


BMJ Open Quality Validation of a method to assess the severity of medication administration errors in Brazil

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ABSTRACT

Introduction Medication errors are frequent and have high economic and social impacts; however, some medication errors are more likely to result in harm than others. Therefore, it is critical to determine their severity. Various tools exist to measure and classify the harm associated with medication errors; although, few have been validated internationally.

Methods We validated an existing method for assessing the potential severity of medication administration errors (MAEs) in Brazil. Thirty healthcare professionals (doctors, nurses and pharmacists) from Brazil were invited to score 50 cases of MAEs as in the original UK study, regarding their potential harm to the patient, on a scale from 0 to 10. Sixteen cases with known harmful outcomes were included to assess the validity of the scoring. To assess test–retest reliability, 10 cases (of the 50) were scored twice. Potential sources of variability in scoring were evaluated, including the occasion on which the scores were given, the scorers, their profession and the interactions among these variables. Data were analysed using generalisability theory. A G coefficient of 0.8 or more was considered reliable, and a Bland-Altman analysis was used to assess test–retest reliability.

Results To obtain a generalisability coefficient of 0.8, a minimum of three judges would need to score each case with their mean score used as an indicator of severity. The method also appeared to be valid, as the judges' assessments were largely in line with the outcomes of the 16 cases with known outcomes. The Bland-Altman analysis showed that the distribution was homogeneous above and below the mean difference for doctors, pharmacists and nurses.

Conclusion The results of this study demonstrate the reliability and validity of an existing method of scoring the severity of MAEs for use in the Brazilian health system.

INTRODUCTION

Assessing the severity of medication errors is crucial for improving patient safety during medication use. Such an assessment makes it possible to differentiate errors in relation to their severity and thus establish risk minimisation strategies targeting errors with the greatest potential for harm.¹

The assessment of potential and actual harm involves different processes, each

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ In addition to estimating the rate of medication administration errors, it is essential to understand their potential severity in order to propose harm mitigation measures.
- ⇒ There are several existing scales to assess the potential severity of medication administration errors; however, only two have been internationally validated, and only in the context of developed countries.

WHAT THIS STUDY ADDS

- ⇒ We found an existing method of assessing the potential severity of medication administration errors to be valid and reliable for use in Brazil. Severity scores were generally higher than those given by judges from the UK and Germany in previous studies.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ We have validated an existing method for assessing the potential severity of medication administration errors for use in the Brazilian context. Therefore, it could be used in future research, contributing to a better understanding of the severity of medication administration errors.

including two steps: (1) identifying the potential or actual harm to the patient related to a medication error and (2) rating the degree or severity of that harm.² Various tools exist to measure and classify the harms associated with medication errors. For example, a systematic review of harm related to prescription errors identified over 40 harm classification tools used before 2013.³ Among these, the The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP)⁴ and Dean and Barber⁵ methods have been validated internationally. A strength of the latter method is that it can be used to assess the potential severity of medication errors that do not have a known outcome, unlike the NCC MERP, in which the patient outcome must be known.⁵



The Dean and Barber scale was developed to assess the potential severity of medication administration errors (MAEs) by calculating the mean scores of four healthcare professionals (including at least one pharmacist, one nurse and one physician). This method has already been used to assess the potential clinical significance of MAEs identified in studies conducted in the UK and Germany, and is valid and reliable in the contexts in which these studies were conducted.^{5,6}

A recent systematic review of MAEs detected by the direct observation method in Latin American hospitals identified 10 studies that estimated the rate of MAEs; however, none of them assessed the severity of these errors.⁷ Considering the differences between Brazil and countries such as Germany and the USA regarding health systems, professional training and performance, and cultural contexts, it is necessary to validate the method within the Brazilian context.

Therefore, this study aimed to validate the existing Dean and Barber method,⁵ originally developed in the UK, for assessing the potential clinical significance of MAEs in Brazil. Specific objectives were to (a) determine the minimum number of judges required for a reliable mean severity score; (b) determine the effect of a judge's profession on the score and (c) test the validity of the mean score in relation to cases with known clinical outcomes, all in the Brazilian context.

METHODS

The present study

We used the method developed by Dean and Barber to assess the potential severity of MAEs.⁵ The method was described in detail in a published protocol.⁸

In brief, 37 healthcare professionals (doctors, nurses and pharmacists) from Brazil were invited to participate in scoring 50 cases of MAEs gathered from an original UK study⁵ regarding their potential harm to patients on a scale of 0–10. By looking at 10 cases (out of 50) scored twice, reliability was assessed, and potential sources of variability in scoring were assessed depending on the error case, the occasion when the scores were given, the scorer, their profession and the interactions among these variables. We chose to have just 10 cases assessed twice to avoid excessive workload for the judges and reduce the risk of non-response. This number was also sufficient in the earlier study.⁵

Generalisability theory was used to analyse the data.

The previous methodology

When creating their method, Dean and Barber chose 50 medication error cases from the literature in nearly equal numbers showing minor, moderate and severe potential clinical outcomes; in 16 of these cases, the patient outcome was already known. These cases were then sent to 30 different healthcare professionals (10 physicians, 10 nurses and 10 pharmacists). These judges were asked to score the potential clinical significance

on a Visual Analogue Scale ranging from 0 to 10 (with 0 corresponding to 'no harm' and 10 corresponding to 'patient death'). Specifically, this error severity classification involves: (1) Minor—very unlikely that the patient will develop any adverse event; (2) Moderate—likely to cause an adverse event in the patient or interfere with the therapeutic goal, but very unlikely to cause death or harm lasting more than a week and (3) Serious—an error that could lead to permanent harm or death to the patient. A subset of 10 cases was evaluated on a second occasion by all judges. The data were analysed using generalisability theory.

Judge recruitment

Judges were recruited from eight large general hospitals. Hospitals were chosen to give geographical diversity, since Brazil is a country of continental dimensions with potential for regional differences in practice. Four of the five regions of Brazil were represented.

The heads of service at these hospitals were contacted to identify doctors (internists, generalists and clinical specialists), nurses and pharmacists with more than 3 years of experience willing to evaluate the potential severity of the 50 medication errors.

After the heads of service's acceptance, 37 professionals were contacted, invited by email and the consent forms and letters describing the scoring process guidelines, the objectives of the study and practical examples of how to perform the scoring were sent to them, regardless of the location. No incentive was offered to professionals to participate in this study.

Scoring process

The invited professionals received a file with the descriptions of 50 cases of EAMs and were instructed to score the cases according to their potential clinical significance, using the scale proposed by Dean and Barber. The scores provided by these professionals were then analysed. Two weeks after receiving the severity ratings based on the 50 cases, each respondent received a random sample of 10 of the 50 cases for rescore; selected using the RV.BINOM function within SPSS 29.0.

That way, it was possible to measure whether the occasion on which the cases were scored was an important source of variance in the responses obtained.

Raters were instructed to record the time spent evaluating all 50 cases and to make relevant comments about the scoring process in a specific space on the form, in addition to completing a brief questionnaire about demographic details, including their occupation and number of years of professional experience, along with any comments about the scoring process).

Translation and contextualisation of the cases

The 50 cases were translated by the principal investigator into Portuguese, updated (if the drugs were no longer available or not in routine use), and adapted to the Brazilian context (making necessary adjustments

regarding drugs, doses, concentrations, units of measurement, pharmaceutical forms and available presentations to ensure that all were medications routinely used in clinical practice in Brazilian hospitals) (online supplemental appendix A).

The translated and adapted versions were double-checked by two experienced hospital pharmacists to ensure that the meaning of each case of MAEs remained unchanged. We used the same cases performed in the UK and Germany^{5,6} to allow comparison with the current study.

Generalisability theory

Cronbach *et al*⁹ developed generalisability theory, a method that systematically allows the effect of multiple sources of variance and their interactions on scores to be measured simultaneously in a single study, based on the premise that in any assessment procedure, variance in scores can be attributed to different identifiable sources.

Generalisability theory also emphasises the estimation of variance components. Once the variance attributed to each source is calculated, the most efficient method for reducing unwanted variations can be determined. The results can be used to identify methods for improving the reliability of a test.¹⁰

The application of generalisability theory occurs in stages. First, generalisability analysis begins with the specification of a universe of admissible observations through the identification of different sources of variation. In the second stage, the generalisability study ('G-study'), estimates the variance components of this universe. This involves creating an appropriate research design, collecting data and determining the extent to which each variable influences scores. Different coefficients of variation are calculated to represent the different situations. For example, a coefficient can be calculated to show the extent to which the score assigned to a case by a physician can be generalised to that assigned to the same case by a pharmacist. The final step is a decision study ('D-study') associated with a prespecified universe of generalisability.^{9,10} Broadly speaking, D-studies emphasise the estimation, use and interpretation of variance components for decision-making, with well-specified measurement procedures.¹¹ Perhaps the most important D-study to consider is the specification of a universe of generalisation, where the universe to which a decision-maker wants to generalise is based on the results of a D-study using a particular measurement procedure.¹⁰ From the estimated variance, the effect of a change in the number of observations on the generalisability coefficient can be explored.

Reliability analysis

Universe of observations

We used the same approach to analysis as that used previously.⁵ The sources of variance in the process of assessing the MAEs errors were those inherent in the cases themselves ('case'), the occasion on which they are assessed ('occasion'), the evaluator ('judge'), the professional

background of the judge ('profession') and the interactions among these. Since each judge is a member of a single profession, the judge factor was considered to be nested within the profession factor ('judge: profession').

Because the scores for the 50 cases of errors were obtained on two occasions for a sample of 10 cases, there are two models for conducting the G-study, depending on the data set used:

Model 1: occasion×case×judge (using the 10 cases scored twice).

Model 2: case×judge: profession (using all 50 cases).

Models 1 and 2 ignored the effect of profession and occasion, respectively. A model that considers all sources of variance for the 10 cases with repeated scores, occasion×case× judge: profession, was not used because the variance per case was anticipated to be too high to perform an analysis of variance (ANOVA).

Generalisability study

The data were evaluated using models 1 and 2 to determine the contribution of each factor to the variance in scores. First, repeated measures of variance analysis was performed and seven sources of variance estimated for model 1: case, occasion, occasion×case, judge, judge×case, occasion×judge and judge×case×occasion. For model 2, the sources of variance were profession, judge 'nested' in profession, case, case×profession and residual variance (case×judge: profession). Online supplemental appendix B provides the equations used to calculate the generalisability coefficients.

The resulting mean square values were then used to calculate the attributable variance for each source, using equations for the mean squares based on those described by Streiner and Norman¹² and Cronbach *et al*.⁹ When the estimated variance components were computed as negatives, a value of 0 was assumed.¹³ The overall generalisability coefficient, coefficients equivalent to inter-rater reliability and test-retest reliability were computed.

Decision study

The D-study was based on the G-study results and obtained the necessary decision-making information for the reliable use of generalised scoring scales. D-study was also used with model 1 to calculate G coefficients that identified the required number of judges to achieve sufficient reliability of the scale's usage.

In the D-study, the effects of different modifications in the evaluation procedure on the generalisability coefficient were investigated, and the accuracy of the obtained measurement results evaluated. Therefore, different scenarios based on the results of the G-study were investigated. The same model as in the G-study was used to calculate the generalisability coefficients for different numbers of judges and occupations. This allowed for identifying the number of judges needed to obtain a reliable average score. The D-study also investigated whether judges needed to be from a different or similar profession. Generalisability coefficients for different numbers



of judges and test occasions were calculated using the formula described by Streiner and Norman.¹² As in previous studies, a generalisability coefficient greater than 0.8 was taken to represent acceptable reliability.⁵

Validity analysis

Sixteen cases (out of 50) with known harmful outcomes were included to assess the validity of the scoring process. These cases were the same as those described in Dean and Barber's assessment method: five MAEs reported in the literature that resulted in minor outcomes (no noticeable adverse effects), five with moderate outcomes (some adverse effects but no lasting impairment) and six with severe outcomes (death or lasting impairment). The mean scores assigned by the 30 judges to these 16 cases were examined to assess whether they reflected the severity. Thus, it was possible to test the method's validity by comparing the scores assigned by the 30 raters to the 16 MAEs with previously established scores.

Test–retest reliability

The test–retest agreement was assessed by performing the Bland-Altman test, as an enhancement to the earlier studies. The Bland-Altman plot helps visualise and interpret the test–retest agreement. By definition, 95% of the differences between repeated measures must be within

agreed-upon limits. We used the Bland-Altman method as an alternative way to test the reliability.

Comparison between the analyses performed in Germany, the UK and Brazil

The mean scores of the studies in Brazil were first compared with those in the UK⁵ and second with those in the Germany⁶ studies. A paired sample t-test was performed, with a significance level set at 95% CI.

Analyses

All analyses were conducted using the R programming language, V.4.0.3 and SPSS 29.0

RESULTS

Judge recruitment

The heads of service at 8 Brazilian hospitals were contacted to identify doctors, nurses and pharmacists willing to evaluate the potential severity of the 50 medication errors. One of the south-eastern hospitals was unable to participate owing to time constraints. The seven participating hospitals were located in four regions of the country (three in the southeast, two in the northeast, one

Table 1 Initially contacted professionals, response rate and final participants

Hospital	Region	Professional group	Letters sent	Response	Response rate (%)	No of final participants
HUPES	NE	Doctors	6	4	67	4
HCPA	SO	Doctors	2	2	100	2
HCUFMG	SE	Doctors	2	2	100	2
HB	NE	Doctors	1	1	100	1
HGV	NO	Doctors	1	1	100	1
HUPES	NE	Nurses	2	2	100	2
HCPA	SO	Nurses	2	2	100	2
HCUFMG	SE	Nurses	2	1	50	1
HB	NE	Nurses	2	2	100	2
HSL	SE	Nurses	2	2	100	2
HGV	NO	Nurses	1	1	100	1
HUPES	NE	Pharmacists	5	3	60	2
HCPA	SO	Pharmacists	2	2	100	2
HCUFMG	SE	Pharmacists	2	2	100	2
HB	NE	Pharmacists	2	2	100	2
HSL	SE	Pharmacists	1	0	0	0
João XXIII	SE	Pharmacists	2	1	50	1
HGV	NO	Pharmacists	1	1	100	1
Total			37	31	84	30

HB, Hospital da Bahia; HCPA, Hospital das Clínicas de Porto Alegre; HCUFMG, Hospital das Clínicas da Universidade Federal de Minas Gerais; HGV, Hospital Getúlio Vargas; HSL, Hospital Sírio Libanês; HUPES, Hospital Universitário Professor Edgard Santos; João XXIII, Hospital João XXIII; NE, Northeast; NO, North; SE, Southeast; SO, Southwest.

Table 2 Analysis of variance

Sources of Variation	df	Sum of squares	Mean sum of squares
Case	9	3224	358.2
Judge	29	496	17.1
Occasion	1	2	2.3
CasexJudge	261	990	3.8
CasexOccasion	9	16	1.7
JudgexOccasion	29	665	22.9
CasexJudgexOccasion	261	932	3.6

*Source: Assunção-Costa (2022)

in the south and one in the north), six of whom declined participation. The first 30 professionals who completed the questionnaire were selected for the study. Ultimately, 30 healthcare professionals participated in the study, including 10 nurses, 10 pharmacists and 10 doctors, who responded to the same protocol in two different instances, as shown in [table 1](#).

All 30 judges submitted completed forms for all 50 cases including 10 repeated cases of MAE evaluations, with the absence of one judge who completed the scoring but did not report the time taken. The time taken for each of the remaining 29 judges to score all 50 cases ranged from 14 to 53 min, with a mean of 26.3 min. The mean score for each MAE ranged from 1.6 to 9.3 (online supplemental appendix B).

Two judges (one doctor and one pharmacist) commented on the scoring process and case clarification.

Example 1: 'I faced doubts regarding certain questions, including the lack of knowledge about two to three medications' further serious adverse events'.

Example 2: 'I found it difficult to contextualise the case-specific available information and to separate process error analysis from the analysis of the patient's potential harm'.

Generalisability study

Model 1

[Table 2](#) presents the ANOVA for model 1 (occasion×case×judge). professionals, including doctors, pharmacists and nurses, who separately evaluated 10 identical MAE cases on 2 separate occasions, participated in the analysis.

Online supplemental appendix C presents the estimated variance components that portray the main source of variance as the difference between MAE cases, followed by the 'judge×occasion' design. Occasion was not an important source of variance. The overall generalisability coefficient was 0.99.

Online supplemental appendices D–F presents a constant G coefficient among the three judges, regardless of profession, given by doctors, pharmacists and nurses, respectively.

Table 3 Sources of variance (doctors, pharmacists and nurses)

Sources of variation	df	Sum of squares	Mean sum of squares
Case	49	6068	123.84
Profession	2	577	288.42
Profession×judge	27	1857	68.77
Casexprofession	98	585	5.97
Casexprofession×judge	1323	4653	3.52

Source: Assunção-Costa, 2022.

Model 2

This model was evaluated by all 30 participants simultaneously, using all 50 cases. [Table 3](#) presents the sources of the variance results. [Table 4](#) presents the number needed to obtain reliable G-coefficients, and [figure 1](#) presents a graph of these estimates, considering the different professions of doctors, pharmacists and nurses. Online supplemental appendix G presents the G-studies and D-studies of doctors, pharmacists and nurses.

The G coefficients were calculated considering judges from different professions and are presented in online supplemental appendix H. For example, a pharmacist, nurse and doctor scoring the same case resulted in a good G coefficient of 0.89.

Validity

[Figure 2](#) shows the mean scores of the 16 cases of known severity. A relationship appears to be existed between the known severity categories and the mean

Table 4 G coefficient estimates to maximise scale reliability for future studies (doctors, pharmacists and nurses)

No of judges	G coefficient
	ρ
1	0.76
2	0.85*
3	0.89
4	0.91
5	0.92
6	0.93
9	0.95
12	0.96
15	0.96
18	0.96
21	0.97

Source: Assunção-Costa, 2022.

(ρ): letter phi has more contributions to the variance. It is a more conservative coefficient representing, therefore, how generalisable the instrument is to different samples in other contexts.

*A generalisability coefficient greater than 0.8 was considered to represent acceptable reliability.

G Coefficient Estimates

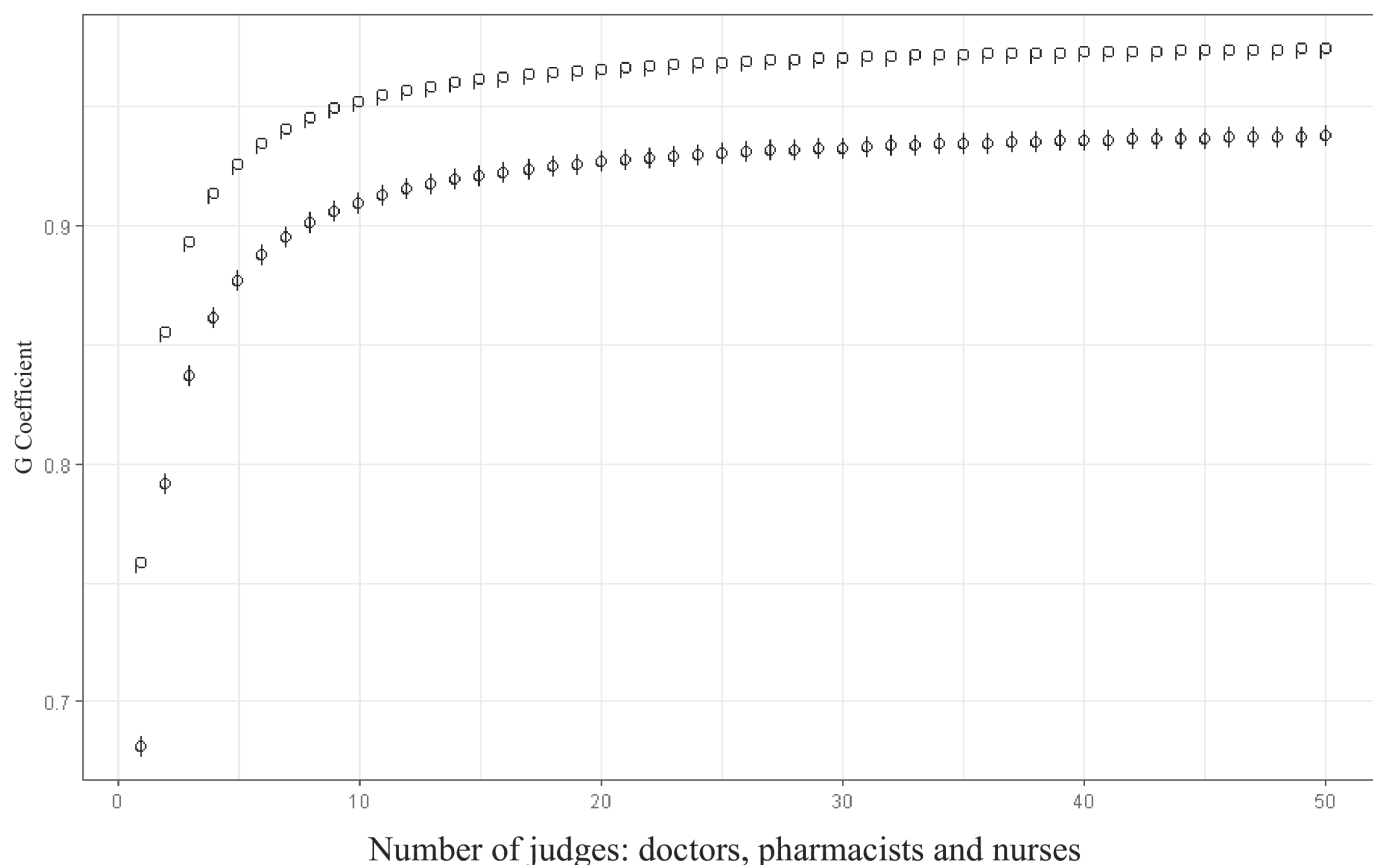


Figure 1 G coefficient estimates to maximise protocol reliability of future studies (doctors, pharmacists and nurses). Embedded text: G coefficients/G coefficients estimates/number of judges—doctors, pharmacists and nurses.

scores assigned by the judges. Minor, moderate and severe cases had mean scores ranging from 2.1 to 5.1, 4.5 to 7.9 and 6.3 to 9.3, respectively. For two minor severity cases (cases 5 and 22), the calculated mean scores were compatible with moderate severity. For one moderate severity case (case 15), the calculated mean score was compatible with a severe case. For one severe case (case 22), the calculated mean score was compatible with moderate severity. The judge-based individual scores assigned to each error indicate the contribution of extremely high or low values to these results. The cases with overlapping scores are described in online supplemental appendix I. In general, the mean scores obtained in Brazil were higher than those obtained in the UK⁵ and German⁶ studies (figure 3). The mean scores of Brazilian judges were 1.36 times (95% CI 1.11 to 1.62; $p < 0.001$; paired samples t-test $t(49) = 10.669$) and 0.49 times (95% CI 0.24 to 0.74; $p < 0.001$; paired samples t-test $t(48) = 4.046$) higher than those of the UK⁵ and German judges,⁶ respectively.

Regarding the case of number 22, which involves the drug paracetamol, there was a difference of 2.6 more points in the average score given by the Brazilian judges in relation to the known scores.

Only six of the four cases had a mean score lower than the scores calculated for the UK and German judges.^{5 6} The maximum difference between scores obtained in Brazil and the UK was 2.7, and 3.9 between Brazil and Germany.⁶

Test-retest reliability

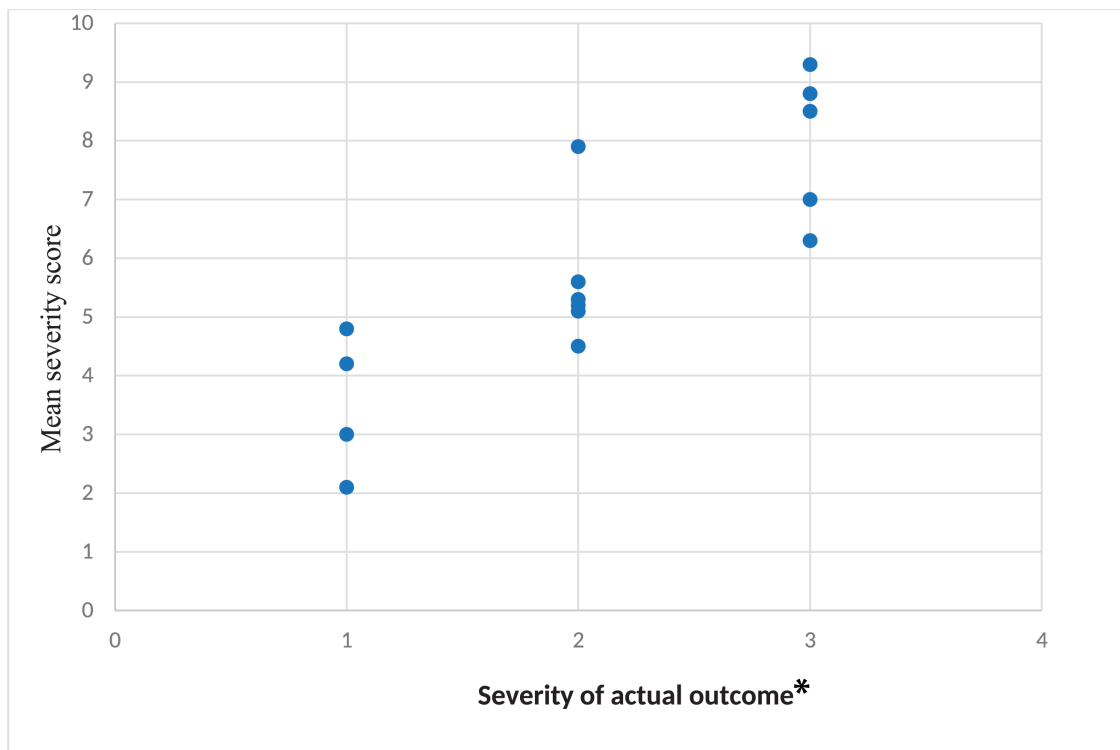
The distribution was homogeneous above and below the mean difference between the two instances with $p = 0.96$ for the doctor, 0.63 for the nurses and 0.38 for the pharmacists. The Bland-Altman plots for doctors, nurses and pharmacists are illustrated in online supplemental appendix J.

DISCUSSION

Key findings

Our findings indicate the suitability of Dean and Barber's⁵ MAE clinical severity scoring scale for use in the Brazilian healthcare system. A Brazilian doctor, nurse and pharmacist's mean score results are reliable and valid, owing to their potential generalisation to the same group of health professionals and because they allow differentiation of minor, moderate and severe errors.

The reliability of this method in Brazil had a remarkable resemblance to the original British study as well



* 1 = minor, 2 = moderate, 3 = severe

Figure 2 Comparing the judges' mean scores and the actual outcome severity. *1=minor, 2=moderate, 3=severe.

as the German research by Taxis *et al*⁶ based on similar coefficients. In both studies, the variance was not significantly affected by judges or their professions. Compared with German and English judges, Brazilian judges also took similar lengths of time to score the cases. We reported results similar to those of Taxis

*et al*⁶ in their German study, which concluded that three judges from different professions were sufficient to obtain a reliable mean score, in contrast to the requirement for four judges reported in the English study. Taxis *et al*⁶ claim the origin of this difference to be the model used in the D-study that calculated the

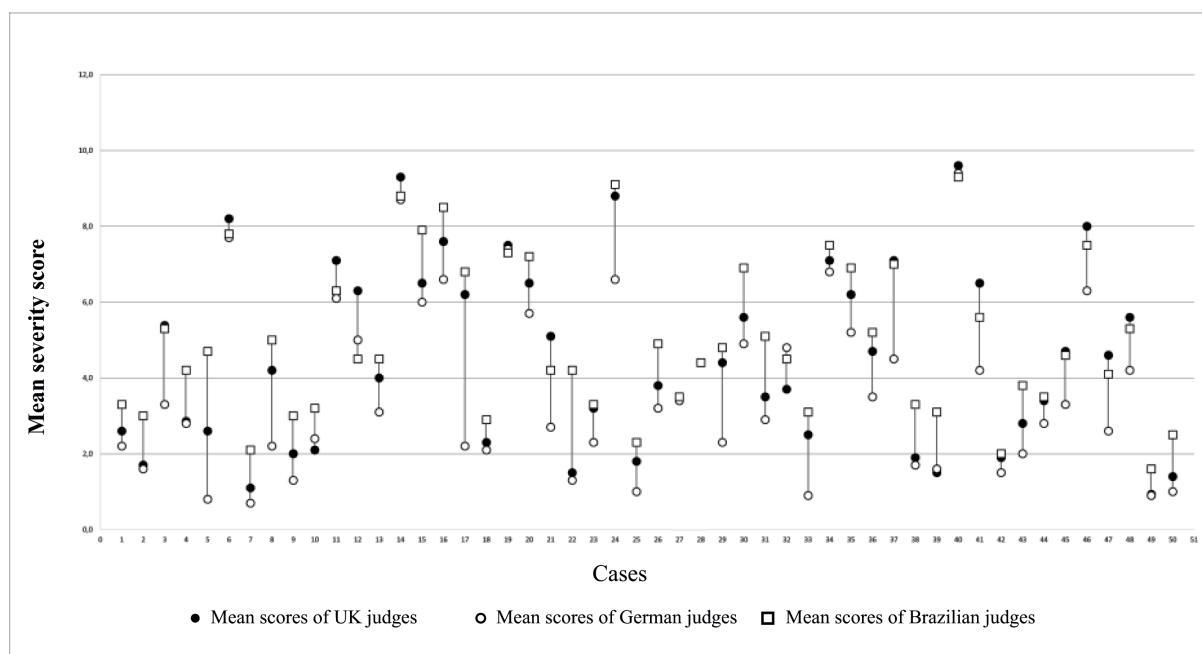


Figure 3 Mean score comparison of Brazil, Germany and the UK.

generalisation coefficient through the ‘no occasion’ facet, which contributed minutely to the variance. In our study, occasion was not an important source of variance.¹⁴

A novel aspect of our study lies in the additional evidence of reliability obtained using the Bland-Altman analysis, which also confirmed the agreement between the responses of each sampled professional provided at two separate instances, corroborating the results obtained by generalisability theory. We used the Bland-Altman method as an alternative way to test the reliability.¹⁴

Implications for practice and future research

This study confirms that this method can also be used in Brazil to assess the severity of medication errors and that the scale is valid for differentiating between MAES with minor, moderate and severe outcomes. There is a debate regarding the instruments for assessing the severity of medication errors and their ability to reflect the harmful effects on patients. This is either due to the absence of an ideal assessment method for the scale’s validity or cases of the validation process not reflecting actual regular cases, thus leading to interpretation biases.⁶ Newly developed tools reduce uncertainties in this evaluation, yet they so far lack validation.¹⁵

In general, judges considered errors with a mean score of less than two as minor errors, posing a low probability of harm to patients. In contrast, mean scores above two, considered moderate and severe, can be attributed to errors that adversely affect patients. Our results corroborated those of Taxis, Dean and Barber.⁶

Overall, the scores were higher in the present study than in the original one. For example, there was a mean score overlap in two minor cases with mean scores assigned to moderate or severe errors. In general, judges in Brazil considered errors more serious than previous judges in the UK and Germany. For example, Brazilian judges considered it more serious for an elderly patient to have a double dose of paracetamol, (case 22), compared with scorers in the UK⁵ and Germany.⁶ It is not clear to what extent this reflects international differences in safety culture or clinical practice, or changes over time in understanding or attitudes to risk. Further research is needed to explore these issues.¹⁶ For example, a contemporaneous study comparing scores among countries would establish whether differences can be attributed to countries rather than reflecting changes over time.

Strengths

This evaluation process included physicians, pharmacists and nurses with experience in the clinical field and working in hospitals distributed across four regions of the country, which provided an overview of the assessment of the potential severity of medication errors in Brazil.

Limitations

A potential limitation is the use of cases from an earlier UK study rather than selecting MAEs from the Brazilian

context. However, using the same or similar cases allowed us to make a more meaningful comparison among countries. There is also very little literature about MAEs in Brazil from which to select suitable cases. The medications described in the errors were all in common use in Brazilian hospitals at the time other studies.

Judges were not chosen at random but were required to have at least 3 years of clinical practice and represented a range of public and private hospitals from different geographical areas. Depending on the judges’ selection criteria, one institution may have contributed the majority of professionals. Such was the case of the northeastern region, which was a potential limitation.

CONCLUSION

The results of this study demonstrate the validity and reliability of Dean and Barber’s scale for assessing the severity of MAEs in the Brazilian health system.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

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APPENDIX A - 50 CASES OF ADMINISTRATION ERRORS: ORIGINAL VERSION⁴ IN ENGLISH AND VERSION INTO ENGLISH AFTER ADAPTATIONS TO BRAZILIAN REALITY

Original	Version translated into English after adaptations to the Brazilian context
1. A hypertensive patient had his blood pressure controlled with enalapril 2.5mg once daily. One dose was missed	A hypertensive patient had his blood pressure controlled with enalapril 5mg once daily. One dose was missed.
2. An elderly patient with a cardiac pacemaker was prescribed enteric coated aspirin 75mg once daily. One dose was omitted.	An elderly patient with a cardiac pacemaker was prescribed enteric coated acetylsalicylic acid (ASA) 100mg once daily. One dose was omitted.
3. A patient was prescribed lithium carbonate 600mg daily (one tablet) but was given a single dose of 1200mg (two tablets).	A patient was prescribed lithium carbonate 600mg daily (two 300mg tablets) but was given a single dose of 1200mg (four 300mg tablets).
4. The first two doses of chloramphenicol eye ointment, prescribed to be administered four times a day, were omitted in a patient with a suspected conjunctivitis.	The first two doses of chloramphenicol eye ointment, prescribed to be administered four times a day, were omitted in a patient with a suspected conjunctivitis.
5. An elderly patient with swallowing difficulties was prescribed ranitidine effervescent tablets 150mg twice daily, for the prophylaxis of ulceration while on diclofenac therapy. An ordinary non-soluble ranitidine tablet was given instead, which the patient swallowed with some difficulty.	An elderly patient with swallowing difficulties was prescribed ranitidine effervescent tablets 150mg twice daily, for the prophylaxis of ulceration while on diclofenac therapy. An ordinary non-soluble ranitidine tablet was given instead, which the patient swallowed with some difficulty.
6. A patient had been receiving warfarin 5mg daily, which was stopped when her INR was found to be 5.4. However, for three days she continued to receive a daily dose of warfarin 5mg.	A patient had been receiving warfarin 5mg daily, which was stopped when her INR was found to be 5.4. However, for three days she continued to receive a daily dose of warfarin 5mg.
7. A patient was prescribed vitamin B compound strong tablets, two daily. One dose of only one tablet was given.	A patient was prescribed vitamin B compound strong tablets, two daily (high dosage of vitamin B compound). One dose of only one tablet was given.
8. A patient with oral Candida was prescribed fluconazole 50mg daily for one week. Fluconazole 200mg capsules were dispensed, which the patient received for the week's course.	A patient with oral <i>Candida</i> was prescribed fluconazole 50mg daily for one week. Fluconazole 150mg capsules were dispensed, which the patient received for the week's course.
9. A patient prescribed Lacrilube eye drops for her dry eyes was given instead one dose of 30ml lactulose orally.	A patient prescribed Lacrifilm® lubricating eye drops for her dry eyes was given instead one dose of 30ml lactulose orally.
10. A patient with an itchy rash was prescribed calamine lotion to be applied three times a day. The first five doses were omitted	A patient with an itchy rash was prescribed calamine lotion to be applied three times a day. The first five doses were omitted

11. A patient with a history of heart failure was administered a dose of oral atenolol 100mg which was intended for another patient	A patient with a history of heart failure was administered a dose of oral atenolol 100mg which was intended for another patient
12. A patient was prescribed six doses of oral folic acid (15mg three times a day) as rescue therapy following methotrexate treatment. The patient instead received six doses of folic acid 15mg.	A patient was prescribed six doses of oral folic acid (15mg three times a day) as rescue therapy following methotrexate treatment. The patient instead received six doses of folic acid 15mg.
13. An elderly patient prescribed oral co-amilorfruse 2.5/20 (Frumil LS) once a day, for the treatment of mild heart failure, was instead given a dose of co-amilorfruse 5/40 (Frumil).	An elderly patient prescribed 20mg furosemide once a day, for the treatment of mild heart failure, was instead given a dose of 40mg furosemide
14. A patient was prescribed soluble insulin 10 units every six hours. This was initially interpreted as 10ml (1000 units), but the mistake was realised and the injection stopped after 2ml (200 units) had been given.	A patient was prescribed soluble insulin 10 units every six hours. This was initially interpreted as 10ml (1000 units), but the mistake was realised, and the injection stopped after 2ml (200 units) had been given.
15. A patient prescribed 5mg morphine IV was given intravenously 5mg of Oramorph (oral morphine solution 10mg/5ml) solution.	A patient prescribed 5mg morphine IV was given intravenously 5mg of Oramorph (oral morphine solution (Dimorf® 10mg/ml).
16. A patient was being treated for acute sciatica by lumbar epidural injection of methylprednisolone acetate. The vial of drug was reconstituted with 30% sodium chloride instead of 0.9% sodium chloride and then administered.	A patient was being treated for acute sciatica by lumbar epidural injection of methylprednisolone acetate. The vial of drug was reconstituted with 20% sodium chloride instead of 0.9% sodium chloride and then administered.
17. A patient with chronic obstructive airways disease was prescribed Augmentin 250/62 suspension, 5ml three times daily for the treatment of a chest infection. The first five doses were omitted.	A patient with chronic obstructive airways disease was prescribed Clavulin® (amoxicillin and potassium clavulanate 250/62) suspension, 5ml three times daily for the treatment of a chest infection. The first five doses were omitted.
18. One 10pm dose of oral metronidazole 400mg was omitted in a patient receiving the drug three times daily for surgical prophylaxis. He was three days post surgery.	One 10pm dose of oral metronidazole 400mg was omitted in a patient receiving the drug three times daily for surgical prophylaxis. He was three days post-surgery.
19. A patient with a known penicillin allergy was prescribed oral ciprofloxacin 500mg twice a day for the treatment of a chest infection. He was given one dose of flucloxacillin 500mg.	A patient with a known penicillin allergy was prescribed oral ciprofloxacin 500mg twice a day for the treatment of a chest infection. He was given one dose of oxacillin 500mg.
20. A patient was prescribed 100mg lamotrigine daily. Lamotrigine 100mg tablets were dispensed instead of the 25mg tablets intended. The patient therefore received 400mg daily for six days instead of 100mg daily.	A patient was prescribed 100mg lamotrigine daily. Lamotrigine 100mg tablets were dispensed instead of the 25mg tablets intended. The patient therefore received 400mg daily for six days instead of 100mg daily.

21. One dose of oral hydrocortisone 10mg was omitted in a patient with chronic adrenal insufficiency who was prescribed 20mg every morning and 10mg every evening.	One dose of oral hydrocortisone 10mg was omitted in a patient with chronic adrenal insufficiency who was prescribed 20mg every morning and 10mg every evening.
22. An elderly patient prescribed paracetamol suspension 250mg/5ml in a dose of 10ml (500mg) every six hours was given one dose of 20ml (1g).	An elderly patient prescribed paracetamol suspension 100mg/ml in a 5ml (500mg) dose every six hours was given one 10ml (1g) dose.
23. One dose of oral metformin 500mg was omitted in a diabetic patient receiving 500mg three times daily.	One dose of oral metformin 500mg was omitted in a diabetic patient receiving 500mg three times daily.
24. A patient prescribed 10ml of morphine elixir 2.5mg/5ml (5mg morphine) was given instead a dose of 10ml of the concentrated elixir 100mg/5ml (200mg morphine).	A patient prescribed 2ml of morphine IV (1mg/ml vials, with 2mg morphine content) was given instead a 20ml (200mg de morphine) dose from an IV 10mg/ml vial.
25. A patient was receiving oral ranitidine 150mg twice a day as prophylaxis against peptic ulceration, while he was also receiving steroids. One evening dose of the ranitidine was missed. He had no history of peptic ulceration.	A patient was receiving oral ranitidine 150mg twice a day as prophylaxis against peptic ulceration, while he was also receiving steroids. One evening dose of the ranitidine was missed. He had no history of peptic ulceration.
26. A patient was prescribed oral vancomycin 125mg four times a day for the treatment of Clostridium difficile colitis. Three days into therapy, two consecutive doses were omitted.	A patient was prescribed oral vancomycin 125mg four times a day for the treatment of Clostridium difficile colitis. Three days into therapy, two consecutive doses were omitted.
27. A patient with long standing Parkinson's disease was prescribed co-beneldopa 250mg (benserazide 50mg and levodopa 200mg) four times a day, but was dispensed a week's supply of modified release co-careldopa 250mg (carbidopa 50mg and levodopa 200mg) in a bottle labelled co-beneldopa.	A patient with long standing Parkinson's disease was prescribed Prolopa® 250mg (Benserazide 50mg and Levodopa 200mg) four times a day but was dispensed a week's supply of Cronomet® 250mg (Carbidopa 50mg and levodopa 200mg) in a bottle labelled Prolopa®.
28. A patient with Crohn's disease was prescribed prednisolone enteric coated tablets 5mg once daily, but was given plain uncoated 5mg prednisolone tablets throughout his four day hospital stay.	A patient with Crohn's disease was prescribed prednisolone enteric coated tablets 5mg once daily but was given plain uncoated 5mg prednisolone tablets throughout his four-day hospital stay.
29. An elderly patient was prescribed oral ranitidine 150mg twice a day as prophylaxis against NSAID-induced ulceration. The first six doses were omitted.	An elderly patient was prescribed oral ranitidine 150mg twice a day as prophylaxis against NSAID-induced ulceration. The first six doses were omitted.
30. A patient prescribed oral penicillin 250mg four times daily was dispensed penicillamine 250mg, which the patient was given for three days before the error was discovered.	A patient prescribed oral penicillin 250mg four times daily was dispensed penicillamine 250mg, which the patient was given for three days before the error was discovered.

31. One dose of oral diltiazem 60mg was omitted in a newly admitted patient with angina who normally took the drug three times a day.	One dose of oral diltiazem 60mg was omitted in a newly admitted patient with angina who normally took the drug three times a day.
32. A newly diagnosed asthmatic patient was prescribed beclomethasone 100 mcg per metered dose, two puffs twice a day. He was given an inhaler containing 250mcg beclomethasone per metered dose, containing sufficient quantity for three weeks.	A newly diagnosed asthmatic patient was prescribed beclomethasone 100 mcg per metered dose, two puffs twice a day. He was given an inhaler containing 250mcg beclomethasone per metered dose, containing sufficient quantity for three weeks.
33. A patient written up for warfarin 10mg was given two 5mg tablets that had expired one month previously.	A patient written up for warfarin 10mg was given two 5mg tablets that had expired one month earlier.
34. A patient was prescribed thyroxine 25 microgrammes daily. The patient was instead administered methotrexate 25mg daily for several days.	A patient was prescribed thyroxine 25 micrograms daily. The patient was instead administered methotrexate 25mg daily for several days.
35. An elderly patient prescribed digoxin elixir 125 micrograms daily for the treatment of chronic atrial fibrillation was given 50 micrograms of the elixir daily for several weeks.	An elderly patient prescribed digoxin elixir 125 micrograms daily for the treatment of chronic atrial fibrillation was given 50 micrograms of the elixir daily for several weeks.
36. A terminally ill patient was prescribed morphine sulphate SR tablets 60mg twice daily. He was given a dose of 60mg Sevredol (non-modified release morphine sulphate) rather than the intended MST tablets.	A terminally ill patient was prescribed morphine sulphate SR tablets 60mg (DIMORF® LC) twice daily. He was given a dose of 60mg (two 30mg tablets) non-modified release morphine sulphate rather than the intended DIMORF® LC (CR).
37. A patient prescribed vancomycin 1g IV twice daily was given one of the doses as a bolus rather than by infusion.	A patient prescribed vancomycin 1g IV daily was given one of the doses as direct IV (bolus) rather than by intermittent infusion.
38. A patient was prescribed gentamicin ear drops, two drops three times a day to the right ear, for the treatment of an ear infection shown to be sensitive to gentamicin. On the second day of treatment, one dose was administered to the left ear instead of the right ear.	A patient was prescribed gentamicin ear drops, two drops three times a day to the right ear, for the treatment of an ear infection shown to be sensitive to gentamicin. On the second day of treatment, one dose was administered to the left ear instead of the right ear.
39. The first two doses of topical Teejel (choline salicylate dental gel BP), prescribed to be applied four times daily, were omitted in a patient with mouth ulcers.	The first two doses of OMCILON-A ORABASE (Triamcinolone acetonide), prescribed to be applied four times daily, were omitted in a patient with mouth ulcers.
40. A patient prescribed cefotaxime 1g IV three times a day for post-partum pyrexia had a dose reconstituted with 10ml of 15% potassium chloride solution instead of 0.9% sodium chloride. The dose was then administered by bolus injection.	A patient prescribed cefotaxime 1g IV three times a day for post-partum pyrexia had a dose reconstituted with 10ml of 19% potassium chloride solution instead of 0.9% sodium chloride. The dose was then administered by bolus injection.

41. An elderly non-diabetic patient was given another patient's 5mg glibenclamide tablet.	An elderly non-diabetic patient was given another patient's 5mg Glibenclamide tablet.
42. An elderly patient with cellulitis was prescribed oral flucloxacillin 1g four times daily. One week after the start of the treatment she was given two consecutive doses of 500mg instead of 1g.	An elderly patient with cellulitis was prescribed oral dicloxacillin 500mg four times daily. One week after the start of the treatment the patient was given two consecutive doses of 250mg instead of one 500mg dose.
43. An elderly patient with a hospital-acquired chest infection was prescribed cefotaxime 1g IV three times a day. Two days into the treatment course he was given one oral dose of cephadrine 500mg instead of the dose prescribed. He was able to swallow oral medication.	An elderly patient with a hospital-acquired chest infection was prescribed cefotaxime 1g IV three times a day. Two days into the treatment course he was given one oral dose of Cephalexin 500mg instead of the dose prescribed. He was able to swallow the oral medication.
44. One dose of salbutamol 400mcg rotacaps was omitted in a patient with chronic obstructive airways disease.	One dose of salbutamol 100mcg rotacaps was omitted in a patient with chronic obstructive airways disease.
45. A patient stabilised on warfarin 5mg daily was given one dose of 7.5mg.	A patient stabilised on warfarin 5mg daily was given one dose of 7.5mg.
46. A patient who was prescribed oral diltiazem 60mg three times a day was given instead one dose of diazepam 60mg.	A patient who was prescribed oral diltiazem 60mg three times a day was given instead one dose of diazepam 60mg.
47. A patient prescribed oral diclofenac 50mg three times a day for post-operative pain control missed the first three doses.	A patient prescribed oral diclofenac 50mg three times a day for post-operative pain control missed the first three doses.
48. A patient with oesophagitis was prescribed omeprazole (Losec) 20mg daily. For three days the patient instead received frusemide (Lasix) 20mg.	A patient with oesophagitis was prescribed omeprazole (Losec®) 20mg daily. For three days the patient instead received frusemide (Lasix®) 20mg.
49. A patient with anaemia was prescribed oral ferrous sulphate 200mg three times a day. One dose was omitted.	A patient with anaemia was prescribed oral ferrous sulphate 200mg three times a day. One dose was omitted.
50. A patient prescribed Augmentin (co-amoxiclav 250/125), one tablet three times a day for a chest infection, was given one dose of two tablets on the third day of therapy. Her renal function was normal.	A patient prescribed Clavulin® (Amoxicillin/potassium clavulanate – 250/125) one tablet three times a day for a chest infection, was given one dose of two tablets on the third day of therapy. Her renal function was normal.

APPENDIX B - MEAN SCORE BASED ON ASSESSEMENT OF 30 JUDGES FOR EACH MEDICATION ADMINISTRATION ERROR

ERROR	MEAN SCORE
1	3.3
2	3
3	5.3
4	4.2
5	4.7
6	7.8
7	2.1
8	5
9	3
10	3.2
11	6.3
12	4.5
13	4.5
14	8.8
15	7.9
16	8.5
17	6.8
18	2.9
19	7.3
20	7.2
21	4.2
22	4.2
23	3.3
24	9.1
25	2.3
26	4.9
27	3.5
28	4.4
29	4.8
30	6.9
31	5.1
32	4.5
33	3.1
34	7.5
35	6.9
36	5.2
37	7
38	3.3
39	3.1
40	9.3
41	5.6
42	2.0
43	3.8
44	3.5
45	4.6
46	7.5
47	4.1
48	5.3
49	1.6
50	2.5

APPENDIX C. Crossed design study with 30 participants on two separate occasions

G STUDY		
Sources of Variation	Estimated variance	Percentage of total variance
Case	5.906	52.9
Judge	0.000	0.0
Occasion	0.000	0.0
Case x Judge	0.131	1.2
Case x Occasion	0.000	0.0
Judge x Occasion	1.610	14.4
Residual	3.518	31.5
D STUDY		
Case	0.591	37.3
Judge	0.000	0.0
Occasion	0.000	0.0
Case x Judge	0.013	0.8
Case x Occasion	0.000	0.0
Judge x Occasion	0.805	50.8
Residual	0.176	11.1
G coefficients		
ρ	0.99	
Φ	0.98	

Source: the author, 2022.

(ρ)- letter phi has more contributions to the variance; it is a more conservative coefficient, thus representing how generalizable the instrument is to different samples in other contexts. ϕ (Greek letter rho) represents how generalizable the instrument is to the sample, considering the relative differentiation between the elements of the object of study in a given sample.

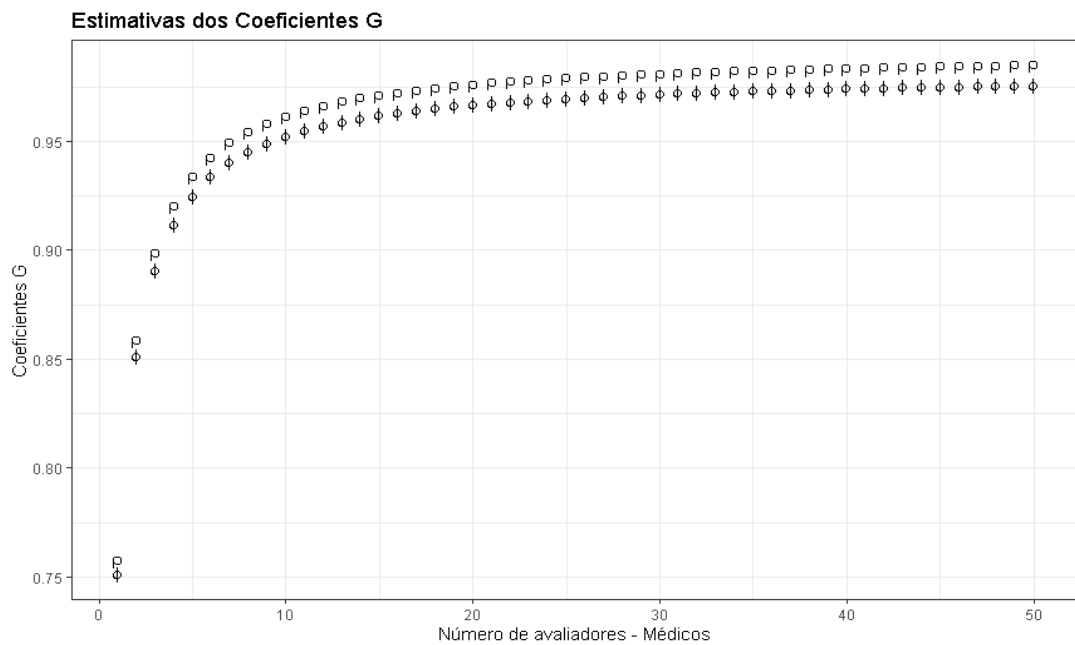
APPENDIX D. G coefficient estimates to maximize scale reliability of future studies (doctors)

Number of judges	G coefficients	
	ρ	Φ
1	0.76	0.75
2	0.86	0.85
3	0.90	0.89
4	0.92	0.91
5	0.93	0.92
6	0.94	0.93
9	0.96	0.95
12	0.97	0.96
15	0.97	0.96
18	0.97	0.96
21	0.97	0.97

Source: The author, 2022.

(ρ)- letter phi has more contributions to the variance; it is a more conservative coefficient, thus representing how generalizable the instrument is to different samples in other contexts. ϕ (Greek letter rho) represents how generalizable the instrument is to the sample, considering the relative differentiation between the elements of the object of study in a given sample.

G coefficient estimates to maximize scale reliability of future studies (doctors)



Source: The author, 2022.

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G coefficients/ G coefficient estimates/ number of judges – doctors

(ρ)- letter phi has more contributions to the variance; it is a more conservative coefficient, thus representing how generalizable the instrument is to different samples in other contexts. ϕ (Greek letter rho) represents how generalizable the instrument is to the sample, considering the relative differentiation between the elements of the object of study in a given sample.

APPENDIX E. G coefficient estimates to maximize scale reliability of future studies (pharmacists)

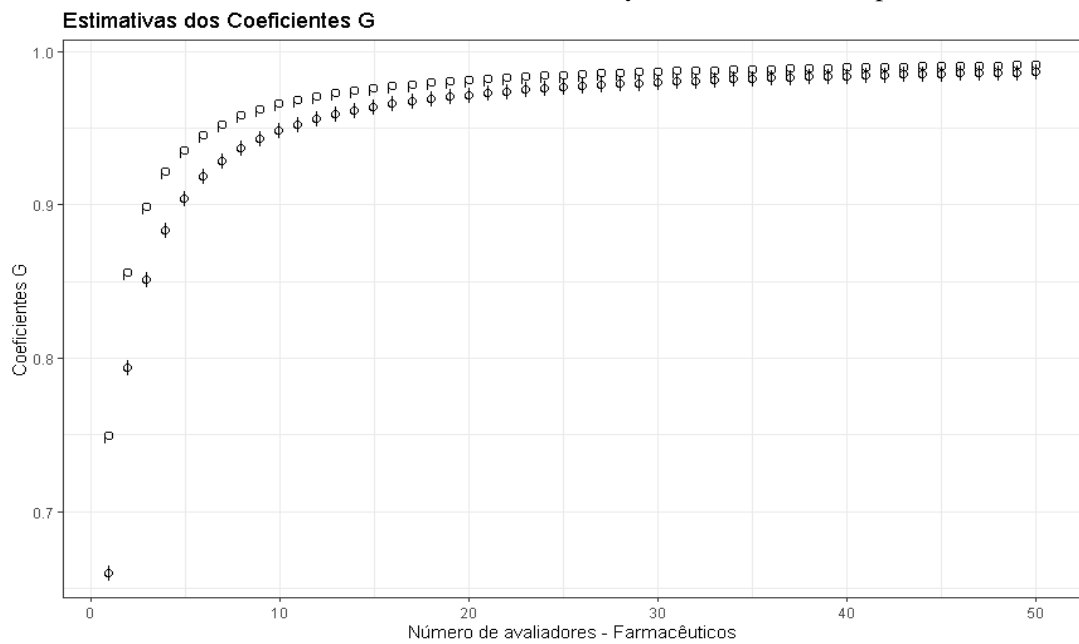
Number of judges	G coefficients	
	ρ	ϕ
1	0.75	0.66
2	0.85	0.79
3	0.90	0.85
4	0.92	0.88
5	0.93	0.90
6	0.94	0.91
9	0.96	0.94
12	0.97	0.96
15	0.97	0.96
18	0.98	0.97
21	0.98	0.97

Source: The author, 2022.

(ρ)- letter phi has more contributions to the variance; it is a more conservative coefficient, thus representing how generalizable the instrument is to different samples in other contexts.

ϕ (Greek letter rho) represents how generalizable the instrument is to the sample, considering the relative differentiation between the elements of the object of study in a given sample.

G coefficient estimates to maximize scale reliability of future studies (pharmacists)



Source: The author, 2022.

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G coefficients/ G coefficient estimates/ number of judges – pharmacists

(ρ) - letter phi has more contributions to the variance; it is a more conservative coefficient, thus representing how generalizable the instrument is to different samples in other contexts. ϕ (Greek letter rho) represents how generalizable the instrument is to the sample, considering the relative differentiation between the elements of the object of study in a given sample.

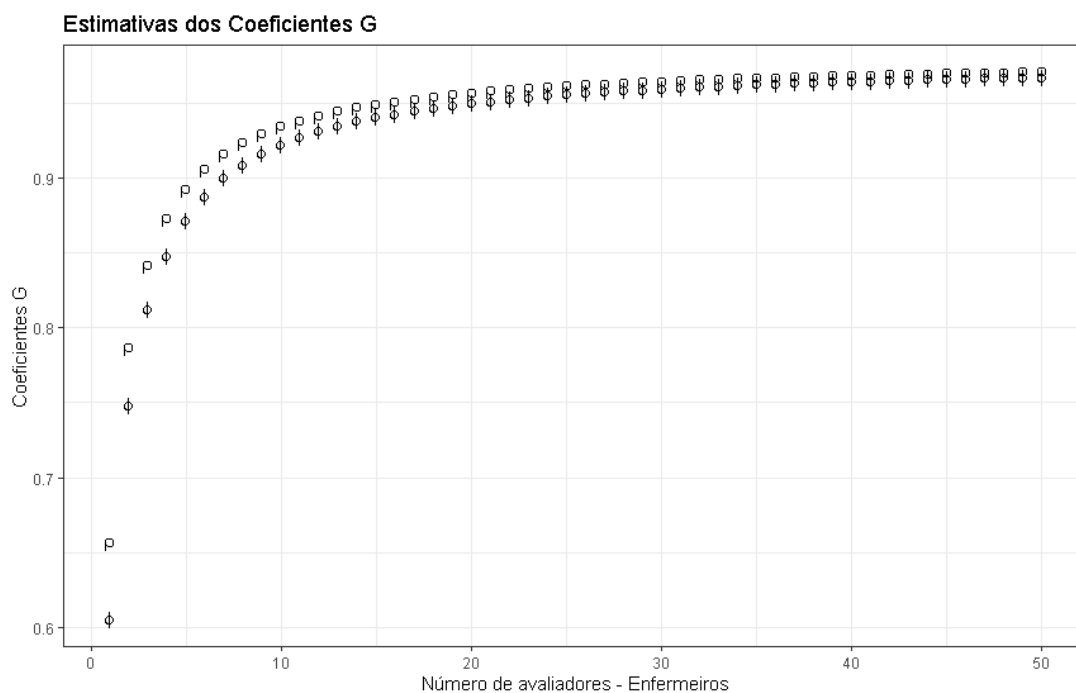
APPENDIX F. G coefficient estimates to maximize scale reliability of future studies (nurses)

Number of judges	G coefficients	
	ρ	Φ
1	0.66	0.60
2	0.79	0.75
3	0.84	0.81
4	0.87	0.85
5	0.89	0.87
6	0.90	0.89
9	0.93	0.92
12	0.94	0.93
15	0.95	0.94
18	0.95	0.95
21	0.96	0.95

Source: The author, 2022.

(ρ)- letter phi has more contributions to the variance; it is a more conservative coefficient, thus representing how generalizable the instrument is to different samples in other contexts. ϕ (Greek letter rho) represents how generalizable the instrument is to the sample, considering the relative differentiation between the elements of the object of study in a given sample.

G coefficient estimates to maximize scale reliability of future studies (nurses)



Source: The author, 2022.

Embedded text:

G coefficients/ G coefficient estimates/ number of judges – nurses

(ρ)- letter phi has more contributions to the variance; it is a more conservative coefficient, thus representing how generalizable the instrument is to different samples in other contexts. ϕ (Greek letter rho) represents how generalizable the instrument is to the sample, considering the relative differentiation between the elements of the object of study in a given sample.

APPENDIX G. Generalizability study (Doctors, Pharmacists, Nurses) APÊNDICE

G STUDY		
Sources of Variation	Estimated variance	Percentage of total variance
Case	3.923	41.7
Profession	0.434	4.6
Case x Profession	0.245	2.6
Judge: Profession	1.305	13.8
Residual	3.517	37.3
D STUDY		
Case	0.078	12.0
Profession	0.434	66.3
Case x Profession	0.005	0.7
Judge: Profession	0.130	19.9
Residual	0.007	1.1
G coefficients		
P	0.97	
Φ	0.98	

Source: The author, 2022. Note: The symbol "x" indicates cross.

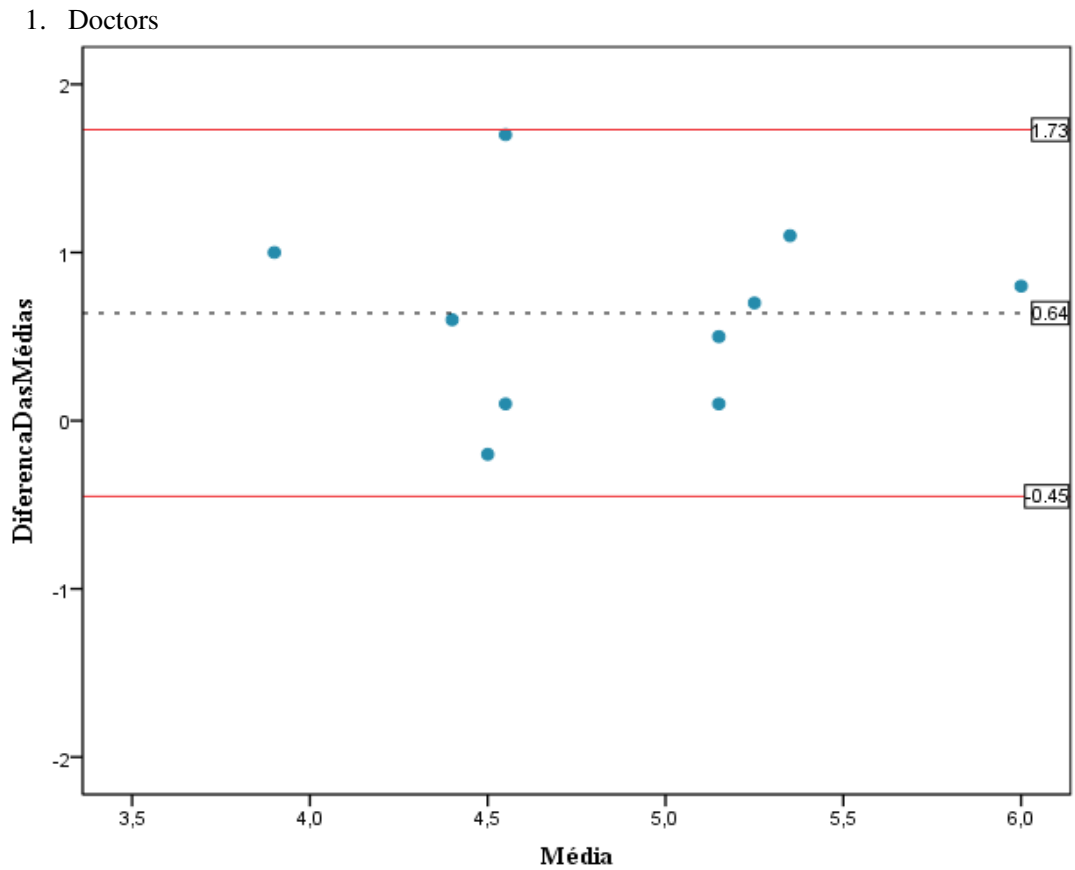
(ρ)- letter phi has more contributions to the variance; it is a more conservative coefficient, thus representing how generalizable the instrument is to different samples in other contexts. ϕ (Greek letter rho) represents how generalizable the instrument is to the sample, considering the relative differentiation between the elements of the object of study in a given sample.

APPENDIX H. G coefficients for a varied number of judges representing different professions

Scenario	G coefficient
1 judge from every two professions (2 judges in total)	0.85
1 judge from each profession (3 judges in total)	0.89
2 judges from every 2 professions (4 judges in total)	0.88
2 judges from every 3 professions (6 judges in total)	0.93

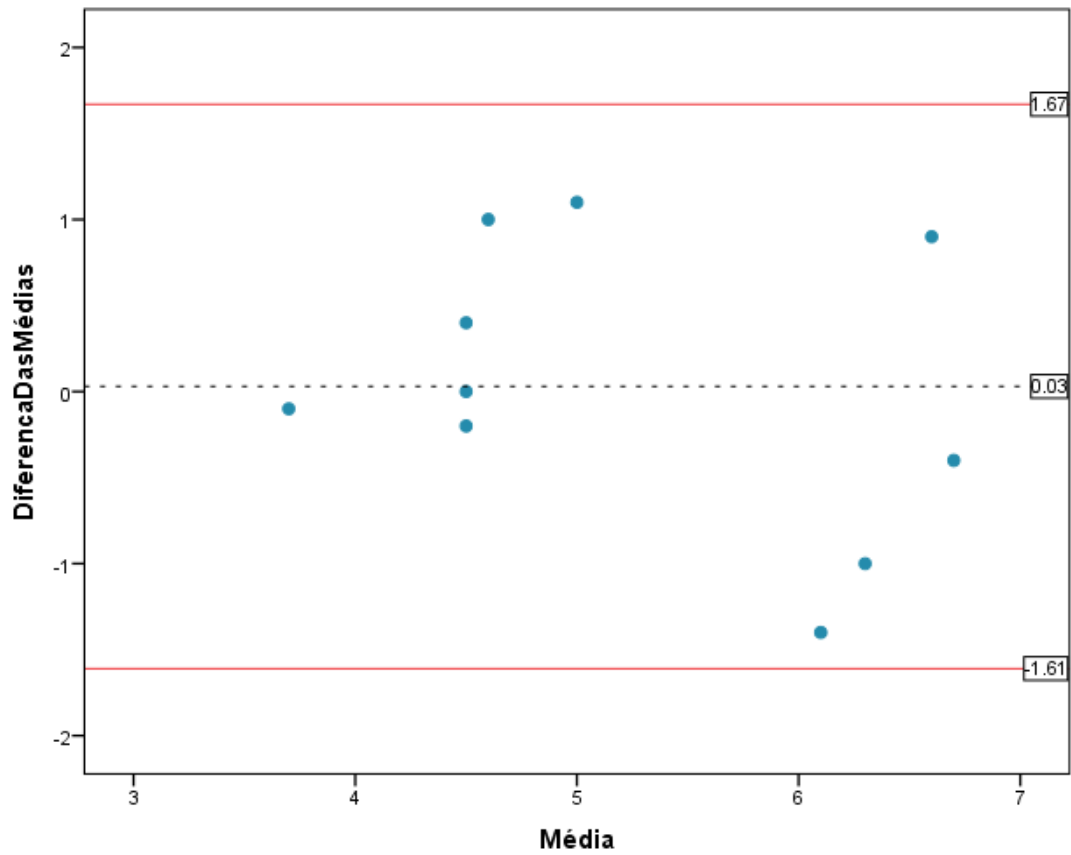
APPENDIX I. Cases of overlapped scores

Case #	Description	Cases with previously known score	Mean assigned score
5	An older patient facing difficulties in swallowing was prescribed effervescent ranitidine 150 mg twice daily for ulceration prophylaxis during continuous diclofenac therapy. A common non-soluble ranitidine tablet was administered, which the patient swallowed with some difficulty.	2.6	4.8
11	A patient with a history of heart failure was given a 100 mg oral dose of atenolol that was intended for another patient.	7.1	6.3
15	A patient prescribed 5 mg of IV morphine, received 5 mg of oral morphine solution intravenously (Dimorf® 10 mg/ml).	6.5	7.9
22	An older patient was prescribed paracetamol oral suspension (100 mg/ml) at a dose of 5 ml (500 mg) every six hours. A dose of 10 ml (1g) was administered.	1.5	4.1

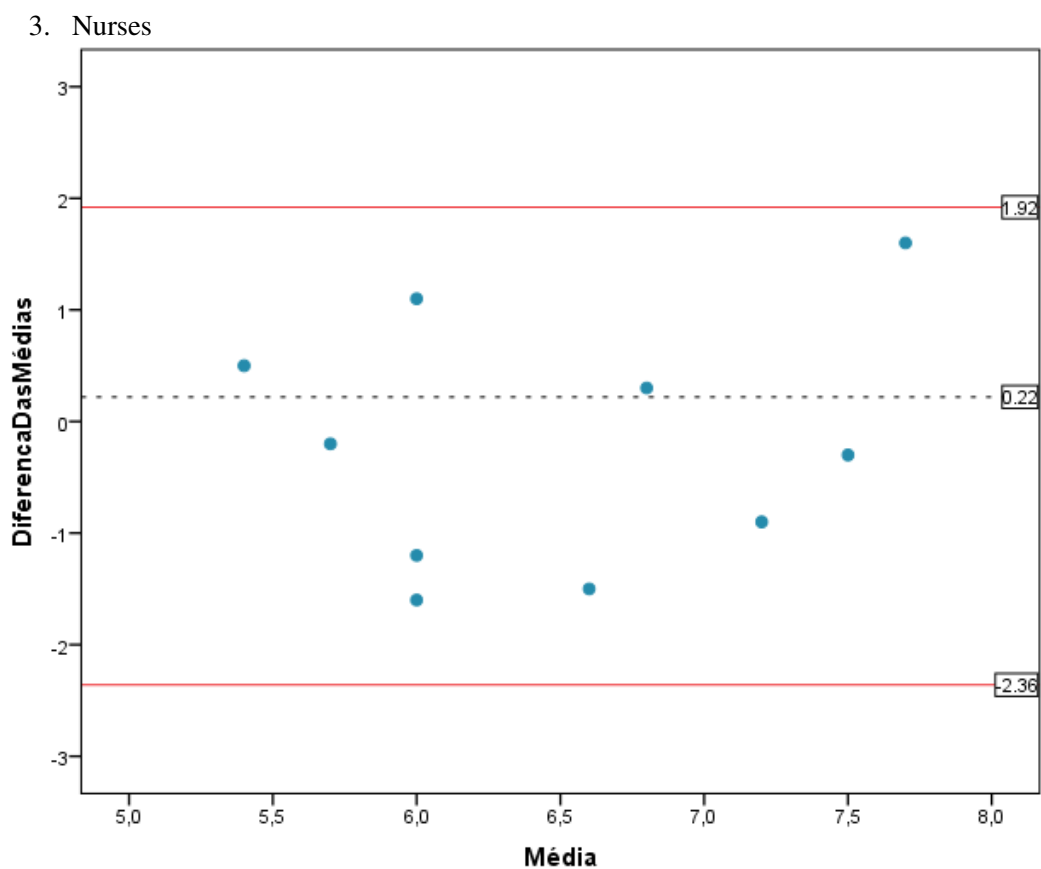
APPENDIX J. Bland-Altman plot

Embedded text: Variations between means/ Mean

2. Pharmacists



Embedded text: Variations between means/mean



Embedded text: Variations between means/mean

FIGURE LENGENDS

Figure 1. G coefficient estimates to maximize protocol reliability of future studies (doctors, pharmacists and nurses)

Figure 2. Comparing the judges' mean scores and the actual outcome severity

Figure 3. Mean score comparison of Brazil, Germany and the UK