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How well do doctors understand a scientific article in English when it is not their first language? A randomised trial

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How well do doctors understand a scientific article in English when it is not their first language? A randomised trial

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How well do doctors understand a scientific article in English when it is not their first language? A randomised trial

Abstract

Introduction

English is the lingua franca of science. How well doctors understand English is therefore crucial for their understanding of scientific articles. However, only 5 % of the world's population have English as their first language.

Methods

Objectives: To compare doctors' comprehension of a scientific article when read in their first language (Norwegian) versus their second language (English). Our hypothesis was that doctors reading the article in Norwegian would comprehend the content better than those reading it in English.

Design: Parallel group randomised controlled trial. We randomised doctors to read the same clinical review article in either Norwegian or English, before completing a questionnaire about the content of the article.

Setting: Conference in primary care medicine in Norway, 2018

Participants: 130 native Norwegian speaking doctors, 71 women and 59 men. One participant withdrew before responding to the questionnaire and was excluded from the analyses.

Interventions: Participants were randomly assigned to read a review article in either Norwegian (n=64) or English (n=66). Reading time was limited to seven minutes followed by seven minutes to answer a questionnaire.

Main outcome measures: Total score on questions related to the article content (potential range -9 to 20).

Results

Doctors who read the article in Norwegian had a mean total score of 10.40 (SD 3.96) compared to 9.08 (SD 3.47) among doctors who read the article in English, giving a mean difference of 1.32 (95% confidence interval 0.03 to 2.62; p=0.046). Age was independently associated with total score, with decreased comprehension with increasing age.

Conclusion

The difference in comprehension between the group who read in Norwegian and the group who read in English was statistically significant but modest, suggesting that the language gap in academia is possible to overcome.

Article summary

Strengths and limitations of this study

- This study contributes to the sparse literature on the subject of science comprehension.
- Participants were bilingual doctors; a presumably homogenous population regarding language, level of education and socioeconomic class.
- The authors were blinded to the outcome whilst analysing the data.

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- The results are probably not generalizable to all non-anglophone scientific communities.
- Further research is needed to ascertain how the language gap in academia most effectively can be closed.

Introduction

English is considered the global *lingua franca* of scientific research and publication, but only about 5 % of the world's population has the privilege of having English as their native language.[1] Equity in global access to research is an important goal. Open access publishing and enabling low- and middle-income countries access to collections of biomedical and health literature through the Hinari program, are important steps in this direction.[2] They do not, however, help readers overcome their language barrier.[3] Non-native English speaking scientists experience disadvantage as they read, do research, publish and attend conferences in a different language than the one that is closest to their culture, thoughts and feelings.[4]

To date, research on second language comprehension has primarily targeted children, adolescents and immigrants to English-speaking countries,[5] while little is known about professionals. Our research group conducted a study in 2002, which concluded that Scandinavian doctors' ability to retain information from a review article was better when they read the article in their mother tongue than in English .[6] To the best of our knowledge, no similar study has been conducted since.

Norwegian is the official language in Norway, and the spoken and written language of daily life, in doctor's offices and hospitals. Children in Norway learn English as a second language in school from age six, and Norway is ranked third in the world for non-native English proficiency.[7]

The aim of our study was to learn about comprehension of science when presented in first versus second language. Our objective was to compare doctors' ability to answer questions correctly about the content in a scientific article after having read the article in either their first language (Norwegian) or their second language (English). Our hypothesis was that doctors reading the article in Norwegian would comprehend the content better than doctors reading the article in English.

Methods

Study design

We performed a parallel group randomised controlled trial among doctors who attended a conference in primary care medicine in Oslo 22nd- 26th October 2018. Participants were randomised to read the same review article on paper in either Norwegian or English (appendix 1).[8]

Setting and participants

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Approximately 1200 doctors working within primary care or public health attended the conference. Participants were consecutively recruited in the conference exhibition area. They were informed that we wanted to test whether different presentations of a scientific article affected reading comprehension and the ability to retain information. Before finally agreeing to participate, attendees were given written information about the study (appendix 2), including that only doctors with Norwegian as first language were eligible for participation.

Randomisation

We randomised participants by letting them pick an envelope from a box. The envelope contained the article in either Norwegian or English. Each participant would open their envelope and start reading the article, as an assistant set a digital alarm clock at seven minutes. After seven minutes, or earlier if the participant had finished reading, the assistant collected the article, handed the questionnaire to the participant and reset the alarm.

Data and variables

The topic of the article was the use of medication in pregnancy,[8] thought to be a relevant issue for GPs. The article had been accepted for publication in the *Journal of the Norwegian Medical Association* but was not yet published at the time of the study. The English version was provided by the professional translation agency that is used routinely by the Journal of the Norwegian Medical Association.[9]

The article was 2300 words long. Reading time and the questionnaire had been separately piloted. Median reading time among pilot readers was 7.49 minutes for those reading in Norwegian and 8.35 minutes for those reading in English. We set the reading time to 7 minutes as we figured that time pressure would highlight possible differences between the two groups, and because we wanted to reflect the time pressure often met in clinical practice. We made minor modifications in the questionnaire based on feedback from the piloting.

Both groups filled in the questionnaire in Norwegian, which covered four components: a) consent to participate, b) demographic information on the participant, c) background knowledge on the topic of the article and d) questions related to the content of the article (appendix 3). Demographic information included gender and age group ($\leq$34, 35-44, 45-54, $\geq$ 55 years). We tested background knowledge on medication in pregnancy with a single multiple choice question with several correct answers (potential range -5 to 5). Questions related to the article content included five multiple choice questions (final scores potentially ranging from -9 to 12), and three open questions (range 0 to 8), adding up to a total potential score range from -9 to 20. Two of the authors (MR and SLS)

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independently scored the answers to the open questions based on pre-specified guidance and blinded for language of the study article. They agreed in 83-94% of cases dependent on variable. In cases of disagreement, consensus was reached by discussion (MR, SLS and RØ).

Power analysis

With random assignment to groups, independent samples of equal size, an alpha-level of 0.05, and power (1-beta) of 0.80 a sample of n=128 would be necessary to detect an effect size of d=0.5 (two-sided test).

Statistical analysis

Data were processed and primary analyses performed blinded for language of the study article. The primary outcome of our study was the total score on questions related to the article content. Groups were compared by two sample t-tests. Additional exploratory analyses were performed by simple and multiple linear regression, with total score on questions related to the article content as dependent variable and the following as independent variables: language, gender, age, and background knowledge score. We tested for interaction between language and the following variables respectively: gender, age, and background knowledge. Finally, we performed two multivariate analyses: one limited to independent variables that were statistically significant in univariate analyses and one including all independent variables. Statistical significance was defined by an alpha level of 0.05. All analyses were performed in IBM SPSS Statistics 25.

Patient and public involvement

This study did not include or directly relate to patients, and was therefore done without patient involvement. Our research subjects are doctors, and the study was designed by doctors and doctors were involved at all stages of the process. The findings will be disseminated to the research subjects and to the general public through The Journal of The Norwegian Medical Association.

Results

130 participants were recruited, of whom 64 read the article in Norwegian and 66 in English. One participant in the first group withdrew before responding to the questionnaire and was excluded from the analyses. This resulted in a final sample of 129 (63 vs 66) (fig. 1).

Table 1 presents demographic data and scores on background knowledge for each group. Participants who read the article in Norwegian had a mean total score on questions related to the

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article content of 10.40 (SD 3.96) compared to 9.08 (SD 3.47) among participants who read the article in English, giving a mean difference of 1.32 (95% confidence interval 0.03 to 2.62; p=0.046).

The results from the linear regression analyses are shown in table 2. Participants > 55 years had a mean total score of 8.29 (SD 2.87) compared with 10.41 (SD 4.35) among participants < 34 years (Unstandardized B -2.13 95% confidence interval -3.81 to -0.44; p=0.014). The effects of language and age on total score were also statistically significant in both multivariate analyses (table 2). We found no statistically significant interactions (data not shown).

Table 1. Characteristics of study population and scores on background knowledge. Values are numbers (percentages) unless stated otherwise.

Variable	Norwegian text (n=63)	English text (n=66)
Gender		
Female	35 (55.6)	35 (53.0)
Male	28 (44.4)	31 (47.0)
Age (years)		
≤ 34	17 (27.0)	22 (33.3)
35-44	17 (27.0)	16 (24.2)
45-54	12 (19.0)	10 (15.2)
≥ 55	17 (27.0)	18 (27.3)
Score on background knowledge, mean (SD)*	1.33 (1.32)	1.06 (1.12)

*Range -5 to 5

Table 2. Linear regression with total score related to the article content as the dependent variable. Univariate and multivariate analyses (model 1 and model 2).

	Univariate analysis		Model 1*		Model 2†	
Variables	Unstandardized B (95% KI)	p-value	Unstandardized B (95% KI)	p-value	Unstandardized B (95% KI)	p-value
Language						
Norwegian	Reference		Reference		Reference	
English	-1.32 (-2.62 to -0.03)	0.046	-1.36 (-2.62 to -0.11)	0.034	-1.29 (-2.55 to -0.03)	0.046
Gender						
Female	Reference		-		Reference	
Male	0.11 (-1.21 to 1.43)	0.871			0.83 (-0.51 to 2.16)	0.222
Age						
< 34	Reference		Reference		Reference	
35-44	0.47 (-1.24 to 2.18)	0.588	0.36 (-1.33 to 2.05)	0.673	0.61 (-0.11 to 2.32)	0.486
45-54	-1.37 (-3.29 to 0.56)	0.163	-1.51 (-3.42 to 0.39)	0.118	-1.46 (-3.37 to 0.44)	0.131
> 55	-2.13 (-3.81 to -0.44)	0.014	-2.19 (-3.85 to -0.53)	0.010	-2.21 (-3.91 to -0.51)	0.011

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Background knowledge††	0.40 (-0.13 to 0.94)	0.140	-	-	0.31 (-0.22 to 0.84)	0.243

*Adjusted for variables statistically significant in univariate analyses

†Adjusted for all independent variables ††Range -5 to 5

Discussion

We investigated whether reading comprehension of a scientific article was best in the subjects' first or second language by randomising 130 native Norwegian doctors to read the same article in either Norwegian or English, and then answer questions about the article content. Doctors who read the article in their first language had more correct answers than the doctors who read the article in English. The difference in score was small, but statistically significant.

Some of us performed a similar study in 2002 among Norwegian, Swedish and Danish doctors. All three groups retained information from a given article better when read in their mother tongue versus English, with a median (IQR) of 4 (3-6) versus 3(2-4) respectively (p=0.01).[6] The two studies are not directly comparable, but our results indicate that the difference might have diminished over the past two decades. Our finding is also in line with previous research in the field of bilingualism.[10]

Comprehension is a complex process that is hard to define and even harder to test. It is the ability to process text, decode its meaning, and to integrate that with what the reader already knows about the subject. We tested comprehension in the same manner as at exams in many medical schools, with a mix of multiple choice and open questions. We tested all participants in Norwegian, a choice we made based on the presumption that true comprehension should be more than simple recollection, i.e. if you read in a second language you should be able to answer questions about it in your first language. A possible pitfall with this design is that the participants asked to read the article in English in a Norwegian context and then answer questions in Norwegian are subject to what is known as linguistic switch costs.[11] Switch costs refer to the cognitive burden of switching languages, which results in longer processing times or higher error rates. This could explain the difference in scores between the groups.

A strength of this study is that research subjects were recruited from a presumably homogenous population regarding language, level of education and socioeconomic class, and then randomised. In the field of bilingualism this is quite rare, as most studies on second language comprehension test bilinguals with a monolingual control group[12]; often the bilingual group consists of a minority population and the monolingual group consists of the cultural majority. This comes with a set of systematic differences between the groups regarding culture, education and socioeconomic class. Furthermore, testing bilinguals versus monolinguals is problematic in itself as it is well documented that bilingualism per se offers a cognitive advantage in some tasks related to executive function.[13]

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One participant in the group who read in Norwegian withdrew before responding to the questionnaire and was excluded from the analyses. Depending on the reason for non-response, the estimated difference between groups might be slightly biased in this complete case analysis.

Our findings are probably not generalizable to all non-anglophone scientific communities for many reasons. For one, English and Norwegian are both Germanic languages which means they have more linguistic features in common than do for instance English and Russian or Hindi. Further, proficiency in English is high in Norway compared to most other countries.[7] Norwegian doctors do also have better access to the Internet and to research articles both in English and in their first language than do many colleagues in low- and middle-income countries. Hence, our results might be a best-case scenario for comprehension of science in a second language. Similar studies in other countries would yield additional insight.

Implications

In order to level the playing field in global academia, we must acknowledge that language is intrinsically linked to power and privilege[1]. If the goal is to leave no-one behind,[14] funding of education in English and academic English in low-income countries is essential. In this mindset, reaching those furthest behind would mean reaching the 6 billion people who do not speak English at all. English as a common language in science offer unprecedented possibilities for cooperation, mutual understanding and dissemination of research, and it can also be a democratising institution if extended to all.

What is already known on this topic

95 % of the world's population does not have English as their first language

First and second languages are processed slightly differently in the brain

Little is known about comprehension of science in a second language

What this study adds

Comprehension of a scientific article was almost as good in English as in Norwegian among the doctors studied

Comprehension decreased with increasing age

The results of this study suggest that the language gap in academia is possible to overcome

Acknowledgments

We thank the participating doctors for their time and patience.

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Footnotes

Contributors: SLS, AB, RØ, PG, MN, EH and MR designed the study and collected the data. SLS, AB, RØ, ES and MR analysed the data. SLS, AB, RØ and MR wrote the first draft of the manuscript. All authors revised the manuscript and approved the final version of the submitted manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. MR acts as the guarantor.

Transparency: MR affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Data sharing: Data is available upon request to the authors.

Funding: The study was funded by The Journal of The Norwegian Medical Association.

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; and no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: Participation was voluntary and based on informed consent. We included few demographic variables to ensure anonymity in accordance with criteria from the Norwegian Centre for Research Data. The Data Protection Officer at the Norwegian Medical Association approved the plan for handling the data. The project confers to the standards for ethical research defined by The Norwegian Research Ethics Committees.

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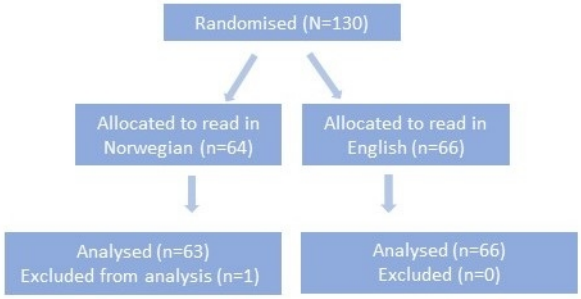

Figure 1. Flow of participants.

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TEXT FOR THE ACCOMPANYING LETTER:

Dear colleague,

The Journal of the Norwegian Medical Association is undertaking a study in which we investigate whether varying presentations of a scientific article affect the amount of information that a reader retains. The results are foreseen to be published in a scientific journal.

Participation is voluntary. If you choose to participate, you will receive a printout of an article that you will be asked to read. You will have limited time to read it (7 minutes), which is assumed to correspond to real conditions in a busy everyday schedule. You will then be provided with a questionnaire that contains some background questions as well as questions about the topic and content of the article. You will have 7 minutes to answer the questions. Your response will be anonymous and cannot be traced back to you.

You can withdraw from the study at any time until your response has been submitted.

We wish to emphasise that this is not a knowledge test. The questions have been designed in such a way that only very few will be able to answer all questions correctly.

Having Norwegian as your first language is a precondition for participating. If Norwegian is not your first language, please let us know.

As a token of our appreciation for your help, you will receive a small consideration from us.

Yours sincerely,

Are Brean
Editor-in-Chief
Journal of the Norwegian Medical Association

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TEXT FOR THE QUESTIONNAIRE:

INSTRUCTIONS:

Tick the answer that you think is the correct one. Where it is indicated that you should tick all that apply, incorrect responses will cause points to be deducted from your total score. Questions 8, 9 and 10 are open-ended, and you are kindly asked to write your answer on the dotted line. You have **7 minutes** to answer all the questions. Your response will be treated anonymously, and the questions are designed in such a manner that hardly anybody will be able to answer them all correctly.

INFORMATION ABOUT YOU:

1. I have read the information leaflet and consent to participate in the study.

□ Yes
□ No

2. Gender

□ Female
□ Male

3. Age

□ 34 years or younger
□ 35–44 years
□ 45–54 years
□ 55 years or older

QUESTIONS UNRELATED TO THE ARTICLE

4. Which of these drugs are normally contraindicated for all or parts of a pregnancy? (Tick all that apply)

□ Omeprazole
□ Cephalexin
□ Valproate
□ Salbutamol
□ Loratadine
□ Atorvastatin
□ Enalapril
□ Misoprostol
□ Metoclopramide
□ Ibuprofen

QUESTIONS RELATED TO THE ARTICLE

5. How soon after delivery will the pharmacokinetic changes that occur during pregnancy be normalised? (Tick one only)

□ 1–2 days
□ 3–4 days
□ 1–2 weeks
□ 3–4 weeks

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6. What are the practical consequences of the pharmacokinetic changes that occur during pregnancy? (Tick all that apply)

□ All those who are on regular medication require a baseline test at the earliest possible stage of pregnancy.

□ Close clinical follow-up, including regularly measurement of blood pressure, is sufficient.

□ For drugs that we know to be affected by pregnancy, a baseline test must be taken, with monthly follow-up tests.

□ For drugs that we know to be affected by pregnancy, measurement of serum concentration may be necessary.

7. Which of these physiological changes occur during pregnancy and may affect the concentration of drugs? (Tick all that apply)

□ Increased gastric pH

□ Increased gastrointestinal motility

□ Increased plasma volume

□ Reduced concentration of α1-acid glycoprotein

□ Reduced glomerular filtration rate

8. According to the article, what is the most important thing to know about a drug in order to estimate how a pregnancy will affect the drug concentration in the mother?

.....

9. What does it mean that a fetus may be doubly exposed?

.....

.....

10. The article lists three issues that may cause therapeutic failure during pregnancy. Which are they?

A. .....

B. .....

C. .....

11. Which of the statements below are true according to the article? (Tick all that apply)

□ Methadone doses should be gradually reduced during pregnancy

□ Methadone is metabolised via CYP3A4 in the liver

□ Caffeine metabolism is reduced during pregnancy

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□ Doses of escitalopram should as a rule be increased during pregnancy

□ Serum concentration of lamotrigine should be measured regularly during pregnancy

□ The dose requirement of methadone may increase during pregnancy

□ Serum concentration of lamotrigine increases during pregnancy

□ The dose requirement of lithium may increase during pregnancy

□ The clinical effect of methadone should be monitored during pregnancy

□ A fall in the concentration of escitalopram may cause therapeutic failure during pregnancy

12. What proportion of pregnant women in Norway have used pharmaceutical drugs during their pregnancy (Tick one only)

□ Nearly 50%

□ Nearly 30%

□ Nearly 80%

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CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	3
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	3
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	4
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	-
Participants	4a	Eligibility criteria for participants	4
	4b	Settings and locations where the data were collected	4
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	4
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	5
	6b	Any changes to trial outcomes after the trial commenced, with reasons	-
Sample size	7a	How sample size was determined	5
	7b	When applicable, explanation of any interim analyses and stopping guidelines	-
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	4
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	4
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	-
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	4
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	5

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		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	-
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	5
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	5
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	6
	13b	For each group, losses and exclusions after randomisation, together with reasons	6
Recruitment	14a	Dates defining the periods of recruitment and follow-up	4
	14b	Why the trial ended or was stopped	-
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	7
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	7
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	7
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	-
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	7
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	-
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	9
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	9
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	9
Other information			
Registration	23	Registration number and name of trial registry	-
Protocol	24	Where the full trial protocol can be accessed, if available	-
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	10

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

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How well do doctors understand a scientific article in English when it is not their first language? A randomised controlled trial

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How well do doctors understand a scientific article in English when it is not their first language? A randomised controlled trial

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How well do doctors understand a scientific article in English when it is not their first language? A randomised controlled trial

Abstract

Introduction

English is the lingua franca of science. How well doctors understand English is therefore crucial for their understanding of scientific articles. However, only 5 % of the world's population have English as their first language.

Methods

Objectives: To compare doctors' comprehension of a scientific article when read in their first language (Norwegian) versus their second language (English). Our hypothesis was that doctors reading the article in Norwegian would comprehend the content better than those reading it in English.

Design: Parallel group randomised controlled trial. We randomised doctors to read the same clinical review article in either Norwegian or English, before completing a questionnaire about the content of the article.

Setting: Conference in primary care medicine in Norway, 2018

Participants: 130 native Norwegian speaking doctors, 71 women and 59 men. One participant withdrew before responding to the questionnaire and was excluded from the analyses.

Interventions: Participants were randomly assigned to read a review article in either Norwegian (n=64) or English (n=66). Reading time was limited to seven minutes followed by seven minutes to answer a questionnaire.

Main outcome measures: Total score on questions related to the article content (potential range -9 to 20).

Results

Doctors who read the article in Norwegian had a mean total score of 10.40 (SD 3.96) compared to 9.08 (SD 3.47) among doctors who read the article in English, giving a mean difference of 1.32 (95% confidence interval 0.03 to 2.62; p=0.046). Age was independently associated with total score, with decreased comprehension with increasing age.

Conclusion

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The difference in comprehension between the group who read in Norwegian and the group who read in English was statistically significant but modest, suggesting that the language gap in academia is possible to overcome.

Strengths and limitations of this study

- We applied a randomised control design.
- The authors were blinded to group randomisation whilst analysing the data.
- Participants were a presumably homogenous population regarding language, level of education and socioeconomic class.
- We studied Norwegian doctors, who might not be representative for doctors in all other non-anglophone communities.
- The questionnaire was in Norwegian (first language) for both groups, which could have introduced a linguistic switch cost for the group that read the article in English (second language).

Introduction

English is considered the global *lingua franca* of scientific research and publication, but only about 5 % of the world's population has the privilege of having English as their native language.[1] Equity in global access to research is an important goal. Open access publishing and enabling low- and middle-income countries access to collections of biomedical and health literature through the Hinari program, are important steps in this direction.[2] They do not, however, help readers overcome their language barrier.[3] Non-native English speaking scientists experience disadvantage as they read, do research, publish and attend conferences in a different language than the one that is closest to their culture, thoughts and feelings.[4 5]

To date, research on second language comprehension has primarily targeted children, adolescents and immigrants to English-speaking countries,[6] while little is known about professionals. Our research group publisheda study in 2002, which concluded that Scandinavian doctors' ability to retain information from a review article was better when they read the article in their mother tongue than in English .[7] To the best of our knowledge, no similar study has been conducted since.

Norwegian is the main official language in Norway, and the spoken and written language of daily life, in doctor's offices and hospitals. Norwegian is also the tuition language of all medical schools in

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Norway. Children in Norway learn English as a second language in school from age six, and Norway is ranked third in the world for non-native English proficiency.[8]

The aim of our study was to learn about comprehension of science when presented in first versus second language. Our objective was to compare doctors' ability to answer questions correctly about the content in a scientific article after having read the article in either their first language (Norwegian) or their second language (English). Our hypothesis was that doctors reading the article in Norwegian would comprehend the content better than doctors reading the article in English.

Methods

Study design

We performed a parallel group randomised controlled trial among doctors who attended a conference in primary care medicine in Oslo 22nd- 26th October 2018. Participants were randomised to read the same review article on paper in either Norwegian or English.[9]

Setting and participants

Approximately 1200 doctors working within primary care or public health attended the conference. Participants were consecutively recruited in the conference exhibition area. They were informed that we wanted to test whether different presentations of a scientific article affected reading comprehension and the ability to retain information. Before finally agreeing to participate, attendees were given written information about the study (appendix 1), including that only doctors with Norwegian as first language were eligible for participation. Participants were given a small token of appreciation (an umbrella, value < 10 £).

Randomisation

We randomised participants by letting them pick an envelope from a box. The envelope contained the article in either Norwegian or English. Each participant would open their envelope and start reading the article, as an assistant set a digital alarm clock at seven minutes. After seven minutes, or earlier if the participant had finished reading, the assistant collected the article, handed the questionnaire to the participant and reset the alarm.

Data and variables

The topic of the article was the use of medication in pregnancy,[9] thought to be a relevant issue for GPs. The article had been accepted for publication in the *Journal of the Norwegian Medical Association* but was not yet published at the time of the study. The English version was provided by

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the professional translation agency that is used routinely by the Journal of the Norwegian Medical Association.[10]

The article was 2300 words long. Reading time and the questionnaire had been separately piloted. Median reading time among pilot readers was 7.49 minutes for those reading in Norwegian and 8.35 minutes for those reading in English. We set the reading time to 7 minutes as we figured that time pressure would highlight possible differences between the two groups, and because we wanted to reflect the time pressure often met in clinical practice. We made minor modifications in the questionnaire based on feedback from the piloting.

Both groups filled in the questionnaire in Norwegian, which covered four components: a) consent to participate, b) demographic information on the participant, c) background knowledge on the topic of the article and d) questions related to the content of the article (appendix 2). Demographic information included gender and age group ($\leq$34, 35-44, 45-54, $\geq$ 55 years). We tested background knowledge on medication in pregnancy with a single multiple choice question with several correct answers (potential range -5 to 5). Questions related to the article content included five multiple choice questions (final scores potentially ranging from -9 to 12), and three open questions (range 0 to 8), adding up to a total potential score range from -9 to 20. Two of the authors (MR and SLS) independently scored the answers to the open questions based on pre-specified guidance and blinded for language of the study article. They agreed in 83-94% of cases dependent on variable. In cases of disagreement, consensus was reached by discussion (MR, SLS, and RØ).

Power analysis

With random assignment to groups, independent samples of equal size, an alpha-level of 0.05, and power (1-beta) of 0.80 a sample of n=128 would be necessary to detect an effect size of d=0.5, which would correspond approximately to a mean difference of 2 assuming SD=4 (two-sided test).

Statistical analysis

Data were processed and primary analyses performed blinded for language of the study article. The primary outcome of our study was the total score on questions related to the article content. Groups were compared by two sample t-tests. Additional exploratory analyses were performed by simple and multiple linear regression, with total score on questions related to the article content as dependent variable and the following as independent variables: language, gender, age, and background knowledge score. We tested for interaction between language and the following

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variables respectively: gender, age, and background knowledge. Finally, we performed two multivariate analyses: one limited to independent variables that were statistically significant in univariate analyses and one including all independent variables. Statistical significance was defined by an alpha level of 0.05. All analyses were performed in IBM SPSS Statistics 25.

Patient and public involvement

This study did not include or directly relate to patients, and was therefore done without patient involvement. Our research subjects are doctors, and the study was designed by doctors and doctors were involved at all stages of the process. The findings will be disseminated to the research subjects and to the general public through The Journal of The Norwegian Medical Association.

Results

130 participants were recruited, of whom 64 read the article in Norwegian and 66 in English. One participant in the first group withdrew before responding to the questionnaire and was excluded from the analyses. All remaining questionnaires were complete, and this resulted in a final sample of 129 (63 vs 66) (fig. 1).

Table 1 presents demographic data and scores on background knowledge for each group. Participants who read the article in Norwegian had a mean total score on questions related to the article content of 10.40 (SD 3.96) compared to 9.08 (SD 3.47) among participants who read the article in English, giving a mean difference of 1.32 (95% confidence interval 0.03 to 2.62; p=0.046).

The results from the linear regression analyses are shown in table 2. Participants > 55 years had a mean total score of 8.29 (SD 2.87) compared with 10.41 (SD 4.35) among participants < 34 years (Unstandardized B -2.13 95% confidence interval -3.81 to -0.44; p=0.014). The effects of language and age on total score were also statistically significant in both multivariate analyses (table 2). We found no statistically significant interactions (data not shown). The assumption of normally distributed observations was confirmed by visual inspection of histograms and QQ-plots.

Table 1. Characteristics of study population and scores on background knowledge. Values are numbers (percentages) unless stated otherwise.

Variable	Norwegian text	English text

	(n=63)	(n=66)
Gender		
Female	35 (55.6)	35 (53.0)
Male	28 (44.4)	31 (47.0)
Age (years)		
≤ 34	17 (27.0)	22 (33.3)
35-44	17 (27.0)	16 (24.2)
45-54	12 (19.0)	10 (15.2)
≥ 55	17 (27.0)	18 (27.3)
Score on background knowledge, mean (SD)*	1.33 (1.32)	1.06 (1.12)

*Range -5 to 5

Table 2. Linear regression with total score related to the article content as the dependent variable. Univariate and multivariate analyses (model 1 and model 2).

Variables	Univariate analysis		Model 1*		Model 2†	
	Unstandardized B (95% CI)	p-value	Unstandardized B (95% CI)	p-value	Unstandardized B (95% CI)	p-value
Language						
Norwegian	Reference		Reference		Reference	
English	-1.32 (-2.62 to -0.03)	0.046	-1.36 (-2.62 to -0.11)	0.034	-1.29 (-2.55 to -0.03)	0.046
Gender						
Female	Reference		-		Reference	
Male	0.11 (-1.21 to 1.43)	0.871			0.83 (-0.51 to 2.16)	0.222
Age						
< 34	Reference		Reference		Reference	
35-44	0.47 (-1.24 to 2.18)	0.588	0.36 (-1.33 to 2.05)	0.673	0.61 (-0.11 to 2.32)	0.486
45-54	-1.37 (-3.29 to 0.56)	0.163	-1.51 (-3.42 to 0.39)	0.118	-1.46 (-3.37 to 0.44)	0.131
> 55	-2.13 (-3.81 to -0.44)	0.014	-2.19 (-3.85 to -0.53)	0.010	-2.21 (-3.91 to -0.51)	0.011
Background knowledge††	0.40 (-0.13 to 0.94)	0.140	-	-	0.31 (-0.22 to 0.84)	0.243

*Adjusted for variables statistically significant in univariate analyses

†Adjusted for all independent variables ††Range -5 to 5

Discussion

We investigated whether reading comprehension of a scientific article was best in the subjects' first or second language by randomising 130 native Norwegian doctors to read the same article in either Norwegian or English, and then answer questions about the article content. Doctors who read the article in their first language had more correct answers than the doctors who read the article in English. The difference in score was small, but statistically significant.

Some of us published a similar study in 2002 among Norwegian, Swedish, and Danish doctors. All three groups retained information from a given article better when read in their mother tongue versus English, with a median (IQR) of 4 (3-6) versus 3(2-4) respectively (p=0.01).[7] The two studies are

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not directly comparable, but our results indicate that the difference might have diminished over the past two decades. Our finding is also in line with previous research in the field of bilingualism.[11]

Comprehension is a complex process that is hard to define and even harder to test. It is the ability to process text, decode its meaning, and to integrate that with what the reader already knows about the subject. We tested comprehension in the same manner as at exams in many medical schools, with a mix of multiple choice and open questions. We tested all participants in Norwegian, a choice we made based on the presumption that true comprehension should be more than simple recollection, i.e. if you read in a second language you should be able to answer questions about it in your first language. A possible pitfall with this design is that the participants asked to read the article in English in a Norwegian context and then answer questions in Norwegian are subject to what is known as linguistic switch costs.[12] Switch costs refer to the cognitive burden of switching languages, which results in longer processing times or higher error rates. This could explain the difference in scores between the groups.

A strength of this study is that research subjects were recruited from a presumably homogenous population regarding language, level of education and socioeconomic class, and then randomised. In the field of bilingualism this is quite rare, as most studies on second language comprehension test bilinguals with a monolingual control group[13]; often the bilingual group consists of a minority population and the monolingual group consists of the cultural majority. This comes with a set of systematic differences between the groups regarding culture, education and socioeconomic class. Furthermore, testing bilinguals versus monolinguals is problematic in itself as it is well documented that bilingualism per se offers a cognitive advantage in some tasks related to executive function.[14]

One participant in the group who read in Norwegian withdrew before responding to the questionnaire and was excluded from the analyses. Depending on the reason for non-response, the estimated difference between groups might be slightly biased in this complete case analysis.

Our findings are probably not generalizable to all non-anglophone scientific communities for many reasons. For one, English and Norwegian are both Germanic languages which means they have more linguistic features in common than do for instance English and Russian or Hindi. Further, proficiency in English is high in Norway compared to most other countries.[8] Norwegian doctors do also have better access to the Internet and to research articles both in English and in their first language than do many colleagues in low- and middle-income countries. Hence, our results might be a best-case scenario for comprehension of science in a second language. Similar studies in other countries would yield additional insight.

Implications

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In order to level the playing field in global academia, we must acknowledge that language is intrinsically linked to power and privilege[1]. If the goal is to leave no-one behind,[15] funding of education in English and academic English in low-income countries is essential. In this mindset, reaching those furthest behind would mean reaching the 6 billion people who do not speak English at all. English as a common language in science offer unprecedented possibilities for cooperation, mutual understanding and dissemination of research, and it can also be a democratising institution if extended to all.

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Footnotes

Contributors: SLS, AB, RØ, PG, MN, EH and MR designed the study and collected the data. SLS, AB, RØ, ES and MR analysed the data. SLS, AB, RØ and MR wrote the first draft of the manuscript. All authors revised the manuscript and approved the final version of the submitted manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. MR acts as the guarantor.

Transparency: MR affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Data sharing: Data is available upon request to the authors.

Funding: The study was funded by The Journal of The Norwegian Medical Association.

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; and no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: Participation was voluntary and based on informed consent. We included few demographic variables to ensure anonymity in accordance with criteria from the Norwegian Centre for Research Data. The Data Protection Officer at the Norwegian Medical Association approved the plan for handling the data. The project confers to the standards for ethical research defined by The Norwegian Research Ethics Committees. References

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Figure Legend

1. Figure 1. Flow of participants.

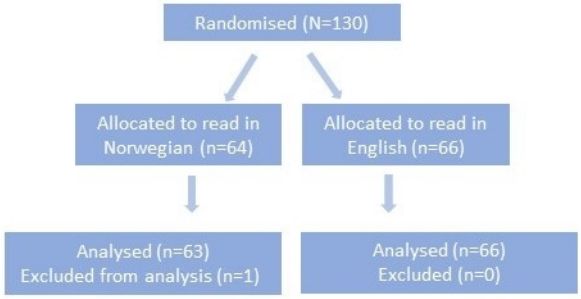

Figure 1. Flow of participants.

206x141mm (96 x 96 DPI)

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TEXT FOR THE ACCOMPANYING LETTER:

Dear colleague,

The Journal of the Norwegian Medical Association is undertaking a study in which we investigate whether varying presentations of a scientific article affect the amount of information that a reader retains. The results are foreseen to be published in a scientific journal.

Participation is voluntary. If you choose to participate, you will receive a printout of an article that you will be asked to read. You will have limited time to read it (7 minutes), which is assumed to correspond to real conditions in a busy everyday schedule. You will then be provided with a questionnaire that contains some background questions as well as questions about the topic and content of the article. You will have 7 minutes to answer the questions. Your response will be anonymous and cannot be traced back to you.

You can withdraw from the study at any time until your response has been submitted.

We wish to emphasise that this is not a knowledge test. The questions have been designed in such a way that only very few will be able to answer all questions correctly.

Having Norwegian as your first language is a precondition for participating. If Norwegian is not your first language, please let us know.

As a token of our appreciation for your help, you will receive a small consideration from us.

Yours sincerely,

Are Brean
Editor-in-Chief
Journal of the Norwegian Medical Association

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TEXT FOR THE QUESTIONNAIRE:

INSTRUCTIONS:

Tick the answer that you think is the correct one. Where it is indicated that you should tick all that apply, incorrect responses will cause points to be deducted from your total score. Questions 8, 9 and 10 are open-ended, and you are kindly asked to write your answer on the dotted line. You have **7 minutes** to answer all the questions. Your response will be treated anonymously, and the questions are designed in such a manner that hardly anybody will be able to answer them all correctly.

INFORMATION ABOUT YOU:

1. I have read the information leaflet and consent to participate in the study.

□ Yes
□ No

2. Gender

□ Female
□ Male

3. Age

□ 34 years or younger
□ 35–44 years
□ 45–54 years
□ 55 years or older

QUESTIONS UNRELATED TO THE ARTICLE

4. Which of these drugs are normally contraindicated for all or parts of a pregnancy? (Tick all that apply)

□ Omeprazole
□ Cephalexin
□ Valproate
□ Salbutamol
□ Loratadine
□ Atorvastatin
□ Enalapril
□ Misoprostol
□ Metoclopramide
□ Ibuprofen

QUESTIONS RELATED TO THE ARTICLE

5. How soon after delivery will the pharmacokinetic changes that occur during pregnancy be normalised? (Tick one only)

□ 1–2 days
□ 3–4 days
□ 1–2 weeks
□ 3–4 weeks

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6. What are the practical consequences of the pharmacokinetic changes that occur during pregnancy? (Tick all that apply)

□ All those who are on regular medication require a baseline test at the earliest possible stage of pregnancy.

□ Close clinical follow-up, including regularly measurement of blood pressure, is sufficient.

□ For drugs that we know to be affected by pregnancy, a baseline test must be taken, with monthly follow-up tests.

□ For drugs that we know to be affected by pregnancy, measurement of serum concentration may be necessary.

7. Which of these physiological changes occur during pregnancy and may affect the concentration of drugs? (Tick all that apply)

□ Increased gastric pH

□ Increased gastrointestinal motility

□ Increased plasma volume

□ Reduced concentration of α1-acid glycoprotein

□ Reduced glomerular filtration rate

8. According to the article, what is the most important thing to know about a drug in order to estimate how a pregnancy will affect the drug concentration in the mother?

.....

9. What does it mean that a fetus may be doubly exposed?

.....

.....

10. The article lists three issues that may cause therapeutic failure during pregnancy. Which are they?

A. .....

B. .....

C. .....

11. Which of the statements below are true according to the article? (Tick all that apply)

□ Methadone doses should be gradually reduced during pregnancy

□ Methadone is metabolised via CYP3A4 in the liver

□ Caffeine metabolism is reduced during pregnancy

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□ Doses of escitalopram should as a rule be increased during pregnancy

□ Serum concentration of lamotrigine should be measured regularly during pregnancy

□ The dose requirement of methadone may increase during pregnancy

□ Serum concentration of lamotrigine increases during pregnancy

□ The dose requirement of lithium may increase during pregnancy

□ The clinical effect of methadone should be monitored during pregnancy

□ A fall in the concentration of escitalopram may cause therapeutic failure during pregnancy

12. What proportion of pregnant women in Norway have used pharmaceutical drugs during their pregnancy (Tick one only)

□ Nearly 50%

□ Nearly 30%

□ Nearly 80%

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CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	3
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	3
	2b	Specific objectives or hypotheses	4
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	4
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	-
Participants	4a	Eligibility criteria for participants	4
	4b	Settings and locations where the data were collected	4
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	4
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	5
	6b	Any changes to trial outcomes after the trial commenced, with reasons	-
Sample size	7a	How sample size was determined	5
	7b	When applicable, explanation of any interim analyses and stopping guidelines	-
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	4
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	4
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	-
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	4
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	5

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		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	-
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	5
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	5
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	6
	13b	For each group, losses and exclusions after randomisation, together with reasons	6
Recruitment	14a	Dates defining the periods of recruitment and follow-up	4
	14b	Why the trial ended or was stopped	-
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	7
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	7
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	7
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	-
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	7
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	-
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	9
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	9
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	9
Other information			
Registration	23	Registration number and name of trial registry	-
Protocol	24	Where the full trial protocol can be accessed, if available	-
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	10

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

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