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Medical education

Assessing the effects of shifting from five to four options single best answer MCQs, in undergraduate Human Physiology Final Written Examination, at Faculty of Medicine, University of Khartoum, Sudan

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ABSTRACT

Background Multiple Choice Questions is an important tool for accurate measurement of knowledge in the medical profession's disciplines.

Objectives The aim of this study is to evaluate the effect of reducing the number of MCQ options from five to four on the quality indicators of Physiology examinations.

Methods A descriptive analytic study was done at the Department of Physiology in the Faculty of Medicine of Khartoum University. The quality indicators of the 5-option examination set provided by Remark software were further analyzed. Using Excel program, the least functional distractor from each item was then omitted, and its percentage was redistributed randomly to the remaining options producing 4-option examination. Quality indicators of the 4-option set were analyzed, and compared to those of the 5-option set.

Results The mean percent score increased significantly from 52.7% to 53.9%; the examination difficulty changed from 51.5 to 53.1, and the discrimination decreased significantly from 0.38 to 0.34. The percent of items with acceptable difficulty increased from 69.5% in 5-option to 71.2% in 4-option type. The proportion of items with 100% distractor efficiency increased from 44.07% in the 5-option to 72.88% in the 4-option type. Only 3.39% of items of both examination sets contained no effective distractors.

Conclusions Shifting from five-option to four-option items; yielded a positive significant impact on pass rate, mean score, distractor efficiency, and difficulty index. Exceptionally, it showed a negative impact on discrimination ability of the items (point bi-serial correlation coefficient). These findings may be encouraging to reduce the number of options without significantly compromising the item's quality.

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INTRODUCTION

Since the early twentieth century, multiple choice questions (MCQs) have been used for assessment of knowledge in both undergraduate and postgraduate health professions' examinations. If they are well-constructed, they will be standardized, equitable, objective, cost effective, reliable and discriminatory[1]. MCQs also enable the assessment of a broad range of content, as each examination paper can contain a large number of items. This makes the MCQ format particularly suitable for cumulative and summative final examinations as well as national licensing tests[2]. The major drawback to the MCQ format, however, is that designing high quality questions is difficult, time-consuming and costly to write[2, 3].

Single best answer (SBA) multiple choice questions consist of a question (*the stem*), one correct or best response (*the key), and* two or more choices from which examinees must choose the correct option (*the distractors*)[4]. For a given topic, there is a natural limit to the number of possibly plausible distractors, and this limit is generally less than four,

which is conventionally used in medical school MCQs papers[1].

Analysis of items is the process of collecting, summarizing and using information from students' responses to evaluate the quality of test items. Remark software (scoring system) provides detailed statistical analysis of students' scores, item difficulty index, and point bi-serial correlation coefficient as a measure of item discrimination[5].

Non-functional or non-effective distractors (NFD/ NED) are defined as distractors chosen by less than five percent of the examinees[5]. Distractor efficiency (DE) is expressed as percent values ranging from 100% in case of items having all distractors functioning to zero % when having all distractors non-functioning[5]. It is calculated as follow; number of effective distractors per item multiplied by 100 over the total number of distractors per item, it ranges from 0-100%. For 5-option any distractor contributed by 25%, as the total number of distractors is four, and by 33.3% in a 4-option question, as the total number is three distractors[5].

Difficulty index (DIFI) or item difficulty is a measure of the proportion of examinees who answered the item correctly; for this reason, it is frequently called the p-value. It ranges between zero and hundred percent (or 0-1), with a higher value indicating that a greater proportion of examinees responded to the item correctly, and it was thus an easier item[6].

The discrimination ability is measured using different methods; one of them is the point bi-serial correlation (r-Pbi), which is a special case of Pearson's correlation coefficient. It quantifies the relationship between an examinee's performance on the given item (a categorical variable: correct / incorrect answer) and the examinee's overall assessment score (a continuous variable: % score on the examination)[5]. A highly discriminating item indicates that the students who had high examination scores got the item correct whereas students who had low examination scores got the item incorrect. According to previous researches, this discrimination index is best classified as follows; less than 0.2 is considered as poor discriminating, 0.2- 0.29 as acceptable, and 0.3- 0.39 as good, and as excellent if it is equal or more than 0.4[5].

Detailed analyses of functionality of individual distractors in an item that have four or more options has shown that the examinees really focus on just two or three distractors, and rarely choose answers from the whole list of options[7]. Less number of distractors allows better selection of alternative options; moreover, creating a test set on the basis of three-option items gives a possibility to enlarge a measuring scale but without an excessive increase in time needed to prepare such an examination[8,9]. Based on these opinions, construction of MCQs with a smaller number of distractors is time saving, for both the constructor and the examinees. The most important point is to ensure that reducing the number of options will not decrease the quality of the examination significantly.

The current study had been conducted to evaluate the effect of reducing the number of MCQs options, from five to four, on quality indicators of Physiology MCQ examination. That is achieved by comparing the student performance (pass rate, and mean score), difficulty and discrimination indices, and distractor efficiency between the two examination sets.

METHODS

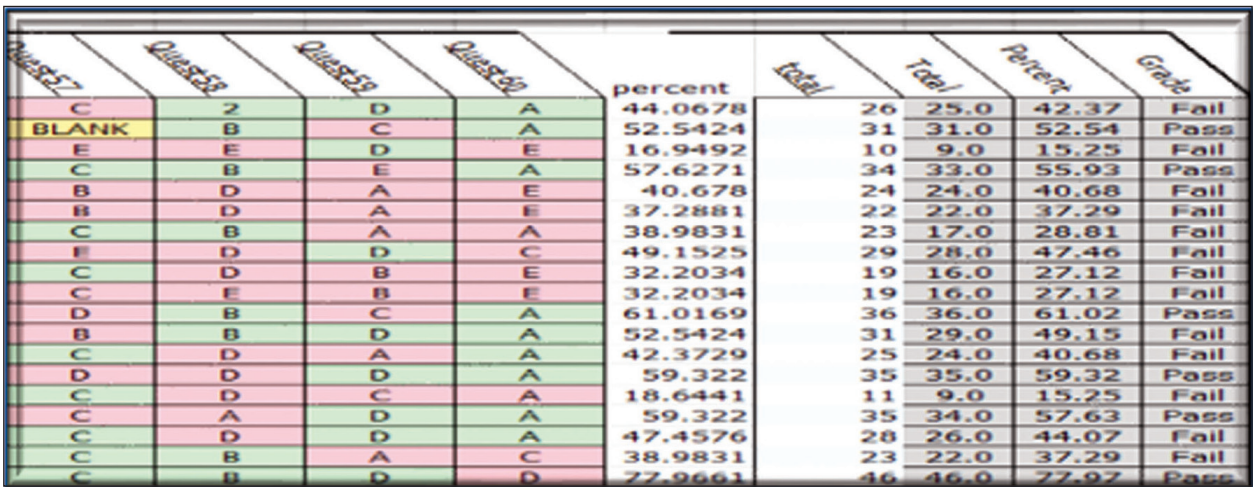
The study was conducted at the Physiology Department, in the Faculty of Medicine of Khartoum University, in the period from July to December 2020. It is an observational, analytical cross sectional study.

Methods of comparison between five- and four- option sets

There are various methods for comparison between two examination sets with different number of options. This can be performed either by re-administering the 5-option examination in a form of 4-option one, or by statistical conversion of the 5-option into 4-option. In this paper we used the second method, as described by Marie Tarrant[4]. This method was achieved by omitting the least

selected option (least effective distractor) for each item. The percentage of the least effective distractor was added randomly to one of the remaining four options. Recalculation and randomization were done using the Excel program. Doing so, sixty items with four options instead of five options were generated.

This had been carried out on End Semester 3 physiology MCQs examination (Excel sheet responses) of Khartoum University medical students held in 2016 (Figure 1).



Quest57	Quest58	Quest59	Quest60	percent	total	Total	Percent	Grade
C	2	D	A	44.0678	26	25.0	42.37	Fail
BLANK	B	C	A	52.5424	31	31.0	52.54	Pass
E	E	D	E	16.9492	10	9.0	15.25	Fail
C	B	E	A	57.6271	34	33.0	55.93	Pass
B	D	A	E	40.678	24	24.0	40.68	Fail
B	D	A	E	37.2881	22	22.0	37.29	Fail
C	B	A	A	38.9831	23	17.0	28.81	Fail
E	D	D	C	49.1525	29	28.0	47.46	Fail
C	D	B	E	32.2034	19	16.0	27.12	Fail
C	E	B	E	32.2034	19	16.0	27.12	Fail
D	B	C	A	61.0169	36	36.0	61.02	Pass
B	B	D	A	52.5424	31	29.0	49.15	Fail
C	D	A	A	42.3729	25	24.0	40.68	Fail
D	D	D	A	59.322	35	35.0	59.32	Pass
C	D	C	A	18.6441	11	9.0	15.25	Fail
C	A	D	A	59.322	35	34.0	57.63	Pass
C	D	D	A	47.4576	28	26.0	44.07	Fail
C	B	A	C	38.9831	23	22.0	37.29	Fail
C	B	D	D	77.9661	46	46.0	77.97	Pass

Figure 1. Student's response Report Excel-sheet

The study sample consisted of two examination's response sheet reports, each contained 60 questions or items, the former had five options (four distractors) per item and the latter contained four options (three distractors) per item. Number of the students who sat for the examination was 336. The Excel sheets data of the 5-option MCQs (Figure 2A) was produced by Remark software, whereas the Excel data of the 4-option MCQs was recalculated from it (Figure 2B). Student performance (mean-score, and pass rate), and quality indicators (Item difficulty indices, discrimination indices, and distractor efficiency) were recalculated using Excel program and then compared to the previous five-option data using the Statistical Package for Social Sciences (SPSS).

A	B	C	D	E
3.49	**25.0**	7.27	44.77	20.64
56.1	15.12	18.02	8.43	5.52
7.27	27.02	2.62	3.49	**59.3**
4.36	9.59	7.56	11.05	**68.9**
31.4	14.53	11.34	34.01	**20.06**
6.69	12.79	8.14	**70.06**	3.49
55.23	25.29	4.66	2.33	11.34
13.95	7.56	7.56	**59.3**	16.57
1.45	16.57	**48.55**	27.91	4.65
19.19	6.1	29.36	4.65	**45.35**
2.62	12.5	**69.47**	12.5	3.2
15.41	**39.25**	32.27	10.47	10.47
34.01	5.23	**48.83**	8.72	5.81
1.45	**88.37**	1.16	4.36	2.9
2.62	25.59	18.9	8.43	**44.19**
8.14	2.03	5.81	**47.97**	35.76
12.21	4.94	**38.66**	5.81	40.7

A	B	C	D
25.0	10.76	44.77	20.64
61.62	15.12	18.02	8.43
7.27	29.64	3.49	**59.3**
13.95	7.56	11.05	**68.9**
42.74	14.53	34.01	**20.06**
6.69	12.79	11.63	**70.06**
55.23	25.29	6.99	11.34
13.95	7.56	**59.3**	24.13
16.57	**48.55**	27.91	6.1
19.19	6.1	34.01	**45.35**
12.5	**72.09**	12.5	3.2
15.41	**49.72**	32.27	10.47
34.01	**54.06**	8.72	5.81
1.45	**88.37**	4.36	4.06
28.21	18.9	8.43	**44.19**
8.14	7.84	**47.97**	35.76
17.15	**38.66**	5.81	40.7

Cells in yellow= least effective distractor

Cells in pink= randomly selected option for addition of the least effective distractor percentage

Figure 2A. Original 5-option condensed test report

Figure 2B. The newly generated 4-option condensed test Report

The equation used for calculation of point bi - serial correlation coefficient:

Where:

X1= the mean score for the student who responded positively to the item

X0= the mean score for the students who responded negatively.

P= the difficulty of the item, the percent selection/100.

Q= (1-P)

St. Dev. = standard deviation for the whole examination

Descriptive statistics and comparison between the two examination sets were done using SPSS. Paired T-test was used for the comparison between parameters of item analysis.

Ethical approval as the software provides anonymous data (i.e., deals with students' identification numbers (IDs) rather than examinees' names), full board review was not required and there was no need for informed consent from the examinees.

RESULTS

Students' performance

The pass rate increased from 56.8 % in the 5-option to 59.5% in the 4-option set. In addition, the mean percent score increased significantly (P=0.001) from 52.7±%١٦,٤٤ in the 5-option to 53.9%±16.01 in the 4-option set.

Difficulty and Discrimination Indices

Table 1 shows that mean item difficulty index (DIFI) was significantly increased in the 4-option exam set compared to the 5-option one (P=0.001), while the discrimination index (rPbi) was significantly decreased (P=0.001).

Table 1. Difficulty and discrimination indices of both exam sets

Parameter	Mean ± SD 5-option set	Mean ± SD 4-option set	T-test Significance
DIFI*	51.52±17.48	53.09 ±17.64	0.001
rPbi-correlation** 0.38± 0.13		0.34± 0.12	0.001

*DIFI = Difficulty index

**rPbi = discrimination index

SD = standard deviation

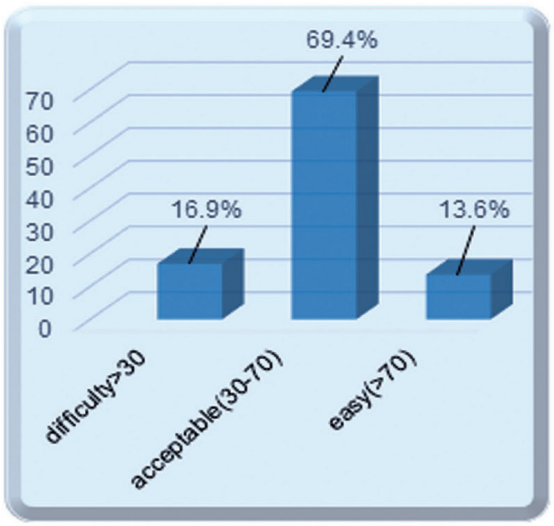


Figure 3. Difficulty index interpretation 5-option set

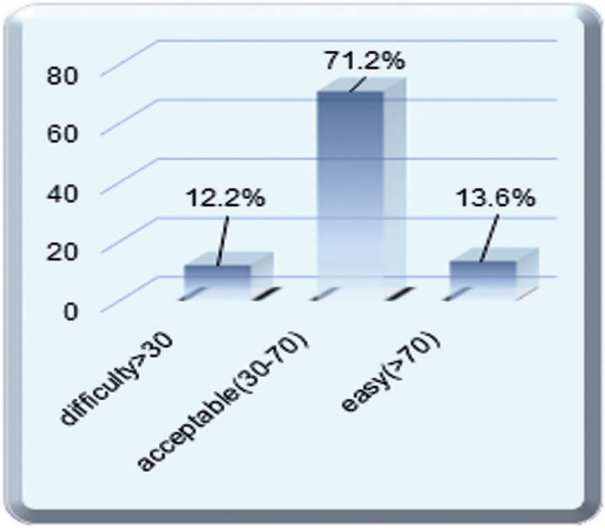


Figure 4. Difficulty index interpretation 4-option set

Figures 3 and 4 show the difficulty index interpretation of both examination sets. They demonstrate that the majority of 5-option and 4-option items (69.5) and (71.2%) had an acceptable difficulty level.

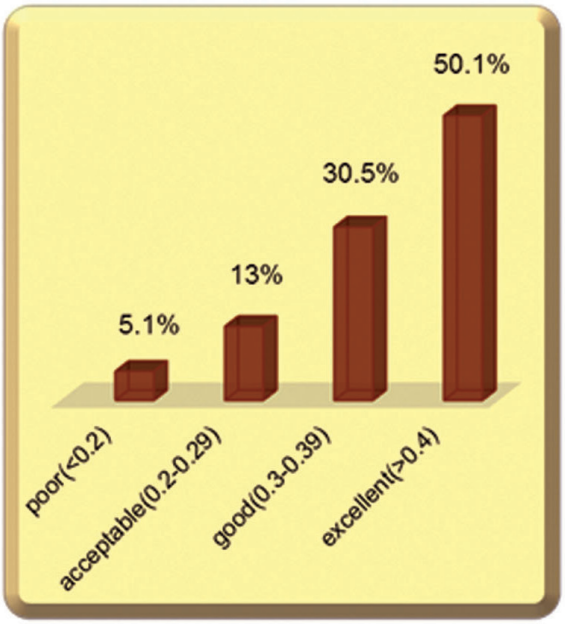


Figure 5. r-Pbi corrélation coefficient 5-option set

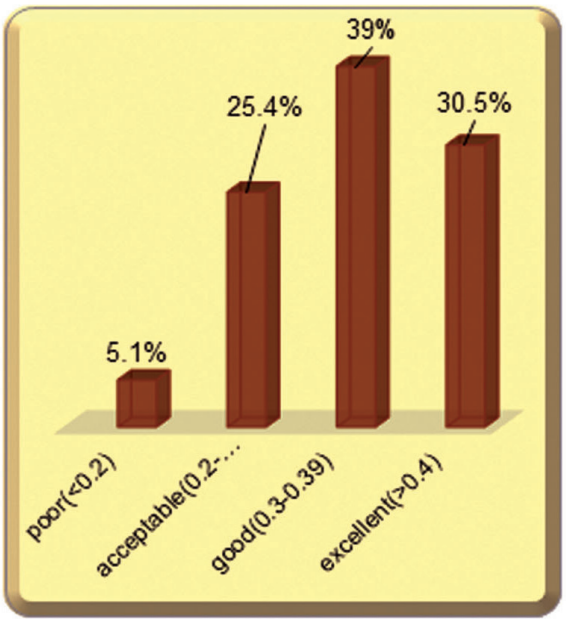


Figure 6. r-Pbi corrélation coefficient 4-option set

Compared to 5-option, 4-option set was also well discriminating. Four-option yielded greater percentage of acceptable discrimination, a smaller number of excellent; and predominant items with good discrimination. The least were the poor discrimination item (5.1%) in both sets (Figures 5 and 6).

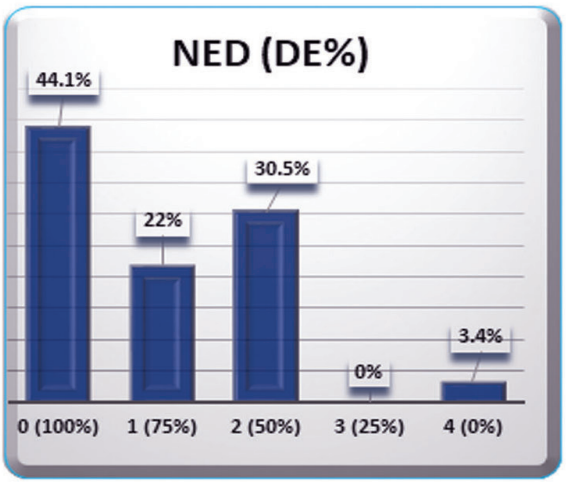
Distractor efficiency_

Table 2 shows that there was a significant reduction in the number of non-effective distractors/NED per item (P=0.002), consequently significant increase in item distractor efficiency (P=0.001) in the 4-option compared to the 5-option set.

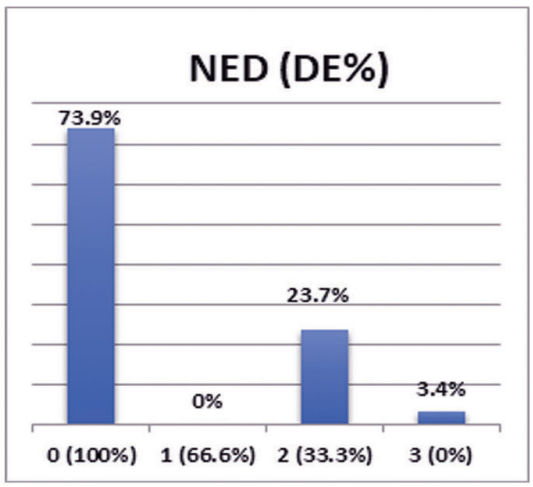
Table 2. Item Distractor efficiency & the number of non-effective distractors (NED)

Parameter	Mean ± SD 5-option set	Mean ± SD 4-option set	T-test Significance
NED	0.97 ± 1.03	0.34 ± ٠.66	0.002
Distractor efficiency (%)	75.85 ± 25.8	88.70 ± 21.98	0.001

SD = standard deviation



NED = non-effective distractors
DE = distractor efficiency
Figure 7. NED 5-option set



NED = non-effective distractors
DE = distractor efficiency
Figure 8. NED 4-option set

Figures 7 and 8, illustrate the number of non-effective distractors (NED) per item and the corresponding distractor efficiency (DE) for 5-option and 4-option examination, respectively. Figure 7, shows that 44.1% of the 5-option items had zero NED (4 effective distractors or 100% DE), 22% had 1 NED (3 effective distractors or 75% DE), 30.5% had 2 NED (2 effective distractors or 50% DE), none of the items had 3 NED (1 effective distractors or 25% DE) and only 3.4% had 4 NED (no effective distractor or zero% DE). On the other hand, Figure 8, shows that 73.9% of the 4-option items had zero NED (3 effective distractors or 100% DE), none of the items had 1 NED (2 effective distractors or 66.6% DE), 23.7% had 2 NED (1 effective distractors or 33.3% DE), and only 3.4% had 3 NED (no effective distractor or zero% DE).

DISCUSSION

The current study compares the general performance (pass rate, and mean score), and quality indicators (distractor efficiency (DE), difficulty index (DIFI), and discrimination power) of five and four-option examination sets. The least effective distractors were omitted from each item, and fifteen options (25.4%) were reallocated randomly to the right answer, this reallocation is expected to affect all parameters whether positively or negatively.

Regarding the general performance of the students, pass rate increased in the 4-option compared to the 5-option type. Out of 365, nine students (2.4%) got the benefit of this recalculation (i.e. they passed the examination after being marginal degrees); similarly, Tarrant et al found that 1.9% had the

benefit of this recalculation in his study [4]. Panczyk[7] and Rahma [10] observed an increase in the pass rate. Furthermore, mean percent score also increased by 1.2 degree (from 52.7 to 53.9); this could be explained by increased difficulty index of the exam (easiness). In addition, increasing both pass rate and mean percent score can be explained by the possibility of increasing the score of the marginal students into the pass score. The students who chose the least effective distractor in this study are probably hesitating and many of them were marginal benefiting from that recalculation.

Regarding the difficulty index; there was significant difference between the two examination sets. The difference between mean difficulty of the two sets was 1.56, (i.e., the four-option had a greater DIFI, in other words, it was easier than the five-option examination). This Significant increase in DIFI was observed also by Panczyk[7] and Rahma[10]. In contrast, Fozzard observed minimal or negligible reduction in DIFI of four compared to five-option (i.e., similar examination difficulty)[11]. Random redistribution of some of the least effective distractor percent into the correct answer has contributed to the increased DIFI in the study.

Discrimination ability of the item was represented by the Point bi-serial correlation coefficient (rPbi). There was significant difference in the mean rPbi of both exams (P = 0.001), with the four-option examination being less discriminating [but still the overall mean was in the good range (0.34)]. In addition, most of the items with four-option have a good to excellent discrimination. Likewise, many authors observed significant reduction in the discrimination ability after decreasing number of distractors from four to three per item[8, 9]; others (Panczyk[7] and Vegada[12]) found no significant difference.

The relationship between the difficulty index (DIFI) and discrimination (rPbi) had been observed by many researchers, they stated that the relationship is not linear, it is rather dome shaped[5, 13]. Correlation statistics showed that the discrimination was maximal at the upper range of acceptable difficulty (50-70%), minimally reduced at the level of very easy items but marked reduction was apparent at the level of very difficult items[8, 9, 14, 15] These observations could explain our findings of reduced rPbi in relation to increase in DIFI.

The average number of non-effective distractors per item decreased significantly from the 5-option to 4-option, their mean values were 0.97 and 0.33 respectively (P=0.001). This result was supported by previous similar findings [4, 10, 11]. Fifty-seven distractors (24.1%) of the 5-option examination were non effective (i.e., they had been chosen by less than 5%), out of the total number of distractors (236). After recalculation and omission of least effective distractors from each item, the 4-option exam set contained nineteen (10.73%) non effective distractors out of total 177 distractors. Mean Distractor efficiency was 75.85%, and 88.7% for 5 and 4-option sets, respectively, the difference is obviously significant (p=0.002). Many researches revealed a similar result of increasing distractor efficiency with decreasing number of options[11]. In fact, when implausible distractors are removed, the remaining distractors will be less and the percent of plausible ones will simply increase. This study had thrown the light on the issue of evaluating the quality of MCQ whenever there is tendency to change any aspect in their construction.

CONCLUSION

Using the method of random redistribution of the percent of the least effective distractors among the other options for comparing sets with different number of option; the outcome uncovered a significant positive impact on pass rate, mean score, distractor efficiency (DE), and difficulty index (DIFI), but a negative impact only on discrimination ability of the items (rPbi). Although most of these results are supportive to moving from five-option to four-option MCQ type without the risk of reducing the quality indicators of MCQs as an important tool of assessment, yet there is great need for further analysis of larger sample size using different methods of comparison.

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3. All illustrations should be numbered on the

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4. Graphics should be clear, camera-ready and all symbols explanations included on the figure or in the legend.
5. Permission to reproduce illustrations or tables should be obtained by the authors and submitted with the manuscript.

Statistical analysis

1. Statistical methods used should be clearly identified and if necessary described.
2. Means and standard errors of the mean and P values should be given to two decimal places.

References

1. Please use the Vancouver Style as shown below.
2. References should be listed numerically by order of their appearance in the text.

The Vancouver Style of Reference Formatting

With the growth of medical knowledge and research, it had become necessary that the formatting of reference citation both within the text of scientific writing and in reference lists should be widely agreed. The first steps to establish a uniform system for formatting manuscripts and references were begun by the Conference of Biological Editors in 1960. The International Committee of Medical Journal Editors (CMJE) held a meeting in Canada in 1979 to launch a uniform style of reference formatting for medical journals and proposed the Vancouver Style. Since then the major medical journals have adopted the 'Uniform requirements for manuscripts submitted to biomedical journals'[(1)], a common style for presentation of papers for publication.

- The justification of an internationally accepted style of reference citation can be summarized as follows:-
- Correct and complete referencing of scientific and medical publications is an essential component of the 'scientific method' when recording the outcome of research.
- To facilitate formatting scientific papers for more efficient peer reviews and publications.
- An unambiguous system of referencing allows other researchers and reviewers of manuscripts to access the cited literature to validate claims and arguments.
- To successfully secure research funding, the research proposal including the existing literature on which it is based should be convincing and easily accessed by reviewers.
- Uniform and complete citation formats facilitates quotation and reference compilation for researchers and postgraduate students.

The following is a summary to supplement the Instructions to Authors for referencing of manuscripts submitted to KMJ. It is based on the Vancouver Style and is the preferred referencing format for writing of dissertations, theses and other referenced writing in the Faculty of Medicine, University of Khartoum:-

1. References should be numbered consecutively throughout the text in the order in which they appear.
2. No references should be included in the abstract.
3. Identify references in the text, tables and legends by numerals in parenthesis e.g. (1), (2,3) or (3-6).
4. When citing authors in the text, acknowledge only the first author where there are three or more authors, e.g. Smith et al (1998) stated that ….(1).
5. Where there are two authors cite both, e.g. Adam and Ehsan (2003) reported that ….(2). Note that numerals in parenthesis at the end of a sentence are written before the full stop.
6. The list of references should begin on a new page and given the numbers which indicate order of citation.
7. All authors should appear in the list of references i.e. all references are listed in full.
8. Where more than 6 authors are registered, write the first 3 authors followed by et al.
9. The order of author/s initials, punctuation, title of article, year, journal title – in accepted abbreviated form, volume and page numbers, constitute a full reference citation. The following are examples of commonly used reference sources:

Reference in journals

General format including punctuation,

Author/s, title of article, title of journal (in italics with no full stops), year; volume number: page numbers.

e.g. Rose ME, Huerbin MB, Melick J, JK et al. Regulation of interstitial excitatory amino acid concentrations after cortical contusion injury. Brain Res 2002; 935: 40-6.

References in books

Author(s) of a book

General format including punctuation.

Author(s) Title: sub-title. Edition. Place of publication: Publisher; Year

e.g. Guyton AC, Hall JE. Textbook of Medical Physiology. 10th Ed. Philadelphia: Saunders; 1990.

Author(s) of a chapter in a book

General format including punctuation

Author(s) of the chapter. Title: sub-title of chapter. In: Author(s) (or editors) of the book. Title: sub-title of book. Place of publication: Publisher; Year; page numbers.

Elmunshid HA. Special senses. In: Sukkar MY, Elmunshid HA, Ardawi MS, editors. Concise Human Physiology 2nd Edn. Oxford: Blackwell Science; 2000.p.401-23.

Reference on-line

Example (from The Michener Institute for Applied Health Sciences, Learning Resource Centre: Irc@ michenere.ca).

Book on the Internet

Foley KM, Gelband H, editors. Improving palliative care for cancer [monograph on the Internet]. Washington: National Academy Press; 2001 [cited 2002 Jul 9]. Available from: http://www.nap.edu/books/o309074029/html/.

Internet homepage/website

Cancer-Pain.org [homepage on the Internet]. New York: Association of Cancer Online Resources, Inc.; c2000-01 [updated 2002 May 16; cited 2002 Jul 9]. Available from: http://www.cancer-pain.org.

For a fuller range of examples of citation from other sources of references, there are innumerable sites on the internet. Please also consult the publications cited in KMJ instructions to authors and the references cited below:-

1. Uniform requirements for manuscripts submitted to biomedical journals: writing and editing for biomedical publication [home-page on the Internet]. Philadelphia, PA: International Committee of Medical Journal Editors; [updated 2003 Nov; cited 2004 Oct 9]. Available from: http://www.icmje.org/.
2. Style manual for authors, editors and printers. 6th Ed. Milton, Qld: John Wiley & Sons; 2002.