Interrupted time series designs in healthcare: systematic review

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Version history

Amendment No.	Protocol version No.	Description of changes	Date of protocol
	Version 1	New document	

Background

Interrupted time series (ITS) are considered one of the strongest quasi-experimental designs and can be used to evaluate a variety of interventions (e.g., national guidelines, health policies, educational programs). ITS designs monitor a certain unit (e.g. population) over a period of time pre-and post-implementation of an intervention. The aim of this review is to find out how ITS studies are being reported and used in the health care setting.

Search Strategy

An electronic search will be undertaken to identify studies that have used ITS methods in MEDLINE. The search will be limited to 2015 with no language restrictions. The search strategy will mainly consist of text words and phrases using truncation symbols and adjacency operators. A detailed search strategy is documented in Appendix 1.1. Of the abstracts found, ten percent will be double assessed for inclusion and any disagreement will be resolved.

Inclusion and Exclusion Criteria

Types of studies

ITS studies will be eligible for inclusion if there is a minimum of two data points collected pre-intervention period and one post-intervention. Systematic reviews, meta-analyses, randomized trials, and studies with a separate control group will be excluded. There was no restriction on the language of study.

Types of participants

This review will have no restrictions on participants.

Types of interventions

Interventions that are associated with health and the healthcare of patients will be eligible. This could be for instance, a program to prevent infection, policies on antibiotic use, clinical or educational.

Types of outcomes

There will be no restrictions on the types of outcomes that can be included in this review.

A screening form (Appendix 1.2) will be used to identify studies that will be included in the review.

Data Extraction Strategy

Full-text copies of the titles and abstracts found eligible at the search strategy stage will be screened and assessed for inclusion by the inclusion and exclusion criteria. Ten percent of these title and abstracts will be doubled assessed and any disagreements will be resolved.

A data extraction form (Appendix 1.3) will record relevant details of the studies. For example, type of intervention; how many data points collected pre-and post-intervention; country of study; method of analysis; did they define a transition period. This form will be piloted on a randomly selected few first to check all the necessary data are being recorded.

Quality Assessment Strategy

Not required, as sections of the PhD will cover this.

Data Synthesis

If studies have multiple publications or corrections, then only the most up-to-date report will be used. Summary descriptions of the extracted data will be reported, either in tabular or graphical form (e.g., years of publications, population level and type of intervention.). The data will also be broken down by intervention type and descriptions reported to see if there are any differences (see Appendix 1.4 for dummy figures and tables).

Appendix 1.1: Search strategy

1. interrupted time series.tw,kw.
2. (pre adj1 post).tw.
3. (segmented adj3 regression).tw,kw.
4. quasi experiment$.tw,kw.
5. (before adj1 after).tw,kw.
6. arima.tw,kw.
7. (trend adj3 analys?s).tw,kw.
8. (longitudinal adj3 chang$).tw,kw.
9. autoregressive integrated moving average.tw,kw.
10. or/1-9
11. limit 10 to yr='2015'
12. randomi$ control$ trial$.ti,tw.
13. meta analys$.ti,kw.
14. limit 11 to "review articles"
15. 11 not (12 or 13 or 14)

Appendix 1.2: Screening form

1. Is the study a systematic review/meta-analysis?
   - ☐ Yes → Exclude
   - ☐ No

   a. If yes, was the review of interrupted time series studies/methods?
      - ☐ Yes
      - ☐ No

2. Did the study collect a minimum of two data points before and one after the intervention?
   - ☐ Yes
   - ☐ No → Exclude
   - ☐ Unsure

3. Did the study use an ITS analysis?
   - ☐ Yes
   - ☐ No → Exclude
   - ☐ Unsure

4. Does the study have a separate control/comparison group?
   - ☐ Yes → Exclude
   - ☐ No
   - ☐ Unsure

5. Is the intervention in health or healthcare?
   - ☐ Yes
   - ☐ No → Exclude
   - ☐ Unsure

6. Is the study to be included in the review?
   - ☐ Yes
   - ☐ No

Appendix 1.3: Data extraction form

Study ID *(surname of first author and year first full report of study was published)*
Report IDs of other reports of this study *(e.g. duplicate publications, follow-up studies)*

Eligibility – review inclusion criteria	
Did the study collect a minimum of two data points before and one after the intervention?	☐Yes ☐No
Did the study use ITS analysis?	☐Yes ☐No
Does the study have a separate control/comparison group?	☐Yes ☐No
Is the intervention in the health or healthcare?	☐Yes ☐No
Is it a full text paper?	☐Yes ☐No
Decision	☐ Include ☐ Exclude

Publication characteristics		***Page/Table/ Figure***
What did the authors define the design as in the title?	☐Interrupted time series ☐Time series ☐Before and after ☐Controlled before and after ☐Change analysis ☐Regression analysis ☐Change point ☐Time series regression analysis ☐Other, please specify: ☐None	
Is the paper published in one of the top four journals?	☐Yes ☐No	
Language of study		
Reference to protocol	☐Yes ☐No	
Funding source statement	☐Yes ☐No	
Country of study		

Study design		***Page/Table/ Figure***
Were the study objectives defined?	☐Yes ☐No	
Was a background/rationale given for doing a ITS study?	☐Yes ☐No • If yes, what was the reason? ☐Practical ☐Ethical ☐Natural experiment (no control over the intervention) ☐No adequate control group ☐Other, please specify:	
How many interruptions (interventions) are there across multiple time points?		

Outcome	☐Primary only ☐Primary and secondary ☐Not specified	
Questions below correspond to the primary outcome or the first reported		
Type of intervention	☐Policy/programs ☐Guidelines ☐Financial ☐Health systems ☐Behavioural ☐Sales and dispensing ☐Other, please specify:	
Level of intervention	☐Individual ☐Organisational ☐Groups, please specify: ☐Large scale/population ☐Multiple countries ☐Other, please specify:	
Participants: who was the target group/recipient?	Population based on: ☐Disease (patients) ☐Demographic ☐Occupational ☐Health professionals ☐Population ☐Other, please specify:	
Study design description	☐Interrupted time series ☐Time series ☐Before and after ☐Controlled before and after ☐Change analysis ☐Regression analysis ☐Change point ☐Time series regression analysis ☐Other, please specify: ☐None	

All further questions relate to the primary outcome or the first outcome reported.

Methodology characteristics		***Page/Table/ Figure***
Temporal design	☐Retrospective (i.e. identification of subjects from past records) ☐Prospective (i.e. recruitment of subjects before any intervention)	
Were the investigators in control of the interruption/intervention?	☐Yes ☐No ☐Not stated	
Unit of intervention	☐Country ☐Region ☐Individuals ☐Household ☐Community ☐Company ☐Hospital/healthcare practice ☐Department ☐Ward ☐Other, please specify:	
Number of units		
Number of sites		
Type of outcome	☐Binary ☐Continuous ☐Rate ☐Other, please specify:	

Data collection		***Page/Table/ Figure***
Data Source	☐Hospital data ☐National data ☐Health records ☐Patient self-reported ☐Other, please specify:	
What was the frequency of the data collection?	☐Yearly ☐Quarterly ☐Monthly ☐Weekly ☐Other, please specify:	
How many data points in the pre intervention period?		
How many data points in the post intervention period?		
How many data points were included in a transition period?		
How many data points were included in other time periods apart from the transition period?		

Statistical analysis		***Page/Table/ Figure***
Was there a description of the analysis?	☐Yes ☐No • If yes, what was the method? ☐Segmented regression ☐ARIMA ☐GEE ☐Other, please specify:	
Was autocorrelation considered?	☐Yes ☐No • If yes, what was the method used to identify autocorrelation? ☐Durbin Watson test ☐ACF ☐PACF ☐Other, please specify: • If yes, was autocorrelation present? ☐Yes ☐No ☐ Not stated • If yes, what method was used to adjust for autocorrelation?: If yes, what order was the autocorrelation?:	
Was nonstationary considered?	☐Yes ☐No • If yes, was it present? ☐Yes ☐No ☐Not stated If yes, what was the method used to adjust for it?:	
Was seasonality considered?	☐Yes ☐No • If yes, was it present? ☐Yes ☐No ☐Not stated If yes, what was the method used to adjust for it?:	

Were covariates adjusted for?	☐Yes ☐No	
Was the unit of analysis the same as the unit of intervention?	☐Yes ☐No • If no, what was the unit of analysis? ☐Country ☐Region ☐Individuals ☐Household ☐Community ☐Company ☐Hospital/healthcare practice ☐Department ☐Ward ☐Other, please specify:	
Was there a sample size calculation undertaken?	☐Yes ☐No ☐No formal calculation • Was there a rational to the sample size used? ☐Yes ☐No	
Was there a description of how missing data will be handled?	☐Yes, please specify: ☐No	
Which period was the intervention time point included?	☐Pre ☐Post ☐Not included ☐Not clear	
Was the statistical software used reported?	☐Yes ☐No	
Was a transition period used in the primary analysis?	☐Yes ☐No • Was an explanation given to why there was or was not a transition period? ☐Yes ☐No ☐Limited • Where the points included in the model ☐Yes	

	☐No	
Apart from the transition period, was there any time period within the study accounted for?	☐Yes, please specify: ☐No • Where the points included in the model ☐ Yes ☐No	
Was a sensitivity analysis carried out?	☐Yes ☐No What was the analysis? • Transition period ☐Yes ☐No • Where the time points included in the model? ☐Yes ☐No • Shape of the pre-intervention line investigated? ☐Yes ☐No • Was any other period apart from the transition period accounted for? ☐Yes ☐No • Where the time points included in the model? ☐Yes ☐No • Subgroup analysis? ☐Yes, please specify: ☐No	

Results		***Page/Table/ Figure***
Were the characteristics of the unit of intervention reported?	☐Yes ☐No	
Missing Data	Was the number of units the same in the pre and post period? ☐Yes ☐No ☐Not clear Was there a description of how missing data was handled? ☐Yes, please specify: ☐No ☐Not relevant	
Are there any outliers?	☐Yes ☐No	
Are results presented graphically?	☐Yes ☐No • Is the quality good enough for data to be extracted? ☐Yes ☐No	
How are the numeric figures reported?	☐Absolute ☐Relative change(s) ☐Other, please specify: • How were they calculated? ☐Relative to last pre point ☐Relative to average baseline period ☐Baseline ☐Not stated ☐Other, please specify:	
Are effect sizes reported?	☐AUC ☐Change in level, please specify if its immediate change or any other period of change: ☐Change in slope ☐Decay effect ☐Intercept ☐Pre intervention slope ☐Other, please specify:	

Are confidence intervals given?	☐Yes ☐No ☐Some	
Are standard deviations reported?	☐Yes ☐No ☐Some	
Are p-values reported?	☐Yes ☐No ☐Some • If yes or some how are they reported? ☐Exact values ☐Only an indication if they were significant or not	

Discussion		***Page/Table/ Figure***
Are key results summarized with reference to the relevant objectives?	☐Yes ☐No ☐Some	
Was there a discussion/statement of any other interventions/events that could have impacted the results?	☐Yes ☐No	
Was there a discussion of stability of unit of intervention (e.g. ward, region) characteristics over time?	☐Yes ☐No	
Where outliers discussed and the potential implications this could have?	☐Yes ☐No ☐No indication of outliers	
Was potential bias discussed?	☐Yes ☐No	
Were weaknesses/limitations discussed?	☐Yes ☐No	
Were strengths discussed?	☐Yes ☐No	
Was an overall interpretation of results given considering all of the findings?	☐Yes ☐No	

Title/ Abstract	
Was the intervention clearly defined?	☐Yes ☐ No
Was the design of the study clearly defined?	☐Yes ☐ No
Was the method of analysis given?	☐Yes ☐ No
Was the number of pre-intervention time points reported?	☐Yes ☐ No
Was the number of post-intervention time points reported?	☐Yes ☐ No
Was the main results reported?	☐Yes ☐ No
Was the impact of the intervention discussed?	☐Yes ☐ No

Appendix 1.4: Dummy figures and tables

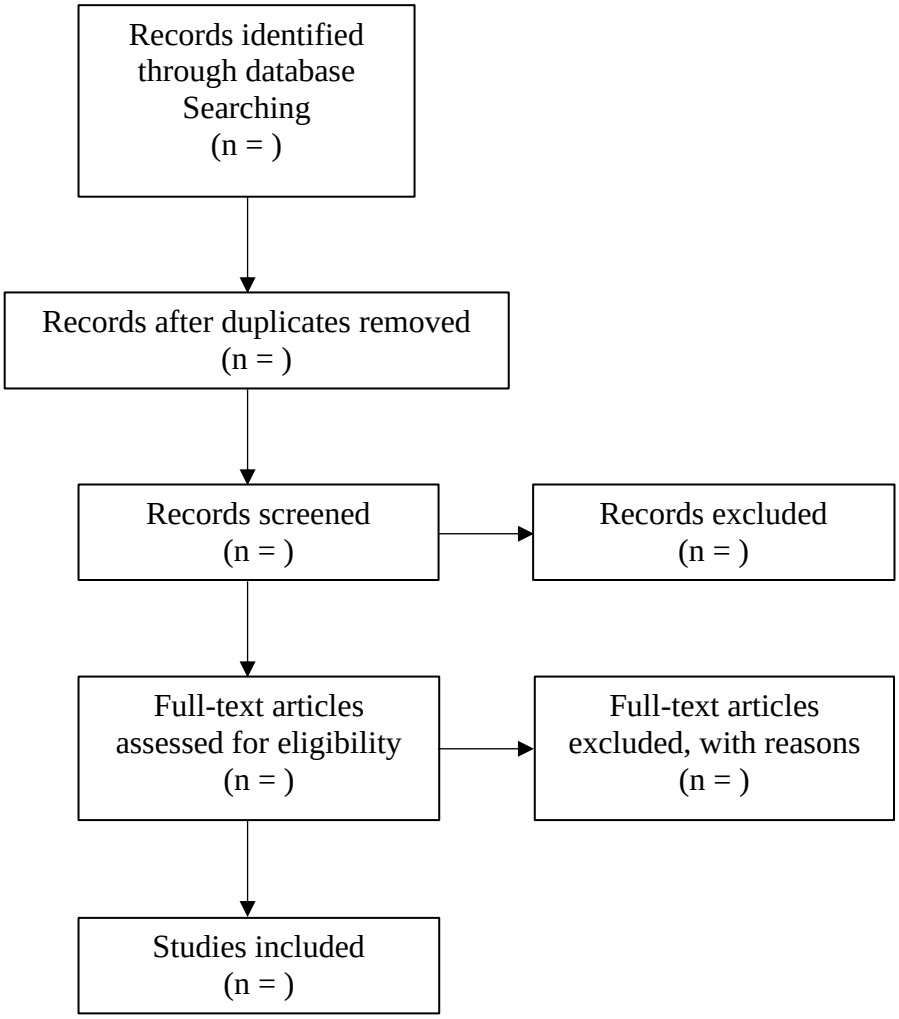

Figure 1. Flow diagram

Table 1. Publication Characteristics

	N =
Top four journal	
Language of study	
English	
French	
⋮	
Country of study	
UK	
USA	
Australia	
⋮	
Definition of study design in the title:	
Interrupted time series	
Time series	
Before and after	
Controlled before and after	
Change analysis	
Regression analysis	
Change point	
Time series regression analysis	
Other	
None	
Funding Source statement	
Protocol referenced	

Values are numbers and percentages

Table 2. Study Design

	N =
The study objectives defined	
Background/rationale given for doing a ITS study	
Outcomes	
Primary only	
Primary and secondary	
Not specified	
The number of interruptions (interventions) across multiple time points	
One	
Two	
Three	

Values are numbers and percentages

Tables below correspond to the primary outcome or the first reported outcome

Table 3. Study Design continued

	N=
Type of intervention	
Policy/programs	
Guidelines	
Financial	
Behavioural	
Screening	
Sales and dispensing	
Other	
Level of intervention	
Individual	
Organisational	
Groups	
Large scale/population	
Multiple countries	
Other	
Target population	
Disease (patients)	
Demographic	
Occupational	
Health professionals	
Population	
Other	
Study design description	
ITS	
Time series	
Time series regression	
Before and after	
Controlled before and after	
Change analysis	
Regression analysis	
Change point	
Time series regression analysis	
Other	
None	

Values are numbers and percentages

Table 4. Methodological Characteristics

	N =
Temporal design	
Retrospective	
Prospective	
Investigators were in control of the intervention?	
Unit of intervention	
Country	
Region	
Household	
Community	
Hospital/healthcare practice	
Department	
Ward	
Other	
Number of units	
Number of sites	
Type of outcome	
Binary	
Continuous	
Rate	
Other	

Values are numbers and percentages

Table 5. Data collection

	N=
Data source	
Hospital data	
National data	
Health records	
Patient self-reported	
Other	
Frequency of data points	
Yearly	
Quarterly	
Monthly	
Weekly	
Other	
Pre-intervention period data points	
Post-intervention period data points	
Data points in the transition period	
Data points in other time periods used apart from the transition period	

Values are numbers and percentages or median (interquartile range), range

Table 6. Statistical analysis

	N=
A description of the analysis	
The method used	
Segmented regression	
ARIMA	
GEE	
Other	
Autocorrelation was considered	
Method used to identify autocorrelation	
Durbin Watson test	
ACF	
PACF	
Autocorrelation present	
Yes	
No	
Not stated	
Method used to adjust for Autocorrelation	
The order of the autocorrelation	
One	
Two	
Nonstationary was considered	
Nonstationary was present	
Method used for nonstationary	
Seasonality was considered	
Seasonality was present	
Method used to account for seasonality	
Covariates adjusted for	
Unit of analysis the same as the unit of intervention	
The unit of analysis if not the same	
Country	
Region	
Individuals	
Department	
⋮	
A sample size was undertaken	
Yes	
No	
No formal calculation	
A rational to the sample size used	
A description of how missing data was handled	
The period the intervention time point was included	
Pre	
Post	
⋮	
Description of the statistical software used	
The transition period was used in the primary analysis	
Explanation for a transition period	
Yes	

No	
Limited	
Other time period used that were not a transition period	
Sensitivity analysis carried out	
Transition period	
Shape of pre-intervention line	
Other periods excluded apart from the transition period	
Subgroup analysis	

Values are numbers and percentages

Table 7. Results

	N=
Characteristics of the unit of intervention reported	
Missing Data	
Number of units in the pre and post period the same	
Yes	
No	
Not clear	
Description of the missing data	
Yes	
No	
Not relevant	
Outliers	
Graph of results	
Quality good enough	
Figures reported	
Absolute	
Relative	
Both	
Other	
The calculation of relative	
Relative to last pre point	
Baseline	
⋮	
Effect sizes reported	
AUC	
Change in level	
Change in slope	
⋮	
Confidence intervals reported	
Standard deviations reported	
p-values reported	
Reported as	
Exact	
Only an indication of significance	

Values are numbers and percentages

Table 8. Discussion

	N=
Key results summarised with reference to objectives	
Discussion/statement of any other interventions/events that could have impacted results	
Stability of the characteristics of the unit of intervention over time	
Outliers and there potential implications	
Bias	
Weaknesses/limitations	
Strengths	
Over interpretation of results	

Values are numbers and percentages

Table 9. Title/Abstract

	N=
Intervention clearly defined	
Design of the study clearly defined	
Method of analysis	
Number of pre-intervention time points stated	
Number of post-intervention time points stated	
Main results reported	
Impact of intervention discussed	

Values are numbers and percentages

Table 10. Number of time points

	Number of time points
Method of analysis	
Segmented regression	
ARIMA	
GEE	
Temporal design	
Retrospective	
Prospective	
Investigators in control of the intervention	
Data source	
Hospital data	
National data	
Health records	
Patient self-reported	
Sample size calculation used	
Frequency of data collection	
Yearly	
Quarterly	
Monthly	

Weekly Other	

Values are median, interquartile range, range

Table 11. Method of analysis and what was considered

Method of analysis	**Autocorrelation**	**Nonstationary**	**Seasonality**
Segmented regression ARIMA GEE ⋮			

Values are numbers and percentages

Table 12. The number of time points and the use of a transition period

Time points	**Transition period**
< 6 6-10 11-20 21-30 31-40 > 41	

Values are numbers and percentages

Table 13. Frequency of data points and was seasonality adjusted for

Frequency	**Seasonality**
Yearly Quarterly Monthly Weekly Other	

Values are numbers and percentages

Table 14. Study design description and the method of analysis

	Segmented regression	ARIMA	GEE	Other
ITS				
Time series				
Before and after				
Control before and after				
Change analysis				
Regression analysis				
Change point				
Time series regression analysis				
Other				