.

CI: confidence interval; IH: inguinal hernia.

Figure 5. Forest plot showing pooled prevalence of inguinal hernia in male. Effect (95% CI): prevalence of IH accompanied by 95% CI.

CI: confidence interval; IH: inguinal hernia.
to show the robustness of the prevalence of IH and determine the influence of a single study on the overall effect prevalence of IH. The result indicated no individual research unduly influenced the pooled prevalence of IH (Supplementary Figures S1 and S2).

**Discussion**

Even though IHs have been the concern of investigation for many years, it is still an attractive research topic for many clinicians and researchers and its global magnitude is not well explained yet. Recent knowledge of the magnitude, risk factors and management strategies are essential to enhance a client’s quality of life.23 Measuring the prevalence (proportion of a population currently suffering from IH) is an essential statistic to deal with the burden of a disease.24 Specifically, rigorously synthesized and summarized pooled prevalence helps to enlighten social and healthcare workers, policy developers and clients to better govern and plan for specific disease burdens. This helps to have a record of mortality and morbidity as well as estimate the economic burden of a disease and identify healthcare service needs.25,26

While doing meta-analysis of prevalence studies, the biggest concern is representativeness of the sample size. Many researchers agreed that population-based studies have external validity; that is their result is applicable to the general population from where the sample is obtained.27 Consequently, this meta-analysis is based on population-based studies. This study summarizes research results conducted throughout the world to identify the pooled prevalence of IH and its proportion in the male and female populations.

Our meta-analysis provides a comprehensive global assessment of IH prevalence by summarizing the results of 10 studies conducted in 9 countries. The prevalence of IH has been reported with different degrees of variability, as low as 0.06% in the United States11 and as high as 24.38% in Israel.12 Another study conducted in the United States reported a 9.41% prevalence of IH4 which is different from the previous study conducted in the United States. As we observed in the quality assessment evaluation, this difference in the prevalence of IH may be due to the use of variable data collection tools among individual studies. In addition, some studies used relatively large sample sizes11,21 as compared with the other included studies.

In the current study, the pooled prevalence of IH was 7.7% (95% CI: 6.06–9.34). Moreover, IH was more prevalent in males than in females. Male predominance in the prevalence of IH is reported in different literatures,28–31 this may be due to the reason that men are usually involved in strenuous activities. Exposure to activities needing higher physical effort is reported as a risk factor for IH to occur.30 Some other factors like persistent processes vaginalis...
ameliorate the prevalence of IH in males. In the subgroup analysis, the highest and lowest prevalence of IH was observed in Asia and America, respectively. This result may not be conclusive regarding regional prevalence of IH because the studies conducted in America and Asia are only two for each and the studies are heterogeneous.

In our review, there has been a substantial variability (heterogeneity) between studies. This heterogeneity was observed between studies conducted in the same continent regardless of the subgroup analysis we have conducted. The reason for this heterogeneity cannot be explained based on the subgroup analysis we have conducted. However, as reported by different investigators, variability between studies may be due to the difference in the lifestyle of the study population, causes of IH and difference in the data collection methods. To manage the presence of between-study heterogeneity, we have used random-effect model to summarize the effect size. In addition to the presence of heterogeneity, there was publication bias, however, the trim and fill test indicated that no individual study significantly affected the overall pooled estimate of IH prevalence.

Strength and limitation

This meta-analysis advances our knowledge of the burden of IH in different ways: It provides the most current global prevalence of IH. Second, the results can be inferred to the general population since it is conducted based on population-based studies. However, we would like to acknowledge some limitations of this meta-analysis. Some population-based studies have been excluded due to reporting of IH with femoral hernia as groyne hernia and so we cannot extract the prevalence of IH separately. We have included studies written only in English, by this additional evidence written in other languages may be missed.

Conclusion

The available literatures summarized in this meta-analysis indicated the global burden of IH is 7.7%. Males are predominantly affected by IH when compared with females. Interpretation of the results should consider the presence of heterogeneity. Further studies with robust methods that focus on establishing the association between IH and risk factors should be conducted. Emphasis, especially for males, should be given to minimizing the risks of having IH.

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Author contributions

All authors contributed to the conceptualization and design of this systematic review. M.S.A. and A.A.T. have done the methodology, study selection, data collection and analysis. M.S.A. wrote the manuscript draft. A.A., W.D. and A.B. supervised the work. All authors edited and agreed on the final version of the article to be published.

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Data availability

All data are incorporated either in the manuscript or supplementary files.

Supplemental material

Supplemental material for this article is available online.

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