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Development and Validation of Authorship Order Score (AOS) for Scientific Publication

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Development and Validation of Authorship Order Score (AOS) for Scientific Publication

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Abstract

Purpose: To develop and validate an objective and comprehensive authorship scoring system for determining the order of authorship in a scientific publication.

Methods: A multi-phased mix-method study (Delphi followed by cross sectional survey) was conducted (January 2017 to March 2019) at King Saud bin Abdulaziz University for Health Sciences (KSAU-HS), Riyadh, Saudi Arabia. The initial Delphi method was followed by a cross-sectional survey with academic faculty members (n = 132). For validity and reliability of a newly developed 15-item tool for identification of authorship order in a scientific publication, exploratory factor analysis was performed using SPSS version 22.

Results: The 15-item tool for identification of authorship order was identified after consensus with 10 research experts through three Delphi rounds. The results of the exploratory factor analysis showed four-factor structure explaining 59% of the variance. The final ordering criteria consisted of 13 items; weightage for each item was normalized based on the percentage agreement of the participants from the cross-sectional survey. The total weightage was 100% for all 13 items.

Discussion: The current authorship ordering criteria consists of key dimensions of research and provides a weightage which can be used to recommend the order of authorship in scientific publication. The scoring system is likely to be useful for publications in different fields in scientific publication. The scoring system is likely to be useful for publications in different fields in science.

Abbreviations: ICMJE, International Committee of Medical Journal Editors; KSAU-HS, King Saud bin Abdulaziz University for Health Sciences; KAIMRC, King Abdullah International Medical and Research Center; MSA, Measures of Sampling Adequacy; KMO, Kaiser-Meyer-Olkin Measure of Sampling Adequacy; EFA, Exploratory Factor Analysis; PCA, Principal Component Analysis.

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Keywords: Authorship; Order; Score; Delphi; Factor analysis

1. Introduction

The growth of science is exemplified by the increasing numbers of scientific journals and conference contributions.[1] The mounting increase in the demand for research is a universal phenomenon that applies to all fields of science. Research is not only contributing to the progression of science and the advancement of humankind but also serves as a major criterion upon which individual researchers and scientists progress in their careers. The same applies to undergraduate and postgraduate students, who are also keen to create a publication record that will increase their chances of admission to academic programs and institutions.

The personal gain associated with increasing a researcher's number of publications can jeopardize the integrity by which the research is authored, paving the way for unethical gift and ghost authorships.[2,3] Most research papers include multiple authors and are based on collaboration and team work.[4,5] As the trend of multi-center and multi-author publications is gaining popularity, the sequence by which the author names appear on a research paper has become more challenging relative to the past.[6,7] The International Committee of Medical Journal Editors (ICMJE) recommends four criteria, and all of them must be met to qualify for authorship. First, an author must have made a substantial contribution to the conception or design of the work; or the acquisition, analysis or interpretation of data. Second, drafting or critically revising the work. Third, final approval of the version to be published and finally, being accountable for all aspects of the work. Regarding the order of authors, ICMJE advises that it should be decided by the research team members or the institution where the research was conducted.[8]

The ICMJE guidelines are used by most journals, including Nature, Science, and PLoS One. However, these guidelines may not be helpful in determining the order of authorship. In attempts to overcome this, some studies have utilized alternative scoring systems that can quantify author contribution and hence determine their authorship order. One of the earliest of these scoring systems was developed in 1985 with an item scoring relating to time and individual weightage for different types of contribution.[9] Peer judgment was also suggested in 1997, whereby each author would rank their colleague.[10] For the same purpose, scores with a varying number of contribution areas and rankings were developed.[11–14] The previously reported scoring systems share a major limitation which is the lack of validation. This might affect the objective quantification of each author's contribution and can be a source of authorship bias.

This study aimed to develop and validate a scoring system for authorship order. This scoring system will hopefully help in providing a structured method of proposing authorship order in a scientific manuscript.

2. Methods

2.1. Research design and settings

This study was conducted between January 2017 to March 2019 by the Research Unit, King Saud bin Abdulaziz University for Health Sciences (KSAU-HS), Riyadh, Saudi Arabia. The Research Unit is part of the College of Medicine and plays a key role in the teaching of both undergraduate and postgraduate research courses. The ethical approval for the research was granted by the King Abdullah International Medical and Research Center (KAIMRC), Riyadh, Saudi Arabia.

The current study was conducted in two phases. During the first consensus building phase, a review of the existing literature on the authorship scoring was done, and the most commonly used scoring criteria were identified. The results were summarized in a presentation to the research team members before a brain-storming session. This was followed by three rounds of Delphi for the development of an instrument. The second phase was for testing and validity of the developed instrument, during which a cross-sectional survey was conducted among the faculty members of the different colleges of KSAU-HS, using the 15-item tool for ranking the order of authors in a scientific publication.

2.2. Consensus building phase

2.2.1. Participants

This phase included three consensus building Delphi rounds. This technique is widely used for the

development of tools, especially in educational settings.[15] Each Delphi round included the ten members of the Research Unit, of which three were associate professors, four were assistant professors, and three were lecturers. The decision on the inclusion of the Delphi members was made based on their experience in research. All members were involved in teaching research methods as well as in writing for scientific publications. Additionally, the members were acting as supervisors for research projects and were well informed with the norms of research publication. One focal person was appointed to coordinate amongst the members, sending reminders, collecting, and analyzing the responses for each Delphi round.

The first round of Delphi included the brainstorming session; the members contributed their opinion about the components of authorship order criteria. The round aimed to enlist all relevant items. Members were encouraged to enlist as many options as possible to maximize the chance of covering the most important ones. After the first round, approximately 55–60 items were identified, analyzed qualitatively, while searching for common items using a similar technique as for thematic content analysis.[16] Initially, all the responses were read multiple times, searching for similar words, key phrases, and certain patterns. In the next step, similar responses were organized, keeping in mind the different phases of the research. The responses were edited to construct criteria consisting of 17 items for the second round of Delphi (Fig. 1).

The aim of the second round of Delphi was ranking and rating of the 17 items on a 5-point Likert scale based on the relevance and importance of the items,[17] (1 = least important and 5 extremely important for authorship order determination). The responses were analyzed quantitatively, and mean ± standard deviation for each item was calculated. The percentage agreement was also measured for each item by adding up the percentages of those who selected 4 (important) or 5 (extremely important) on the Likert scale. Any item that had a mean score ≤ 3 and percentage agreement $<70\%$ was deleted for the next round.[18] As a result of the second round, two items were deleted based on the panel consensus. In the third and last round, 15 items were shared with the members, and the panel rating was shared to decide the final list of items for the authorship order determination. At the end of the third round, each member was sent the same questionnaire with the list of 15 items with the mean rating of each item (Fig. 1). The member's previous rating was also shared, and they were given a chance to change their opinion on the rating. During this whole process, care was taken not to share the individual rating of each member with the others, to avoid the influence of the opinion of specific members on others. During the three Delphi rounds, each member was contacted three times, items were revised twice, and each member was given a chance to revise their opinion once. At the end of the third round, the final rating for each item was measured using mean ± SD, and all the 15 items were retained.

2.3. Testing and validation phase

2.3.1. Participants and sample size

This part of the study aimed at testing the validity of the newly developed criteria for determining the order of authorship. For this purpose, a cross-sectional survey was conducted with faculty members from various health profession disciplines (medicine, nursing, dentistry, public health, and applied medical sciences)

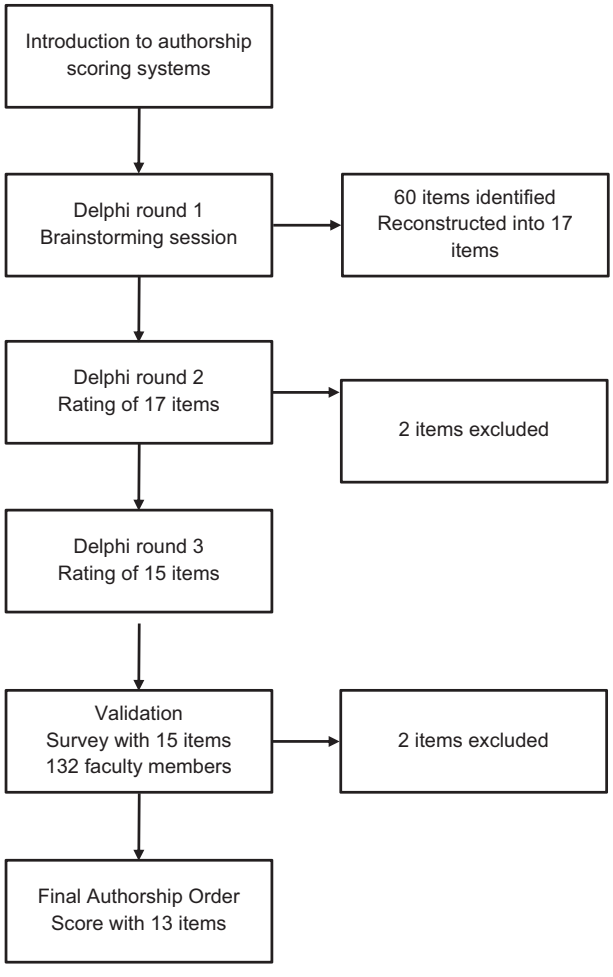

Fig. 1. Study flowchart.

at the KSAU-HS Riyadh campus. It is recommended that for validation and factor analysis studies, there should be 5–10 participants selected for each item in the instrument.[19] Therefore, a sample size of 135 was reached by considering nine participants per item. The survey included 15 items identified from the three Delphi rounds. It also included the demographic profile of the participants and questions related to the number of publications. All of the faculty members were approached at their workplace, and a hard copy of the questionnaire was given for data collection. The instructions in the questionnaire included the statement that, if any of the items are rated low, it should not be included when considering the hierarchy of authorship.

2.4. Statistical analysis

The data were entered in Microsoft Excel and later transferred to IBM SPSS Statistics version 22 for analysis. To measure the consistency of the items, the Cronbach alpha was calculated to check for overall reliability, which was 0.76 and is considered as a good measure of reliability.[20,21] To assess the Measures of Sampling Adequacy (MSA), anti-image matrices were determined for each item. Additionally, the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity were applied to assess the appropriateness of the sample and the items for applying exploratory factor analysis.[22] In the next step, exploratory factor analysis (EFA) was performed using Principal Component Analysis (PCA) as the extraction method and Varimax rotation. Additionally, for extraction, the items having Eigenvalues >1 were considered for retention. For suppressing the small coefficients, the absolute value was set at <0.4. The threshold for keeping the items was set at 0.3, and those items with low factor loading were removed from the final item list.[23]

Descriptive statistics were presented as frequency and percentages for the final 13 items. The Likert scale ratings of 4 (important) and 5 (extremely important) were combined to calculate the overall percentage agreement for each item. Based on this agreement, the weightage for each item was further normalized to determine the total percentage out of 100. The items were sorted from high to low weightage and rounded off to a whole number for ease of calculation of the Authorship Order Score.

The research was approved by the Institutional Review Board of King Abdullah International Medical Research Center. During all phases of the research, care was taken to ensure confidentiality and anonymity. Informed consent was taken verbally from participants during Delphi rounds, whereas written informed consent was taken during the testing and validation phase.

3. Results

3.1. Phase 1 –development and consensus building phase

In the first Delphi round, 55–60 items were proposed for inclusion. These were reconstructed into 17 items and sent for rating in round two. Two items (funding arrangement and conference presentation) had low mean scores and therefore were deleted (Table 1). In round three, 15 items were rated. All participants were sent the rating for revision along with the mean panel rating, based on which no item was deleted further. All the 15 items were retained by the end of round three. Two of the items, data collection and submission to journal, had a low mean score. However, based on group consensus, these items were retained as they were considered integral for determining the authorship order (Table 1).

3.2. Phase 2 – testing and validation phase

The developed 15-item tool was administered to 132 faculty members for testing as a hard copy survey. The median age of faculty members was 40 years (IQR: 33, 48 years), having a median working experience of 9 years (IQR: 4, 17 years). The median number of publications by the faculty members was 5 (IQR: 2, 13). More than half of the faculty members were non-Saudi nationals (n = 66, 57%), and 68 (51%) had a PhD degree while 33 (25%) had a Master's degree. The majority of the respondents were assistant professors or above (61%) as shown in Table 2.

3.3. Exploratory factor analysis (EFA)

As a first step to conduct EFA, the suitability of the sample for factor analysis was assessed using KMO and Bartlett's Tests. The overall KMO measure of sampling adequacy statistic was 0.75, whereas Bartlett's test of sphericity was significant (Chi-square = 432.4, p-value <0.001). For all 15 items, anti-image matrices were carefully examined, and the MSA for most of the items was above 0.70 (minimum, 0.63). Three items had an MSA above 0.80, while the remaining items scored between 0.70 and 0.79, except for two items which were less than 0.50, which were deleted. The factor loadings for each item were

Table 1
Summary of the scores in the initial Delphi rounds (N = 10).

Item no	Components of the scoring system	Round 1	Round 2	Round 3
		Mean ± SD	Mean ± SD	Mean ± SD
1.	Study concept/Research question	4.8 ± 0.3	4.8 ± 0.3	4.7 ± 0.5
2.	Literature review	4.1 ± 0.6	4.2 ± 0.7	3.8 ± 0.6
3.	Identifying aims and objectives	3.8 ± 1.2	4.0 ± 1.1	3.8 ± 1.2
4.	Study design	3.7 ± 1.1	3.8 ± 1.1	3.7 ± 1.2
5.	Proposal writing	3.8 ± 0.6	3.8 ± 0.6	4.2 ± 0.4
6.	Instrument selection or construction	3.7 ± 0.7	3.7 ± 0.7	3.5 ± 0.9
7.	Funding arrangement	2.4 ± 1.2	2.5 ± 1.1[a]	Deleted item
8.	Editing and critical revision of proposal	3.8 ± 0.6	3.8 ± 0.6	3.8 ± 0.6
9.	Data collection	3.1 ± 1.0	3.2 ± 1.0	3.1 ± 0.9
10.	Data management	3.4 ± 0.7	3.5 ± 0.7	3.4 ± 0.5
11.	Performing statistical analysis	4.5 ± 0.5	4.5 ± 0.5	4.7 ± 0.4
12.	Interpretation and finalization of results	4.7 ± 0.7	4.7 ± 0.7	4.7 ± 0.7
13.	Manuscript writing	4.8 ± 0.3	4.8 ± 0.3	4.8 ± 0.3
14.	Submission to journal	3.1 ± 1.0	3.2 ± 0.8	3.2 ± 1.1
15.	Correspondence with journal	3.5 ± 1.1	3.5 ± 1.0	3.5 ± 1.1
16.	Editing and critical revision of manuscript	4.0 ± 1.1	4.0 ± 1.0	4.1 ± 1.2
17.	Conference presentation	2.8 ± 1.0	2.6 ± 1.0[a]	Deleted item

[a] Item not included round 3.

assessed, based on the low sampling adequacy, and low factor loadings of <0.3, two of the items (submission to the journal and critical revision of the proposal) were excluded in this phase.

Only 13 items were included for the EFA, which was performed using PCA as the method of extraction of factor. With Eigenvalue set at >1 using PCA along with Varimax rotation; initially, five factors were extracted

Table 2
Descriptive profile of participants in the cross-sectional survey (N = 132).

Variables		Median	IQR
Age in years Median (Q1-Q3)		40	(33–48)
Years of experience Median (Q1-Q3)		9	(4–17)
Total number of research publications Median (Q1-Q3)		5	(2–13)
Number of months since last publication Median (Q1-Q3)		5	(1–12)
		n	%
Nationality	Saudi	50	43%
	Non-Saudi	66	57%
College	College of Medicine-Male	28	22%
	College of Medicine-Female	10	8%
	College of Public Health	11	9%
	College of Nursing	11	9%
	Other	69	54%
Highest qualification	PhD	68	51%
	Master	33	25%
	Bachelor	15	11%
	Diploma	1	1%
	Other clinical qualification	17	13%
Job title	Professor	10	8%
	Associate Professor	13	10%
	Assistant Professor	58	43%
	Lecturer	30	22%
	Teaching assistant	16	12%
	Other	7	5%
Current position	Clinical only	11	8%
	Teaching faculty	91	69%
	Both (clinical and teaching)	30	23%

Table 3
Exploratory factor analysis pattern matrix of the final 13 items (N = 132).

Items	Factor 1	Factor 2	Factor 3	Factor 4
Study concept/Research question	0.45			
Proposal writing	0.75			
Identifying aims and objectives		0.78		
Instrument selection or construction		0.77		
Literature review		0.49		
Study design		0.48		
Data collection			0.88	
Data management			0.84	
Performing statistical analysis			0.43	
Interpretation and finalization of results				0.68
Manuscript writing				0.58
Editing and critical revision of manuscript				0.79
Correspondence with journal				0.60

[a]Extraction method: principal component analysis. rotation method: Varimax with Kaiser Normalization. Rotations converged in six iterations.

with a cumulative variance of 64.6%. Based on the initial loading and judgment; the number of factors was further reduced to four, with a total variance of 59.7%. These four factors were considered as the best and most suitable, and no further reduction was made (Table 3).

3.4. Internal consistency

The internal consistency of the final 13-items Cronbach alpha was calculated as 0.79. The corrected item-total correlation for 13 items was between 0.27 and 0.56. None of the item deletions greatly increased the Cronbach alpha value, therefore all the items were retained (Table 4).

3.5. Participant agreement on the items

For measuring the agreement of the participants on the initial 15 items included in the testing phase, the cut-off point for retaining any of the items was set at 70%. The top three highest scoring items considered most relevant for ordering the authors were manuscript writing (92%), conception of study (90%), and contribution in proposal writing (89%). The interpretation of the results, study design, and setting the aims and objectives all had more than 80% agreement. Only three items scored less than 70% agreement, of which two items (submission to the journal and critical revision of proposal) were considered for deletion, which was also confirmed by low factor loading during EFA. One of the items (correspondence with the journal) had a low agreement of 53%, but was still included in the final ordering criteria considering its relevance to authorship order (Table 5).

After the final agreement was computed, the weight for each of the 13 items was determined by normalizing the total percentage agreement. Normalization of agreement percentage between 0 and 100 was done using the formula [(level of agreement for each item)/ total agreement × 100], where the total agreement was the sum of all items. For simplicity, the weight was rounded to a nearest whole number. For all of the 13 items, the level of contribution by each author can be assigned as either: 0, having no contribution; 1, as a partial contribution; or 2, full contribution. Afterward, the overall contribution score for each author is calculated as the sum of the product of the level of contribution with the weightage of 13 items. This was divided by two to bring the maximum total score to

Table 4
Internal consistency of the final 13 items (N = 132).

Factors	Items	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
1 Conception	Study concept/Research question	0.27	0.79
	Proposal writing	0.24	0.79
2 Planning	Identifying aims and objectives	0.46	0.78
	Instrument selection or construction	0.42	0.78
	Literature review	0.53	0.77
	Study design	0.37	0.78
3 Execution	Data collection	0.38	0.78
	Data management	0.45	0.78
	Performing statistical analysis	0.55	0.76
4 Writing	Interpretation and finalization of results	0.56	0.77
	Manuscript writing	0.34	0.78
	Editing and critical revision of manuscript	0.43	0.78
	Correspondence with journal	0.48	0.77

Table 5
Summary of the agreement and weightage of the final 13 items (N = 132).

Items	Mean score	Agreement		Weightage[a]
		Frequency	Percentage	
Manuscript writing	4.4	129	92%	9
Study concept/Research question	4.4	127	90%	9
Proposal writing	4.2	124	89%	9
Study design	4.3	121	86%	9
Identifying aims and objectives	4.2	121	86%	8
Interpretation and finalization of results	4.3	119	86%	8
Literature review	4.1	114	81%	8
Editing and critical revision of manuscript	4.0	100	71%	7
Performing statistical analysis	3.8	100	71%	7
Data collection	3.8	99	71%	7
Data management	3.8	97	70%	7
Instrument selection or construction	3.7	98	70%	7
Correspondence with journal	3.5	73	53%	5
Total weightage				100

[a] Items are arranged in descending order based on their weightage.

100. The expected minimum score is 0, and the max score is 100. Based on the calculated score, the hierarchy of the authors from first to last can be assigned in descending order. The final file of the criteria for scoring along with the weightage, which can be used by the authors for determining the order of authorship, is provided online as an additional file (Fig. 2, S1 File).

4. Discussion

The idea of authorship is well understood, and the ICMJE authorship guidelines are used by many prestigious journals. There is a lack of any such agreed upon guidelines for ordering the authors. Furthermore, there is no yardstick to assess the actual substantial contribution of authors, and the question of the order of authors depends upon the individual contributions of the team members. The current scoring system was developed as a guide to assist in determining the authorship order. The item correspondence with the journal had less agreement but was still retained due to the relevance of the corresponding author with the order of authorship. Research shows that the corresponding author is assumed to have taken the lead in all stages of the research. Regardless of whether the corresponding author is the first or the last author, their role is considered significantly more important compared to other authors, as reported by Bhandari et al.[24] In a recent paper, Duffy reports that in the majority of the cases the first author is the corresponding author and takes responsibility for the whole group during publication.[25] Therefore, the item correspondence with the journal was retained in the final list of items. Kassis, in a paper on the perception of faculty about authorship criteria, has used an 11-item criterion for determining authorship and author order.[26] Five of the items proposed in our paper have also been proposed by Kassis, which include idea generation, literature review, data analysis, and contributions to the manuscript.

In this study, we have used the idea of weighing each step of research and translating it to percentages. Similar ideas have been proposed by Clement,[13] Tscharntke et al.,[27] and Jawad,[28] who have given hypothetical relative weights to rank the contribution of the authors. Our method was different from that of Clement, who proposed a 5-step approach with each step having a different matrix and a different weightage, making the method difficult to apply. The current idea proposed by this study encompasses all the stages of the project, from conception to manuscript correspondence, and is easier to understand.

Schmidt, in 1987, proposed a percentage scoring framework.[29] Winston also proposed a point scoring system.[9] The main limitation of these approaches is the exclusion of the low scoring authors after the total point calculation. In the current idea, we do not propose any cutoff points for inclusion or exclusion. Also, the items included in the current study are more exhaustive, giving an opportunity for all contributors to be considered in the publication.

Similarly, Bhopal et al. considered an 8-point scoring system involving peer judgment of all of the team, one by one, to rank the others until the order is finalized amongst the team members. The idea is not only subjective; the issue of being ranked by the other team members can also increase the complexity of the

No	Items	Weightage	Example 1		Example 2	
			Author XX contribution	Author XX score	Author YY contribution	Author YY score
2	Study concept/Research question	9	2	9	2	9
7	Literature review	8	1	4	2	8
5	Identifying aims and objectives	8	2	8	2	8
4	Study design	9	1	5	2	9
12	Instrument selection or construction	7	1	4	2	7
3	Proposal writing	9	2	9	1	5
10	Data collection	7	0	0	2	7
11	Data management	7	2	7	1	4
9	Statistical analysis	7	2	7	0	0
6	Interpretation and finalization of results	8	2	8	0	0
1	Manuscript writing	9	2	9	1	4.5
8	Editing and critical revision of manuscript	7	2	7	1	4
13	Correspondence with journal	5	2	5	0	0
	Total score out of 100:	**100**		**81**		**64**

Author contribution	
No contribution	0
Partial contribution	1
Full contribution	2

Fig. 2. Example of the application of the authorship order score.

issue, further increasing tension among the authors.[10] Some of the existing criteria for ordering the authors represent the time spent at each of the phases of the project as one of the key determinants of order. The authorship ranking cannot be finalized until all steps of the research process have been carried out, and the whole team knows how much each member has contributed. Our proposal disregards the time spent factor. Some members might work more efficiently than others, so that their order could be undermined if the time spent is taken into consideration, as suggested by Kossyln.[30] Another approach, called the QUAD system, is a method of listing the percentage of contributions in certain research steps to specify the order of authors, which is used by Nature and other journals to transparently declare the author's contributions. Most of the reputable journals specifically ask for mentioning of the author's contribution at the end of the manuscript to increase the transparency of the authorship, but this cannot be used directly for the ranking of the authors.[31] In summary, many authorship scoring systems and frameworks exist, but none can be generalized to all research settings and domains.

The study was built on a review of existing literature on authorship, and the rigorous methodology is one of the strengths of the study. This scoring system could be considered as a guide when determining the order of authors. Limitations of the study include the initial step in the phase of the Delphi study as a result of which the initial items were developed. The opinion of one expert might vary from others, and if a similar technique was repeated with another group of experts, the results might vary. Nevertheless, we believe the results would be similar as the most important items based on the different phases of the study are included in the criteria. To overcome this issue of subjectivity during the development phase, in addition to the brainstorming session, three rounds were conducted in which the rating was not done during the round, the experts shared their opinion later with the focal person, and panel rating was shared in the proceeding round. The individual ratings were not disclosed at any point during the panel discussions.

Another limitation of this scoring system is related to its practical application when more than one author has a similar score after the application of the criteria. This, in turn, might lead to a difficult situation when deciding which of those authors should be first. The issue of equal contribution can be overcome by specifically indicating an equal contribution of those authors in the manuscript, regardless of their order. Although the practice is not accepted in many journals, the idea is repeatedly being proposed by many researchers.[32] Another way to overcome this has been proposed by

Petroianu,[33] by counting the number of items to which the contributions were made. If one author contributed to nine items, but the other contributed to eleven items, the author contributing to more items should be considered higher in order of hierarchy.

5. Conclusion

This 13-item scoring system provides a validated and practical guide for determining the order of authorship for scientific publications. We highly recommend having an initial open discussion among research team members with regards to the order of authors. If an agreement is reached, then the use of this scoring system might not be required. In cases where there is disagreement related to the order of authors, the use of this scoring system might help (once the decision on whom to include as an author has been made based on the ICMJE criteria). Further research might be required to improve this scoring system. It is likely to be useful for publications in a wide range of fields in science.

Ethical approval

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Other disclosure

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Declaration of competing interest

None

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.hpe.2020.04.006.

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