Journal of Clinical Epidemiology 132 (2021) 34–45

ORIGINAL ARTICLE

Methods for depicting overlap in overviews of systematic reviews: An introduction to static tabular and graphical displays

Konstantinos I. Bougioukas[a], Elpida Vounzoulaki[b,c], Chrysanthi D. Mantsiou[d], Eliophotos D. Savvides[e], Christina Karakosta[a], Theodoros Diakonidis[a], Apostolos Tsapas[d,f,g], Anna-Bettina Haidich[a,*]

[a]*Department of Hygiene, Social-Preventive Medicine & Medical Statistics, School of Medicine, Faculty of Health Sciences, Aristotle University of Thessaloniki, University Campus, 54124 Thessaloniki, Greece*

[b]*Diabetes Research Centre, Leicester General Hospital, University of Leicester, Leicester, UK*

[c]*National Institute for Health Research Applied Research Collaboration-East Midlands, Leicester Diabetes Centre, Leicester LE5 4PW, UK*

[d]*Second Medical Department, Clinical Research and Evidence-Based Medicine Unit, Aristotle University of Thessaloniki, Thessaloniki, Greece*

[e]*1st Department of Urology, Medical School, G. Gennimatas General Hospital, Aristotle University of Thessaloniki, Thessaloniki, Greece*

[f]*Second Medical Department, Diabetes Centre, Aristotle University of Thessaloniki, Thessaloniki, Greece*

[g]*Harris Manchester College, University of Oxford, Oxford, UK*

Accepted 2 December 2020; Published online 9 December 2020

Abstract

Background and Objective: To introduce potential static tabular and graphical techniques for visually presenting overlap between systematic reviews (SRs) included in overviews of systematic reviews (OoSRs).

Methods: The graphical approaches described include Venn and Euler diagrams, as well as matrix-based, node-link, and aggregation-based techniques. We used fundamental concepts of mathematics from set and network theory to develop our novel graphical approaches. The graphical displays were created using R.

Results: Overview authors have the flexibility to choose from a variety of visualizations, depending on the characteristics of their study. If the OoSRs include few SRs, a Venn or an Euler diagram can be used. In case of OoSRs with more SRs, Upset plots, heatmaps, and node-link graphs are more appropriate for visualizing overlapping SRs. Stacked bar plots constitute an aggregation-based technique of illustrating overlap. Strengths and limitations of each graphical approach are presented.

Conclusion: The degree of overlap should be explored for the entire study and for specific outcomes of interest. The proposed graphical techniques may assist methodologists and authors in identifying overlap, which in turn may improve validity and transparency in OoSRs. More research is needed to understand which technique would be most useful and easiest to understand. © 2020 Elsevier Inc. All rights reserved.

Keywords: Graphical display; Heatmap; Degree of overlap; Overview of systematic reviews; Upset plot; Visualization

1. Introduction

An overview of systematic reviews (OoSRs) is a type of ‘‘next generation’’ knowledge synthesis product that has emerged as a result of the rapidly increasing number of published systematic reviews (SRs) [1]. The primary aim of OoSRs is to integrate evidence from multiple SRs within the same field and address a broad spectrum of research questions using explicit and systematic methods [2].

Over the last few years, the rapid growth of OoSRs has introduced numerous challenges, due to methodological variations as well as unclear areas [3]. To address these challenges, reporting guidelines for overviews of intervention SRs [4,5] as well as articles that investigated the variations in methodological approaches [6–13] have recently been published, to support the reporting and conduct of OoSRs. Although a large volume of guidance exists, there is a lack of consensus regarding many of the more complex

Conflict of interest statement: None.

Financial support: The research work was supported by the Hellenic Foundation for Research and Innovation (HFRI) under the HFRI PhD Fellowship grant (Fellowship Number: 1551), Greece.

* Corresponding author. Department of Hygiene, Social-Preventive Medicine & Medical Statistics, School of Medicine, Faculty of Health Sciences, Aristotle University of Thessaloniki, University Campus, 54124 Thessaloniki, Greece

E-mail address: haidich@auth.gr (A.-B. Haidich).

https://doi.org/10.1016/j.jclinepi.2020.12.004

0895-4356/© 2020 Elsevier Inc. All rights reserved.

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.

What is new?

Key findings

- A variety of graphical options can be used by analytic methodologists and overview authors to explore or/and communicate the degree of overlap in overviews of systematic reviews (OoSRs).
- The suggested graphical approaches include Venn or Euler diagrams, Upset plots, pairwise intersection heatmaps, bipartite networks, node-link graphs, and stacked bar plots.

What this adds to what is known?

- There is currently limited information on how to depict overlap in OoSRs. This study introduces potential static tabular and graphical techniques for visually presenting overlapping SRs in OoSRs.

What is the implication, what should change now?

- The proposed taxonomy of tabular and graphical displays has the potential to improve validity and transparency of the conduct and reporting of OoSRs.

phases of the overview process, such as dealing with primary study overlap.

One of the key challenges, unique to OoSRs, is addressing multiple overlapping SRs [14,15], which include overlapping information and data, due to the inclusion of the same primary studies. While some overview authors choose to include all SRs and then carefully examine and compare them to avoid double-counting data in their analysis, others prefer to simply acknowledge the overlap as a potential limitation of their study. Another commonly used method is to apply decision rules to include only some of these SRs, to avoid any overlap (e.g., by including the most recent, the largest, or the one with the highest quality among relevant SRs) [16]. Two recently published studies have developed decision tools to assist overview authors with handling overlapping SRs [17,18]. In addition to that, Cochrane recently updated their guidance for conducting OoSRs highlighting that it is important to ''map out which primary studies are included in which systematic reviews'' [19]. Furthermore, Pieper et al. (2014) provided guidance on creating citation matrices and calculating the ''corrected covered area'' (CCA) as a quantitative measure of the extent of primary study overlap between the SRs [14]. Although these recommended approaches can be used as an initial step for exploring overlap in OoSRs, they may not be adequate to address the issue. For example, if the same primary studies are included across SRs, but they are assessed for different outcomes by different SRs, the CCA for the entire citation matrix may result in a misleading inference about overlap in data [14,17]. Therefore, where necessary, supplementary diagnostic tools should be used such as graphical displays.

Data visualization is an excellent method for exploring and presenting the extent to which multiple relevant SRs include the same primary studies. However, there is limited knowledge and applicability of data visualization methods in OoSRs. A recent study assessing 50 OoSRs with health care interventions found that only 8% (4/50) of these OoSRs reported methods for visualizing overlap (e.g., using a citation matrix) [15].

To our knowledge, there is limited information in the existing literature on graphical options that can be used to depict overlap in OoSRs. Therefore, we aimed to introduce potential static tabular and graphical techniques for visually presenting overlap between SRs that may assist methodologists and overview authors in exploring and communicating the degree of overlap in OoSRs.

2. Methods

2.1. Protocol and registration

A protocol for this study was developed a priori and was registered with the Open Science Framework (https://osf.io/eqc7v/).

2.2. Taxonomy of graphical displays and mathematical background

We reviewed articles published by Alsallakh et al. [20–22] and pertinent work on set visualization [23–25] to choose tabular and graphical displays for depicting overlap in OoSRs. Criteria for inclusion were the applicability in OoSRs, the visual complexity (the amount of detail or intricacy in a picture), and the potential of these graphs to be used as a stand-alone static visual display.

We applied a classification system to group the different types of tabular and graphical displays as per pertinent taxonomy suggested by Alsallakh et al. [20]. The following categories were used: (a) Venn and Euler diagrams, (b) matrix-based techniques, (c) node-link techniques, and (d) aggregation-based techniques. Fundamental concepts of mathematics from set [25] and network theory [26] were used to describe our novel approaches (see Appendix 1).

2.3. Empirical illustration

The overlap can be investigated across all included SRs or/and at the outcome level [17]. We implemented the proposed tabular and graphical displays to empirical examples of published health care OoSRs using the R programming language (version 4.0.2) [27]. We used three OoSRs [28–30] for illustrating Venn and Euler diagrams and the study by Miyazaki et al. [31] for the remaining graphs to

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.

allow for greater comparability. Miyazaki et al. 2017 summarize the evidence from 6 SRs that include 14 unique randomized control trials evaluating three outcomes: the incidence of type 2 diabetes mellitus (T2DM), the glycemic load, and the anthropometric changes (see Appendix 2). The selection of the examples was based on the usefulness (i.e., the number of included SRs, information for the SRs, and primary studies provided by the Miyazaki et al. 2017 study) of the articles in demonstrating specific aspects of the proposed visual techniques. However, no judgment of study quality is implied by this selection.

Box 1 Set theory terminology applying to OoSRs

Intersection set—the set consisting of the primary studies (elements) that are common between the SRs (sets) participating in the intersection.
Size of intersection set—the number of primary studies (elements) included in an intersection set.
Degree of intersection—the number of SRs (sets) participating in the intersection.
Exclusive intersection—contains all primary studies (elements) that are common between the SRs (sets) participating in the intersection and do not belong to other SRs.

3. Results

3.1. Venn and Euler diagrams

Diagrams that use circular or elliptical areas to represent sets and intersections. A Venn diagram depicts all possible intersections between the SRs, even if some of them are empty, whereas an Euler diagram depicts only intersections that are not empty (see also Appendix 1).

3.1.1. Examples

When there are three SRs in an overview (such as in the Byrne et al. study [28]), every set is shown with circles, but as soon as we get to four SRs, circles do not work (Table 1). Ellipses can work for up to five SRs (such as in the Xing et al. study [29] and the Wells et al. study [30]). It is worth noticing that Euler-like diagrams can also be used (see Appendix 3).

3.2. Matrix-based techniques

3.2.1. The citation matrix of OoSRs

A citation matrix is a two-dimensional cross table, consisting of columns with the individual SRs and rows with unique primary studies. For each primary study, a check mark (✓) is used to indicate the SRs in which it has been cited.

3.2.1.1. Example. We created a citation matrix for the overview published by Miyazaki et al. [31] (Fig. 1). The tabular data for this overview are presented in columns corresponding to the six SRs and rows corresponding to a total of 14 unique primary studies.

3.2.2. Upset plot

When the number of SRs exceeds five, Venn and Euler diagrams become difficult to read and interpret. Another effective approach to visualize overlapping reviews is the Upset plot which depicts exclusive intersections (see Box 1).

3.2.2.1. Example. In Fig. 2 we depicted the overlapping of primary studies between SRs that are included in the Miyazaki et al. overview [31] (6 SRs and 14 primary studies).

The Upset plot consists of three parts [32]:

(a) The horizontal bar chart (blue bars) that shows the number of primary studies that are included in each SR (Fig. 2A).
(b) The intersection matrix in the center of the plot consists of rows that correspond to the different reviews included in the OoSRs and columns that correspond to the intersection sets. The reviews that are part of an intersection are presented as vertically connected filled dark circles (Fig. 2B).
(c) The top vertical bar chart which shows with different colors the primary studies included in each exclusive intersection. The height of the bars corresponds to the total number of primary studies included in the intersection (the intersection size) (Fig. 2C).

3.2.3. Pairwise intersection heatmap

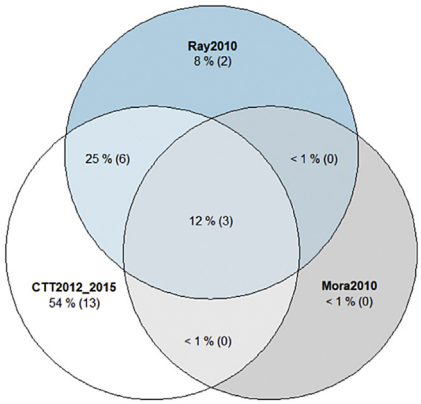
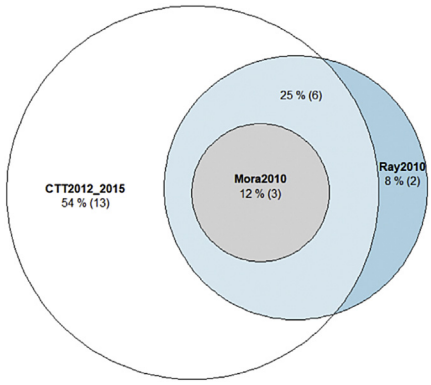
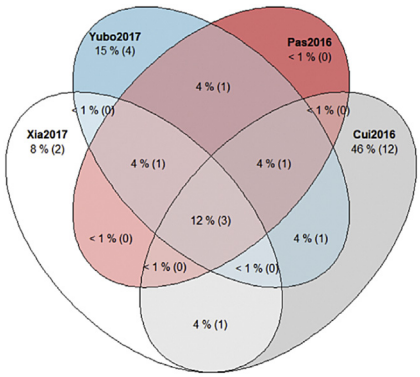
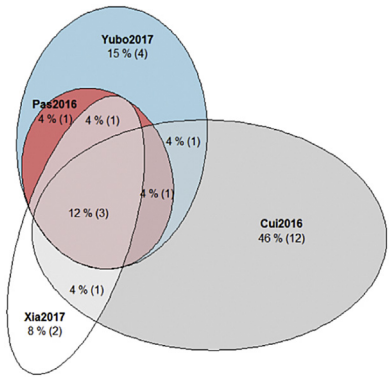
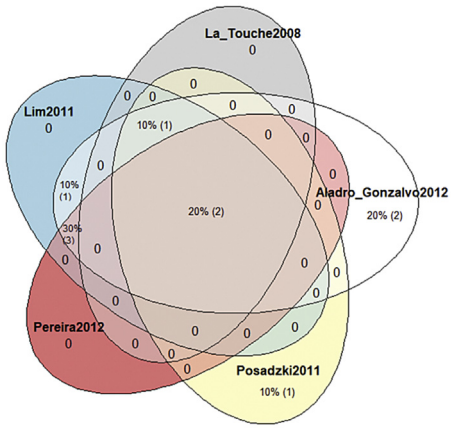
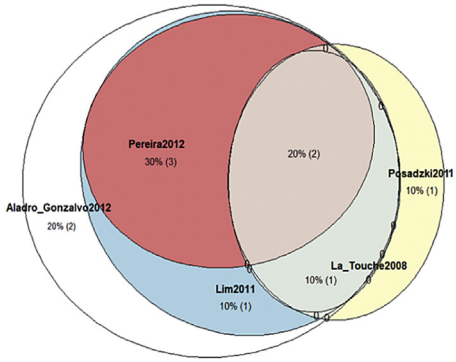
With an increasing number of studies, visualizing all possible intersections becomes impractical by using Venn and Euler diagrams or Upset plots. One possibility is to visualize pairwise intersections with heatmaps. The cells within the triangular matrix contain color-coded data that demonstrate the degree of overlap between pairs of SRs. Either the number of primary studies that are common between pairs of SRs or the CCA formula [14,17,33] can be used as a measure of the overlap.

3.2.3.1. Example. We created a pairwise intersection heatmap for our working example. It is verified that the SRs by Chasan et al. 2014 (9 primary studies), Gilinsky et al. 2015 (11 primary studies) and Guo et al. 2016 (12 primary studies) have at least 9 primary studies in common which corresponds to deep purple color in the color scale of the heatmap (Fig. 3A). In addition, we can observe that the only primary study included in Middleton et al. 2014 review is not included in any other review (white tiles).

As per CCA measure (see Appendices 4 and 5), the SRs by Chasan et al. 2014 and Gilinsky et al. 2015 have the largest overlap (81.8%) which corresponds to deep green

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.

Table 1. Examples of Venn diagrams and their respective Euler diagrams that illustrate the intersections between systematic reviews (SRs) in published OoSRs that include three, four, or five SRs

Overview of systematic reviews	No. of SRs (primary studies)	Venn diagram	Euler diagram
Byrne et al. 2019 [28]	3 (24)		
Xing et al. 2018 [29]	4 (26)		
Wells et al. 2013 [30]	5 (10)		

Percentages (and absolute numbers) inside the circles/ellipses represent the overlap of primary studies included in the reviews (e.g., Byrne et al. 2019 includes a total of 24 primary studies, 6 of which are common between CTT2012_2015 and Ray2010 reviews and do not belong to other SRs [25%, 6/24]). Euler diagrams depict only intersections that are not empty, and the areas are proportional to the size of the intersections.

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.

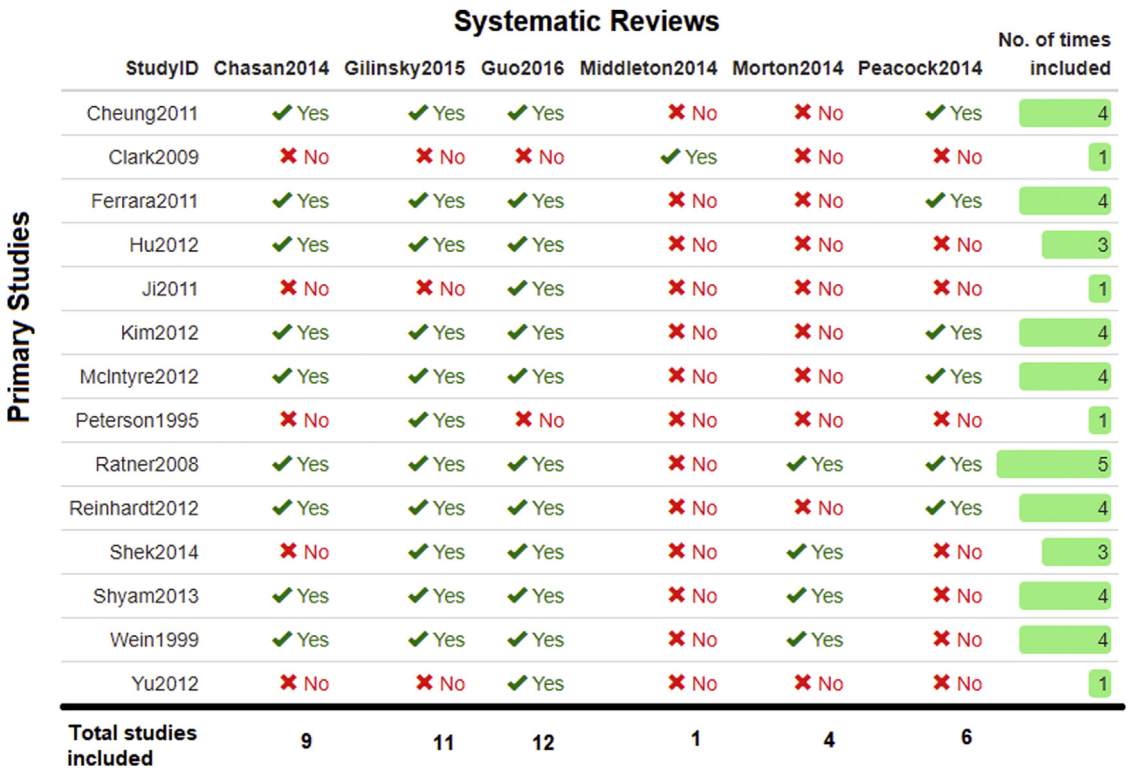


Fig. 1. Citation matrix for the Miyazaki et al. study [31] (6 SRs and 14 unique primary studies). The tabular data are presented in columns corresponding to the 6 systematic reviews (SRs) and rows corresponding to a total of 14 unique primary studies. Check marks (✓) indicate when a primary study is included in an SR (Yes). The total number of primary studies included in each SR is presented in the last row. The green tiny bars on the right of the matrix demonstrate the number of times a primary study is included in SRs. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

color (note that the overall CCA is equal to 41.4%) (Fig. 3B).

3.3. Node-link techniques

3.3.1. Bipartite citation network

A network consists of nodes and links. For OoSRs, we introduce the bipartite citation network [24], where the nodes are divided into two sets such that connection is only allowed between two nodes in different sets. The one set of nodes represents the SRs and the other set represents the primary studies. Each SR is connected by a link with the primary studies that are part of it.

3.3.1.1. Example. The bipartite "cloud-like" citation network of the Miyazaki et al. [31] study reveals a cluster of three SRs (Chasan et al. 2014, Gilinski et al. 2015, and Guo et al. 2016) which have many primary studies in common, indicating high degree of overlap between these SRs (Fig. 4).

3.3.2. Node-link graph with systematic reviews

The bipartite citation network can be compressed to a graph with only one type of node [34] such that the node-link graph with SRs. This type of graph contains only SR nodes, where two SR nodes are connected when they have at least one common primary study node in the bipartite network. The thickness of links represents the number of primary studies that are common between two linked SRs or alternatively the corresponding CCA. The size of nodes represents the number of primary studies included in SRs. This type of visualization is an alternative approach to heatmaps.

3.3.2.1. Example. We created the node-link graph for our empirical example (Fig. 5). By looking at the plot and with the help of the legends, we can deduce that Gilinsky et al. 2015 and Guo et al. 2016 are the largest SRs and have 10 primary studies in common. In addition, we can observe that the Middleton et al. 2014 review is not connected with the other reviews. The version of this graph with the CCA is presented in Appendix 6.

3.4. Aggregation-based techniques (bar plot)

Some OoSRs include many SRs and a large number of primary studies. In that case, depicting and clarifying the extent of overlap among the included SRs becomes unfeasible when relying on the aforementioned graphical displays. Aggregation techniques (such as a bar plot) can be used to address this issue by using frequency representations to exhibit the number of primary studies in each SR

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.

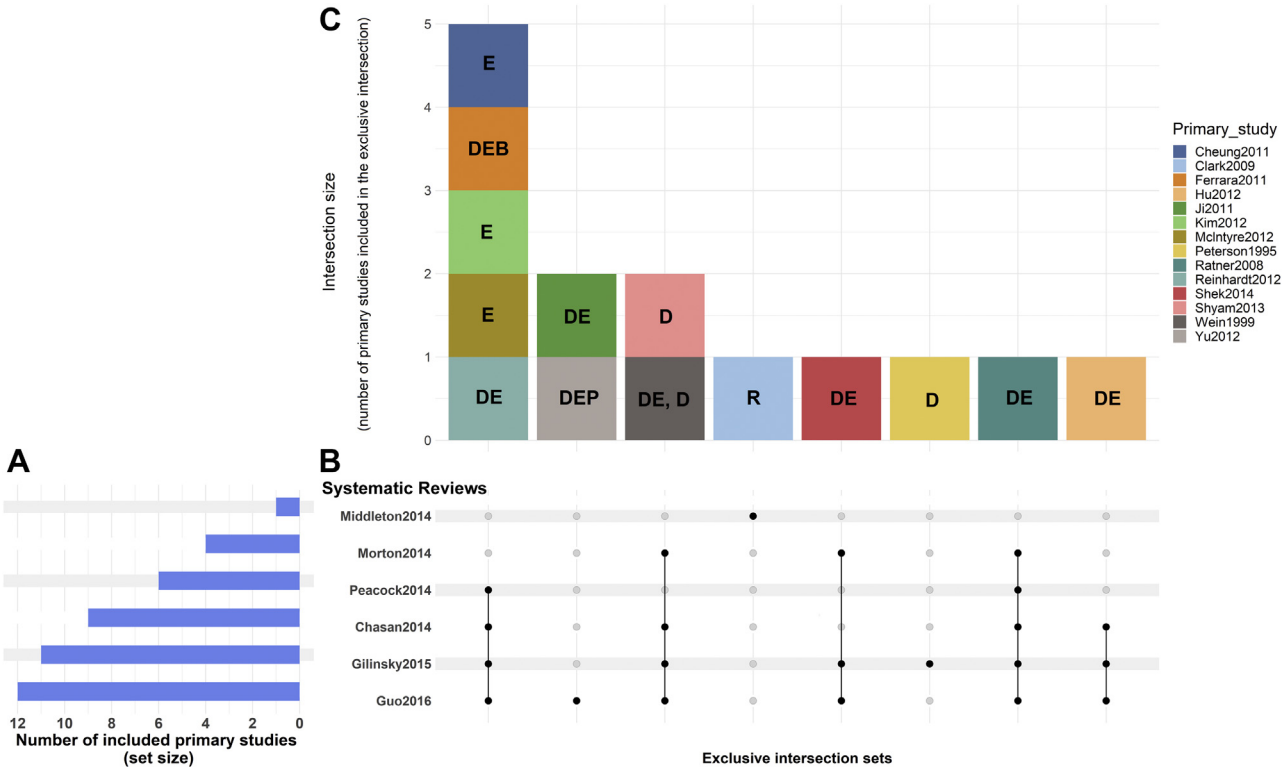


Fig. 2. Example of an Upset plot for the Miyazaki et al. study [31] (6 SRs and 14 primary studies). It consists of three parts: (A) the horizontal blue bars on the left-hand side, (B) the exclusive intersections sets (vertically connected filled dark circles) in the center of the plot, and (C) the top vertical bar chart which shows the intersection size. Different colors in the bars correspond to different primary studies. The interventions described in the included reviews were: D, diet; DE, diet and exercise; DEB, diet, exercise, and breastfeeding; DEP, diet, exercise, and psychosocial support; E, exercise; and R, reminder. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

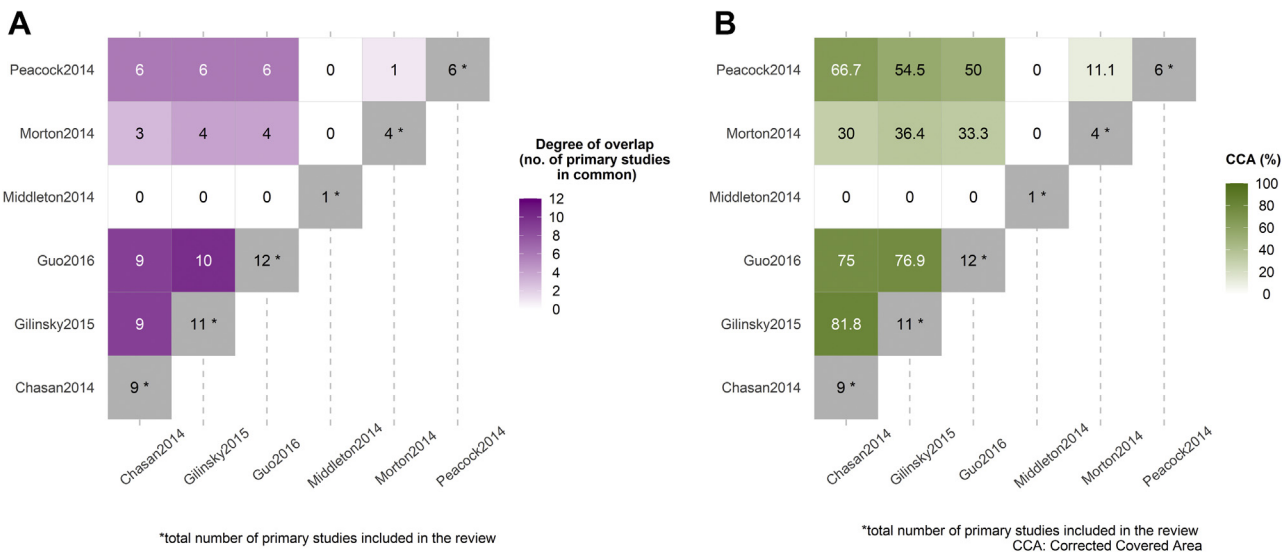


Fig. 3. Pairwise intersection heatmaps showing the degree of overlap in the Miyazaki et al. study [31] (6 SRs and 14 primary studies). The color-coded cells within the triangular matrix demonstrate (A) the number of primary studies that are common between pairs of SRs or (B) the % corrected covered area (CCA) for pairs of SRs. The diagonal gray-colored cells indicate the total number of primary studies included in each review. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.

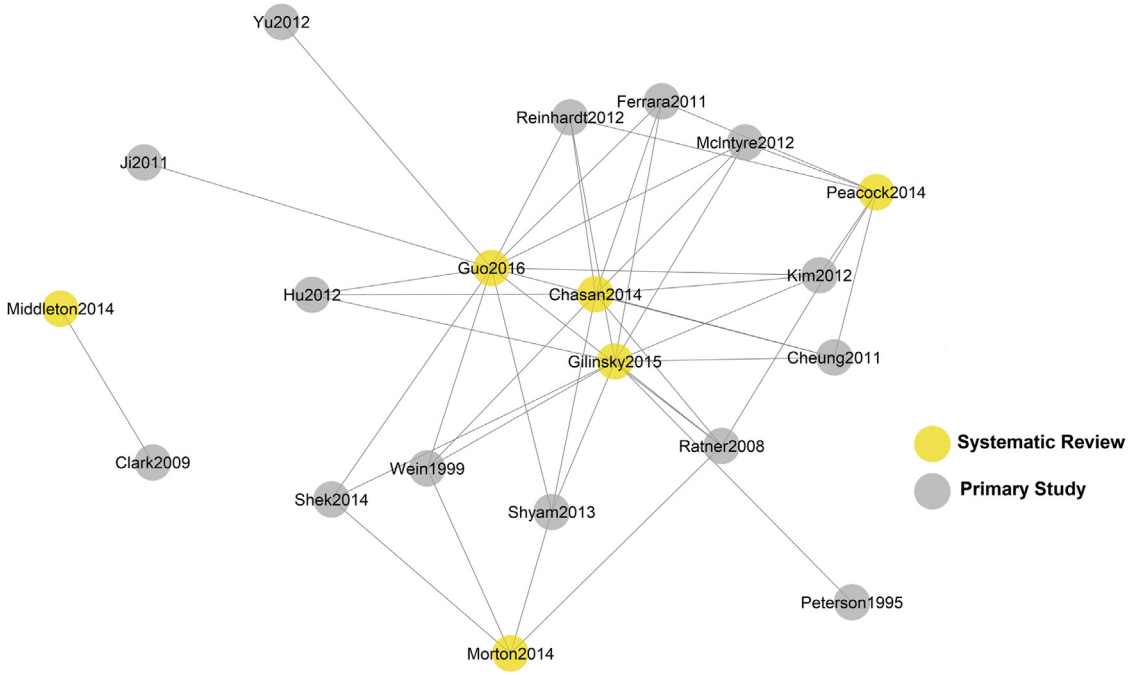


Fig. 4. A ''cloud-like'' citation network visualization of the Miyazaki et al. study [31] (6 SRs and 14 primary studies). The systematic reviews (SRs) are displayed as round yellow nodes, whereas the primary studies are displayed with gray color. The links represent the connections between SRs and the primary studies. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

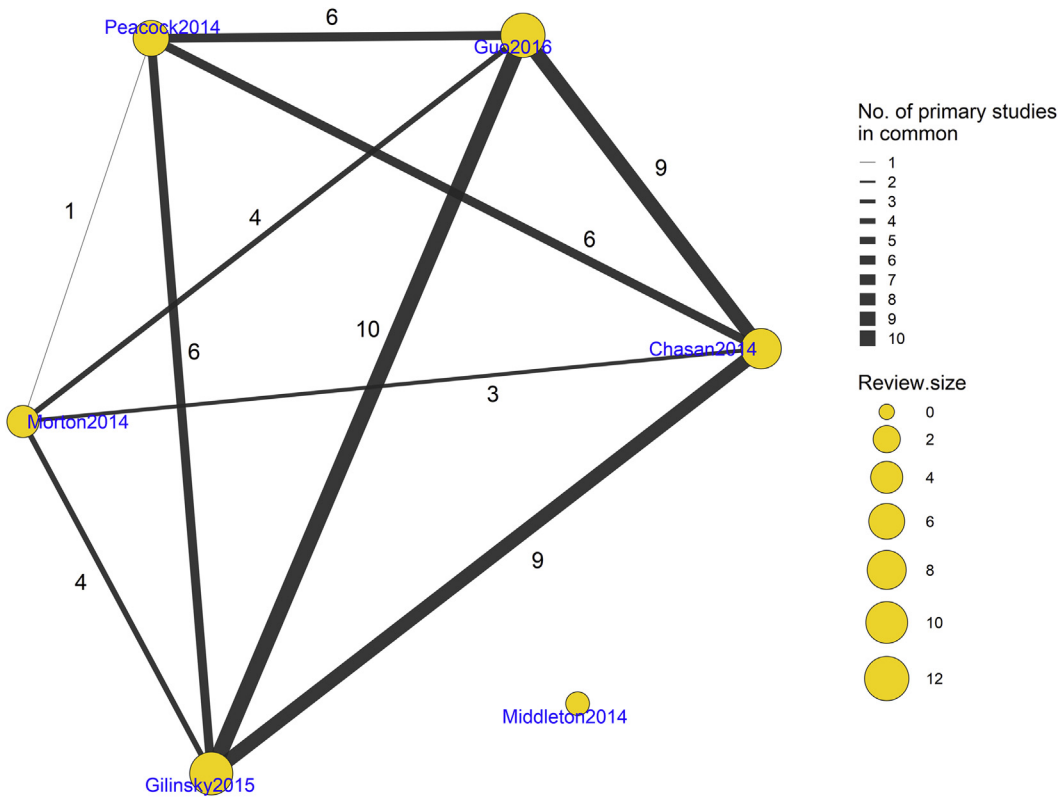


Fig. 5. Node-link graph of the Miyazaki et al. [31] study (6 SRs and 14 primary studies). The size of the nodes is proportional to the total number of primary studies included in each systematic review and the thickness of the lines proportional to the number of primary studies that are in common between two linked SRs.

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.

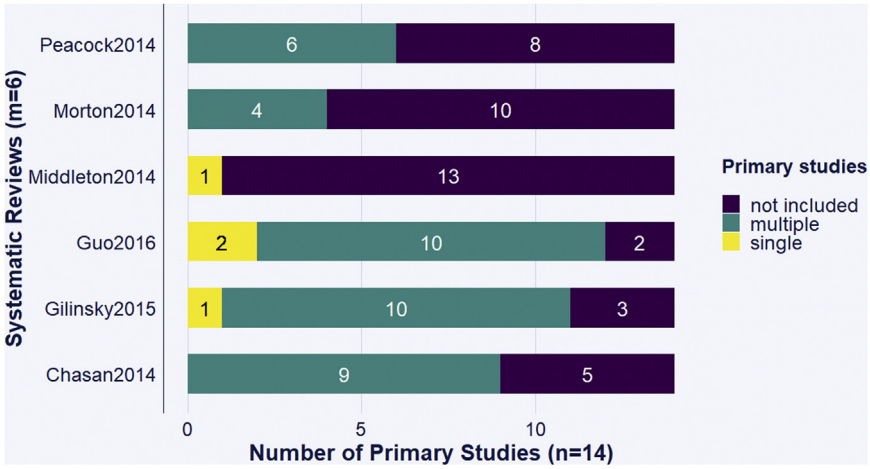


Fig. 6. Example of a stacked bar plot for the Miyazaki et al. study [31] (6 SRs and 14 primary studies). Each horizontal bar corresponds to a different SR and consists of up to three sub-bars: single, multiple, and not included. These levels describe whether the primary studies are exclusively included in a specific SR (yellow sub-bar), or they are also included in at least one of the other SRs (green sub-bar), or not included at all in the specific SR, respectively (dark purple sub-bar). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

and the proportion of them that are part of more than one SR.

3.4.1. Example

In Fig. 6, we present the overlapping information for our working example with a stacked bar plot. We can easily identify that Guo et al. 2016 review is the most recent and largest study including 12 primary studies, two of which are exclusively included in this SR (yellow sub-bar), whereas the remaining 10 are also included in at least one of the other SRs (green sub-bar). Note, also, that two primary studies are not included at all in this SR (dark purple sub-bar). Overall, five of the six reviews (with the exception of the Middleton et al. 2014 study) have many primary studies in common (green sub-bars).

In Table 2, we highlight in a summary table the strengths and weaknesses of each visual proposed technique.

3.5. Exploring overlaps for specific outcomes

We can also focus on exploring the overlap among reviews for specific outcomes of interest. The Upset plot in Fig. 7 depicts the overlap of primary studies between SRs that are included in our empirical example of the Miyazaki et al. study for the outcome measures of glycemic load, which were assessed in five of the six included SRs (see Appendix 2).

The degree of overlap as per CCA% for the glycemic load is 25%. Three reviews (Chasan et al. 2014, Gilinsky et al. 2015, and Guo et al. 2016) reported data about glycemic load from three primary studies (Hu et al. 2012, Kim et al. 2012, and McIntyre et al. 2012). Furthermore, the Shek et al. 2014 and Wein et al. 1999 primary studies are evaluated in Gilinsky et al. 2015 and Guo et al. 2016 for glycemic outcome measures. Finally, the Shyam et al. 2013 trial is included in four reviews. Of note, data for glycemia and metabolite outcomes from Clark et al. 2009, Ji et al. 2011, Peterson and Jovanovic 1995, Ratner et al. 2008, and Yu et al. 2012 were not reported in more than one review.

The CCA% for the incidence of T2DM and the anthropometric change outcomes are 33% and 42%, respectively. Therefore, the degree of overlap as per CCA% varies with the type of outcome in this overview. The Upset plots are presented in Appendix 7.

4. Discussion

Overlapping SRs is a methodological issue unique to OoSRs that, if disregarded or improperly handled, may lead to inaccurate results or misleading conclusions [14,17]. Assessing the degree of overlap in OoSRs can generate valuable information. In case of high degree of overlap between the included SRs, for instance, the conclusions of each SR should be examined to evaluate the degree of their agreement. If discordance in conclusions exists, potential reasons should be sought. In case of low degree of overlap in OoSRs, different eligibility criteria, search strategies, interventions, and outcomes may have been applied by the authors of the SRs. Therefore, it is important to further explore the scope of the OoSRs. A low degree of overlap is usually something to be expected for broad-scope OoSRs. However, in narrower-scope OoSRs, low degree of overlap might also be present. Authors should further assess the comprehensiveness as well as the quality of the included SRs to identify the underlying reasons for the low degree of overlap [17].

The introduction of static tabular and graphical displays to explore, assess, and present the degree of overlap among

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.

Table 2. Strengths and weaknesses of the proposed visual techniques

Visual technique	Strengths	Weaknesses
Venn and Euler diagrams	• The classic approach to show intersections between a small number of SRs (up to five). • They are generally easy to understand.	• Beyond five SRs, strange shapes need to be used to represent all the intersection combinations and understanding the diagrams can be misleading or nearly impossible. • It is not possible to know which same primary studies are included in reviews.
Matrix-based techniques		
Citation matrix	• Most commonly used visual approach for illustrating overlapping reviews. • It presents which same primary studies are included in reviews. • Useful for calculating the CCA.	• It can often become overwhelming, especially when a large number of SRs and primary studies need to be displayed and difficult to follow.
Upset plot	• A comprehensive way to identify overlap between SRs. • It may present all the exclusive intersections. In instance of a large overview, the number of intersections can be reduced by setting the degree of intersection (i.e., degree of intersection $\geq$2). • It may present which same primary studies are included in reviews using different colors for the primary studies. • It may present the interventions described in the included SRs	• Theoretically, Upset plots can display more than 25 different SRs and 40 intersections. However, in practice plotting all intersections of 10 or more SRs at once may not be feasible [25]. • If there is a large number of primary studies (>30), it can be difficult to distinguish between a wide variety of colors. In this case, the Upset plot can illustrate only the number of primary studies included in the intersections. • Needs familiarity—for an inexperienced reader, it can be difficult to interpret this composite graph at first.
Pairwise intersection heatmap	• An easy way to identify patterns of high or low overlap between pairs of SRs at a glance using a color scheme with increasing saturation. • It is suitable when OoSRs include many SRs and a large number of primary studies. • Either the number of primary studies that are common between pairs of SRs or the calculation of CCA for each pair of SRs can be used as a measure of the overlap.	• It is not possible to know which same primary studies are included in the pairs of reviews. • It does not provide information on intersections of SRs with degree of intersection higher than two.
Node-link techniques		
Bipartite ''cloud-like'' citation network	• It is generally easy to understand. When many primary studies are part of multiple SRs, there are more links, indicating higher degree of overlap in the OoSRs. • It can identify clusters of reviews with many links to primary studies. • It can display exactly which primary studies are connected to which SRs.	A large number of primary studies and SRs can often lead to a complex or even chaotic visualization due to edge crossing and overplotting.
Node-link graph with systematic reviews	• An easy way to identify high or low overlap between pairs of SRs at a glance using the size of the nodes and the thickness of the links. • It can identify clusters of highly connected reviews. • Either the number of primary studies that are common between pairs of SRs or the calculation CCA for each pair of SRs can be used as a measure of the overlap.	• It is not possible to know which same primary studies are included in the pairs of reviews. • It does not provide information on intersections of SRs with degree of intersection higher than two. • Due to edge crossing, node-link graphs suffer from increasing clutter as the number of links increases.

(*Continued*)

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.

Table 2. Continued

Visual technique	Strengths	Weaknesses
	• Alternative graph to pairwise intersection heatmap	
Aggregation-based techniques		
Bar plot	• Simple chart choice. It is generally easy to understand. • It is suitable when OoSRs include many SRs and a very large number of primary studies. • It constitutes an aggregative method of presenting overlap. The potential differences in the length of the sub-bars corresponding to each SR are explained by clinical or methodological differences (e.g., different research question, eligibility criteria for study inclusion, and search dates) among the SRs included in the OoSRs.	• It is not possible to depict the specific SRs that are in overlap. • It is not possible to know which same primary studies are included in reviews.

Abbreviations: CCA, corrected covered area; OoSRs, overview of systematic reviews; SRs, systematic reviews.

SRs could be an important part of an OoSRs. Of note, based on the focus of the OoSRs, it may be essential to investigate potential overlap of information in particular primary outcomes of interest in addition to the overall degree of overlap across all included SRs [13,14,17,35]. This may allow authors to avoid double-counting data in their analysis, identify discrepant findings between the SRs due to flaws in the methods process, or help them decide which SRs to include so as to avoid overlap. Our study provides an introduction to different visualization methods for depicting overlap in OoSRs. We classified and described the proposed graphical displays highlighting some advantages and limitations for each of them.

The most common graphical representation of overlap in OoSRs is citation matrices to date [29–31,36–43]. Some authors have also used pairwise intersection matrices [44–46], Venn diagrams [47,48], pie charts [49], and bar charts [50]. In our study, we also presented Euler diagrams, Upset plots, heatmaps, and node-linked graphs. Therefore, the overview authors have the flexibility to choose between graphical displays depending on the characteristics and the purpose of their study (e.g., number of SRs and primary

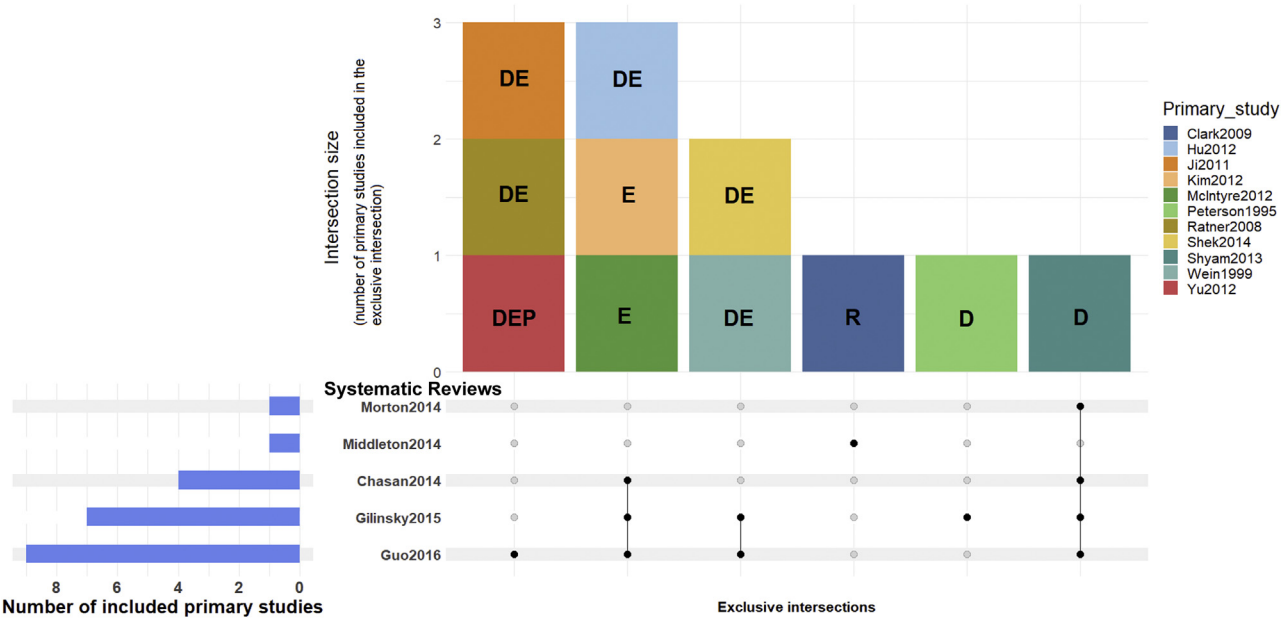


Fig. 7. The Upset plot of the Miyazaki et al. study [31] for the glycemic load outcome (5 SRs and 11 primary studies) that visualizes the primary studies included in each exclusive intersection with different colors. The height of the vertical bars corresponds to the total number of primary studies included in the intersection. The interventions described in the included reviews were as follows: D, diet; DE, diet and exercise; DEP, diet, exercise and psychosocial support; E, exercise; and R, reminder. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.

studies and outcomes). For example, if OoSRs include few SRs, a Venn or an Euler diagram can be used. The Upset plot can readily illustrate exclusive intersections between SRs, however, for an inexperienced reader, it can be difficult to interpret at first. Heatmaps or node-link graphs are more straightforward to interpret, but they are less informative than Upset plots. Finally, bar plots may represent an aggregative method to depict overlap in large OoSRs. An experienced methodologist with analytical skills should be involved as part of the team when conducting an OoSRs to facilitate using the presented techniques (for relevant software see Appendix 8).

Some limitations of our study need to be acknowledged as well. First of all, this study might have overlooked some potentially relevant options for graphical displays. Second, as this is an introductory article, we did not use examples from the literature to test different scenarios and conditions for each proposed visualization technique, and we acknowledge that some of them may require more evaluation or/and refinement. Furthermore, we did not present interactive plots and any software or apps that can be used for visualization other than R were not investigated.

Future research could further investigate the potential uses as well as the limitations for each proposed diagram, for different scenarios and conditions (different number of SRs and primary studies and different study designs throughout SRs). In addition, automation of exploring overlap among SRs is essential to support the production of the proposed graphical displays. Developing user-friendly static or dynamic tools explicitly for the purpose of visualizing overlap (i.e., online dashboards with static or interactive charts such as the matrices provided by Epistemonikos database [https://www.epistemonikos.org]) would be particularly useful for methodologists and overview authors in the future.

5. Conclusion

Overall, the degree of overlap among reviews should be explored for the entire study and for specific outcomes of interest. This study is the first to introduce several potential techniques for depicting overlap in OoSRs that can assist methodologists and overview authors in exploring and communicating the degree of overlap in OoSRs. The proposed static tabular and graphical displays have the potential to improve validity and transparency of the conduct and reporting of OoSRs. However, more research is needed to understand which technique would be most useful and easiest to understand.

CRediT authorship contribution statement

Konstantinos I. Bougioukas: Conceptualization, Methodology, Investigation, Data curation, Software, Formal analysis, Visualization, Project administration, Writing - original draft, Writing - review & editing. **Elpida Vounzoulaki:** Methodology, Investigation, Validation, Writing - original draft, Writing - review & editing. **Chrysanthi D. Mantsiou:** Methodology, Validation, Writing - original draft, Writing - review & editing. **Eliophotos D. Savvides:** Methodology, Validation, Writing - original draft, Writing - review & editing. **Christina Karakosta:** Visualization, Validation, Writing - original draft, Writing - review & editing. **Theodoros Diakonidis:** Data curation, Software, Formal analysis, Validation, Writing - review & editing. **Apostolos Tsapas:** Methodology, Validation, Writing - review & editing. **Anna-Bettina Haidich:** Conceptualization, Methodology, Validation, Visualization, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition.

Appendix

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclinepi.2020.12.004.

References

[1] Hartling L, Chisholm A, Thomson D, Dryden DM. A descriptive analysis of overviews of reviews published between 2000 and 2011. PLoS One 2012;7.
[2] Hartling L, Vandermeer B, Fernandes RM. Systematic reviews, overviews of reviews and comparative effectiveness reviews: a discussion of approaches to knowledge synthesis. Evidence Based Child Heal 2014;9:486−94.
[3] McKenzie JE, Brennan SE. Overviews of systematic reviews: great promise, greater challenge. Syst Rev 2017;6:185.
[4] Bougioukas KI, Bouras E, Apostolidou-Kiouti F, Kokkali S, Arvanitidou M, Haidich A-B. Reporting guidelines on how to write a complete and transparent abstract for overviews of systematic reviews of health care interventions. J Clin Epidemiol 2019;106:70−9.
[5] Bougioukas KI, Liakos A, Tsapas A, Ntzani E, Haidich AB. Preferred reporting items for overviews of systematic reviews including harms checklist: a pilot tool to be used for balanced reporting of benefits and harms. J Clin Epidemiol 2018;93:9−24.
[6] Hunt H, Pollock A, Campbell P, Estcourt L, Brunton G. An introduction to overviews of reviews: planning a relevant research question and objective for an overview. Syst Rev 2018;7:39.
[7] Lunny C, Brennan SE, McDonald S, McKenzie JE. Toward a comprehensive evidence map of overview of systematic review methods: paper 1-purpose, eligibility, search and data extraction. Syst Rev 2017;6:231.
[8] Lunny C, Brennan SE, McDonald S, McKenzie JE. Toward a comprehensive evidence map of overview of systematic review methods: paper 2 - risk of bias assessment; Synthesis, presentation and summary of the findings; and assessment of the certainty of the evidence. Syst Rev 2018;7.
[9] Ballard M, Montgomery P. Risk of bias in overviews of reviews: a scoping review of methodological guidance and four-item checklist. Res Synth Methods 2017;8:92−108.
[10] Pollock M, Fernandes RM, Newton AS, Scott SD, Hartling L. The impact of different inclusion decisions on the comprehensiveness and complexity of overviews of reviews of healthcare interventions. Syst Rev 2019;8:18.
[11] Pollock M, Fernandes RM, Hartling L. Evaluation of AMSTAR to assess the methodological quality of systematic reviews in overviews

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.

of reviews of healthcare interventions. BMC Med Res Methodol 2017;17:48.
[12] Pollock A, Campbell P, Brunton G, Hunt H, Estcourt L. Selecting and implementing overview methods: implications from five exemplar overviews. Syst Rev 2017;6:145.
[13] Hennessy EA, Johnson BT, Keenan C. Best practice guidelines and essential methodological steps to conduct rigorous and systematic meta-reviews. Appl Psychol Health Well Being 2019; 11:353–81.
[14] Pieper D, Antoine SL, Mathes T, Neugebauer EAM, Eikermann M. Systematic review finds overlapping reviews were not mentioned in every other overview. J Clin Epidemiol 2014;67:368–75.
[15] Lunny C, Brennan SE, Reid J, McDonald S, McKenzie JE. Overviews of reviews incompletely report methods for handling overlapping, discordant and problematic data. J Clin Epidemiol 2020;118: 69–85.
[16] Cooper H, Koenka AC. The overview of reviews: unique challenges and opportunities when research syntheses are the principal elements of new integrative scholarship. Am Psychol 2012;67:446–62.
[17] Hennessy EA, Johnson BT. Examining overlap of included studies in meta-reviews: guidance for using the corrected covered area index. Res Synth Methods 2020;11:134–45.
[18] Pollock M, Fernandes RM, Newton AS, Scott SD, Hartling L. A decision tool to help researchers make decisions about including systematic reviews in overviews of reviews of healthcare interventions. Syst Rev 2019;8:29.
[19] Pollock P, Fernandes R, Becker LA, Dawid P, Hartling L. Chapter V: overviews of reviews. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJWV, editors. *Cochrane Handbook for Systematic Reviews of Interventions* version 6.1 (updated September 2020). Cochrane; 2020.
[20] Alsallakh B, Micallef L, Aigner W, Hauser H, Miksch S, Rodgers P. The state-of-the-art of set visualization. Comput Graph Forum 2016; 35:234–60.
[21] Alsallakh B, Ren L. PowerSet: a comprehensive visualization of set intersections. IEEE Trans Vis Comput Graph 2017;23:361–70.
[22] Alsallakh B, Aigner W, Miksch S, Hauser H. Radial sets: interactive visual analysis of large overlapping sets. IEEE Trans Vis Comput Graph 2013;19:2496–505.
[23] Conway JR, Lex A, Gehlenborg N. UpSetR: an R package for the visualization of intersecting sets and their properties. Bioinformatics 2017;33:2938–40.
[24] Pavlopoulos GA, Kontou PI, Pavlopoulou A, Bouyioukos C, Markou E, Bagos PG. Bipartite graphs in systems biology and medicine: a survey of methods and applications. Gigascience 2018;7:1–31.
[25] Lex A, Gehlenborg N. Sets and intersections. Nat Methods 2014;11:779.
[26] Newman M. Chapter 6: mathematics of networks. In: Newman M, editor. Networks An Introd. 2nd ed. Oxford: Oxford University Press; 2018.
[27] R Core Team. R. A Language and Environment for Statistical Computing 2020.
[28] Byrne P, Cullinan J, Smith A, Smith SM. Statins for the primary prevention of cardiovascular disease: an overview of systematic reviews. BMJ Open 2019;9:e023085.
[29] Xing D, Wang Q, Yang Z, Hou Y, Zhang W, Chen Y, et al. Mesenchymal stem cells injections for knee osteoarthritis: a systematic overview. Rheumatol Int 2018;38:1399–411.
[30] Wells C, Kolt GS, Marshall P, Hill B, Bialocerkowski A. Effectiveness of Pilates exercise in treating people with chronic low back pain: a systematic review of systematic reviews. BMC Med Res Methodol 2013;13:7.
[31] Miyazaki C, Tanase-Nakao K, Arata N, Mori R, Kawasaki M, Ota E. Nonpharmacological interventions to prevent type 2 diabetes in women diagnosed with gestational diabetes mellitus: a systematic overview. Diabetol Int 2017;8:160–80.
[32] Lex A, Gehlenborg N, Strobelt H, Vuillemot R, Pfister H. UpSet: visualization of intersecting sets. IEEE Trans Vis Comput Graph 2014;20: 1983–92.
[33] Pérez-Bracchiglione J, Niño de Guzmán E, Roqué Figuls M, Urrútia G. Graphical representation of overlap degree of primary studies in systematic reviews included in overviews. Abstr. 26th Cochrane Colloquium, Santiago, Chile. Cochrane Database Syst Rev 2020;1(Suppl 1):151–2.
[34] Zhou T, Ren J, Medo M, Zhang Y-C. Bipartite network projection and personal recommendation. Phys Rev E Stat Nonlin Soft Matter Phys 2007;76:46115.
[35] Kho ME, Poitras VJ, Janssen I, Chaput J-P, Saunders TJ, Giangregorio LM, et al. Development and application of an outcome-centric approach for conducting overviews of reviews. Appl Physiol Nutr Metab 2020;45:S151–64.
[36] Chen S-Y, Zhang X-R, Chen J, Ge W-Q, Wang W-W, Wang X-S, et al. An overview of meta-analyses of endovascular bridging therapies for acute ischemic stroke. Biomed Res Int 2018;2018:9831210.
[37] Grassi A, Compagnoni R, Ferrua P, Zaffagnini S, Berruto M, Samuelsson K, et al. Patellar resurfacing versus patellar retention in primary total knee arthroplasty: a systematic review of overlapping meta-analyses. Knee Surg Sports Traumatol Arthrosc 2018;26:3206–18.
[38] Ooi SL, Giovino M, Pak SC. Transcendental meditation for lowering blood pressure: an overview of systematic reviews and meta-analyses. Complement Ther Med 2017;34:26–34.
[39] Schussel V, Kenzo L, Santos A, Bueno J, Yoshimura E, de Oliveira Cruz Latorraca C, et al. Cannabinoids for nausea and vomiting related to chemotherapy: overview of systematic reviews. Phytother Res 2018;32:567–76.
[40] Wijnhoven BPL, Van Lanschot JJB, Tilanus HW, Steyerberg EW, Van Der Gaast A. Neoadjuvant chemoradiotherapy for esophageal cancer: a review of meta-analyses. World J Surg 2009;33:2606–14.
[41] Young B, Wynn PM, He Z, Kendrick D. Preventing childhood falls within the home: overview of systematic reviews and a systematic review of primary studies. Accid Anal Prev 2013;60:158–71.
[42] Xing D, Wang B, Zhang W, Yang Z, Hou Y, Chen Y, et al. Intra-articular platelet-rich plasma injections for knee osteoarthritis: an overview of systematic reviews and risk of bias considerations. Int J Rheum Dis 2017;20:1612–30.
[43] Tamayo-Velázquez M-I, Simón-Lorda P, Villegas-Portero R, Higueras-Callejón C, García-Gutiérrez J-F, Martínez-Pecino F, et al. Interventions to promote the use of advance directives: an overview of systematic reviews. Patient Educ Couns 2010;80:10–20.
[44] Bidonde J, Busch AJ, Bath B, Milosavljevic S. Exercise for adults with fibromyalgia: an umbrella systematic review with synthesis of best evidence. Curr Rheumatol Rev 2014;10:45–79.
[45] Fishta A, Backe E-M. Psychosocial stress at work and cardiovascular diseases: an overview of systematic reviews. Int Arch Occup Environ Health 2015;88:997–1014.
[46] Guo P-P, Li P, Zhang X-H, Liu N, Wang J, Chen D-D, et al. Complementary and alternative medicine for natural and treatment-induced vasomotor symptoms: an overview of systematic reviews and meta-analyses. Complement Ther Clin Pract 2019;36:181–94.
[47] Andersen JH, Fallentin N, Thomsen JF, Mikkelsen S. Risk factors for neck and upper extremity disorders among computers users and the effect of interventions: an overview of systematic reviews. PLoS One 2011;6:e19691.
[48] Plaszewski M, Bettany-Saltikov J. Are current scoliosis school screening recommendations evidence-based and up to date? A best evidence synthesis umbrella review. Eur Spine J 2014;23:2572–85.
[49] List T, Axelsson S. Management of TMD: evidence from systematic reviews and meta-analyses. J Oral Rehabil 2010;37:430–51.
[50] Ilomäki J, Jokanovic N, Tan ECK, Lönnroos E. Alcohol consumption, dementia and cognitive decline: an overview of systematic reviews. Curr Clin Pharmacol 2015;10:204–12.

Downloaded for Anonymous User (n/a) at Ramathibodi Hospital from ClinicalKey.com by Elsevier on May 03, 2021.
For personal use only. No other uses without permission. Copyright ©2021. Elsevier Inc. All rights reserved.