# SAGE Research Methods Cases Medicine & Health Submission for Consideration

**Case Title**

**"Establishing the effectiveness of public health interventions using sequential meta-analysis: case study using stair-promotion interventions"**

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**Discipline**

Public Health [D26]

**Sub-discipline**

*If you chose Medicine, Public Health, or Nursing as discipline, pick sub-discipline from the relevant list below. There are no sub-discipline options for Dentistry.*

[For Medicine: choose sub-discipline]

Environmental Public Health [SD-PH-1]

[For Nursing: choose sub-discipline]

**Academic Level of intended readership**

**Postgraduate**

**Contributor Biographies**

Adrian Bauman is Professor of Public Health at the University of Sydney, Australia. He has extensive experience in public health program evaluation, and in epidemiology and health promotion research. He is best known for work in physical activity and public health research and policy. He co-directs the WHO Collaborating Centre on Physical Activity, Nutrition and Obesity. He is well-published in the scientific literature (from 2014-present has been named in the Thompson Reuter (Clarivate) lists of the most cited researchers). He works in research translation methods, and in scaling up interventions to the population level, as well as in complex program evaluation and systems approaches to prevention. In his spare time, he is a daily dog walker, and a slow but regular cyclist.

Karen Milton is a lecturer in public health in the Norwich Medical School at the University of East Anglia, UK. In this role she teaches medical students about the importance and principles of public health, and particularly the primary prevention of chronic disease. Her research area is physical activity and public health, where she aims to advance knowledge and understanding of 'what works' to get populations more active to reduce the burden of noncommunicable diseases. Karen's interest in this field spans the measurement of physical activity, population level interventions, evaluation and policy research. She has been involved in developing national and international physical activity recommendations as well as supporting a range of countries to develop national physical activity strategies. Karen spends her spare time being active and is a keen open water swimmer.

**Published Articles**

Bauman A, Milton K, Kariuki M, Fedel K, Lewicka M. Is there sufficient evidence regarding signage-based stair-use interventions? A sequential meta-analysis. *BMJ Open*. 2017; 7: e012459.

**Abstract**

Prevention trials often generate significant health or risk factor improvements, but these improvements are limited to the selected samples of people enrolled in these studies. In order to make population health gains, we need to develop methods for translating evidence from these trials into practice at the broader community and population levels. One barrier to this process is researchers themselves, who conduct replications of small-scale trials, rather than conducting intervention research at scale. Our example of this is interventions to encourage short episodes of physical activity through signs promoting stair use. We pooled the evidence from these interventions from 1980 to 2014. We carried out a meta-analysis to estimate the proportion of people that changed from the elevator to the stairs following the introduction of signage. Our innovation was to use a sequential meta-analysis method, usually described in relation to clinical settings and trials. We used this method to estimate when there was sufficient evidence of stair-sign effectiveness for public health actions to be scaled-up, and we found this was around 2006. Studies since then have not contributed new evidence to the field. Methods here enabled us to see when policymakers should have implemented this intervention to the community at large, and researchers then should have focused their investigations on identifying barriers and facilitators to their implementation and assessing intervention effects at scale.

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**Learning Outcomes**

Describe the research evidence that is generated by individual studies in stair use promotion

Outline the transferability of research methods across disciplines

Explain the purpose and usefulness of sequential meta-analysis

Discuss the applicability of sequential meta-analysis to public health interventions

Appreciate the need for research translation of effective interventions

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**Case Study**

**Introduction to the issue that led to this paper**

Promoting physical activity is important in chronic disease prevention and in improving health and well-being in individuals and in communities. Despite substantial evidence of the benefits of physical activity, efforts to increase physical activity at the population level have not been very successful in many countries (Sallis 2016). Physical activity rates have remained static for one to two decades in many high-income countries, and may have decreased in many economically developing middle-income countries, contributing substantially to increased noncommunicable disease risk.

There are several contributors to this lack of success. Firstly, the research evidence for interventions often comes from small-scale controlled studies, which do not provide evidence for what works at scale and in the real world. In addition, there are challenges to implementing evidence-based

physical activity interventions at the whole community level. This involves substantial cost and effort, and usually requires working beyond the health sector with a myriad of other agencies.

To increase physical activity participation, innovative solutions are required. In 2017, we published a paper summarising the effects of stair use interventions, which are one potential type of scalable intervention for population health improvement (Bauman 2017). The purpose of this case study is to explain why we did that study, what it added to the literature, and in particular, to focus on the research methods used. This illustrates an example of adapting research methods from one discipline to another, contributing to the evidence base for effective public health interventions, and providing guidance, especially for researchers in this field.

**Section summary:**

- Currently, levels of physical activity are not increasing in many countries
- Population-level delivery of interventions is required to increase physical activity levels
- Physical activity levels are declining in many middle-income countries, as economic development removes physical activity from everyday life

**What is the paper about?**

Stair climbing requires an energy expenditure of approximately 8.5 kcal/kg/h and can be classified as vigorous intensity physical activity, which is a level that is beneficial to health, even in small amounts (Gottschall et al., 2010; Lewis et al., 2012). Stair climbing has been associated with a wide range of health outcomes including reduced risk of all-cause mortality (Rey-Lopez 2019), as well as improved fitness including lower resting heart rate, increased aerobic capacity and improved dynamic balance (Donath et al., 2014).

A simple, inexpensive and potentially scalable intervention is to encourage stair use among people who typically use the escalator or elevator (Dolan et al., 2006, Nocon et al., 2010). These interventions often use 'point-of-decision' prompts, usually in the form of signs or messages, at a point where individuals are shown a choice between stair climbing or escalator/elevator use. The motivational sign is easy to understand and is designed to encourage people to change from the inactive escalator to an active choice to use the stairs (see Figure 1, for examples).


Figure 1. Examples of stair use promotional signs [for use in Government buildings], New South Wales Government, Australia 2015

(https://www.8700.com.au/fast-facts-on-fast-food/infographics/take-the-stairs-4/ )

To date there have been many stair use interventions, which used a variety of signs to the left or the right of the foot of the stairs/escalator, or used banner rises as a location for message placement. The promotional messages were brief, with either a picture or a few words indicating the benefits of the choice to use the stairs. Many studies were conducted in health facilities, university buildings or university libraries, with only a few conducted in general community settings such as shopping centres or train stations. Therefore, the evidence base was limited to the settings used, but did provide a best-case estimate of how well stair use signage could motivate people to change to using the stairs.

The purpose of this study was to summarise the evidence on the effectiveness of stair use interventions, using a technique known as meta-analysis. This involves the pooling of results from multiple studies to initially determine the overall average effect of an intervention. In this paper, we used this technique in a number of unusual ways; our overall purpose was not just to determine the average intervention effect, but rather to determine when the evidence was sufficient from all the studies that had been conducted to recommend stair sign interventions for wide-scale dissemination.

**Section summary:**

- Innovative widespread interventions are needed to increase physical activity at the population level
- A promising approach is to implement “signs to motivate stair use” in community settings
- Once the evidence is established that interventions work, they need to be scaled up across multiple settings

**The history of relevant methods: sequential meta-analysis**

Sequential meta-analysis overcomes some of the limitations inherent in the traditional approach to meta-analysis, as it allows for pooling of estimates despite study heterogeneity and it adjusts for the impact of multiplicity (repeated significance testing). However, another use for meta-analysis was developed in clinical research and attempted to understand when there were sufficient randomised controlled trials to introduce or change therapy, and when the evidence was convincing that no further trials were needed. This technique, initially described as cumulative meta-analysis, identified that lidocaine treatments for heart attacks were ineffective by the 1980s. The key point was identifying "when there was sufficient evidence to change clinical practice", although this therapy was mistakenly used in clinical practice for many further years (Mulrow, 1994).

This technique, now usually called sequential meta-analysis, has been used to identify potential risk factors for disease, and indicate over serial trials whether the evidence for a particular risk factor is consistent or lost (Bolland 2014). Furthermore, clinical interventions can be pooled and meta-analysed to assess when there is sufficient evidence for that intervention to be scaled-up in clinical practice, as was demonstrated for exercise as a treatment for knee osteoarthritis (Uthman 2013).

These methods have been reviewed by the Cochrane Collaboration, and focus on estimating pooled effects of controlled trials, and to identify when no further trials are needed (Cochrane 2018). The Cochrane expert group had some concerns about this method, given the dichotomisation of pooled results as "effective or ineffective" at a particular threshold, and also the range of potential stakeholders who might use the results (Cochrane 2018). For this public health meta-analysis, the primary aim was quite different, as it was targeting researchers, to reduce the further and unnecessary conduct of wasteful studies, and to focus efforts on dissemination of this proven public health intervention. This is in the context of reducing unnecessary research from being conducted (Chalmers 2009), which could have been informed by a prospective meta-analysis or living systematic review (Elliott 2014).

More recent methods in trial sequential meta-analysis have used techniques for monitoring boundaries of significance, using cumulative Z curve boundaries over time. By plotting the accumulating pooled evidence for an intervention over time, it is possible to see the point at which the z-curve sequential monitoring boundary is crossed (when pooled statistical significance is identified). This is the point in time at which the intervention is deemed to be effective (Wettersley 2017). This method also avoids type I and type II errors due to sequential testing, which were problems in previous methods for sequential meta-analysis. These more recent approaches have demonstrated cross-sectionally that exercise is consistently associated with body mass index or obesity levels (Kelley 2015), and that exercise is associated with depression (Krogh 2017), and these methods show exactly when there was sufficient evidence to reach these meta-analytic conclusions.

Sequential meta-analysis has not typically been applied in public health. A key reason for this is that public health evidence is not often generated through randomised controlled trials, which is the type of study design to which sequential meta-analysis has almost always been applied. In addition, interventions in public health and measures of both exposure and outcome often vary between studies. For example, behavioral interventions are rarely comparable, and measures of physical activity or diet are often widely different between studies. This can present challenges for pooling public health intervention data.

Stair use interventions provide an unusual degree of comparability among studies. Most of the interventions are signage based, simple, and relatively similar in terms of characteristics and duration, and therefore the interventions can be pooled. Similarly, the outcomes of these studies are usually measured as the proportion of people using the stairs before and after the signage, and

these research designs and outcome metrics of physical activity are highly comparable among studies. This means that studies can be subjected to meta-analysis. One issue is that they are almost always uncontrolled, in other words they are before-after studies, which is different to other sequential meta-analyses that usually pool data from controlled trials. However, it is quite possible to calculate effect sizes (the standardised mean difference, commonly used in meta-analysis) for a single group design, or separately for intervention and control group subjects in randomised trials. Here, single group estimates of stair use intervention effects were calculated and pooled.

Several previous researchers had estimated average effect sizes across stair use interventions. The first review was of eight studies, reported in 2006 (Dolan et al., 2006), which estimated around a 2.8% average increase in stair use following exposure to a sign. A narrative systematic review of 25 studies reported positive results of these interventions (Nocon et al., 2010). The next review assessed 50 studies, and reported that over two-thirds of these studies showed an increase in stair use following the promotional intervention (Bellicha et al., 2015). Other systematic reviews and syntheses of the evidence have reported similar results (Soler et al., 2010, Jennings et al., 2017). These studies typically demonstrated that on average, stair use signage increased stair usage by an absolute increase of 3 to 6%.

Given this published research, there was no need for another meta-analysis that simply estimated the average effect size. Our purpose was slightly different; we wanted to estimate, amongst the plethora of studies, when there was sufficient evidence for scaling up these interventions to the wider community setting, and no need for further small-scale stair use research. Hence, we applied the trial sequential meta-analytic method to all the stair use interventions that we could identify which had similar interventions and outcome measures, such that we could identify when sufficient evidence was available. This was conducted retrospectively, using all published stair use studies from the very first one in 1980 through until the end of 2014.

**Section summary:**

- Meta-analysis is an established method for pooling data from clinical trials to summarise their efficacy
- This study adapted meta-analytic methods to public health settings, where non-randomised pre-post designs were used to evaluate stair promoting signs
- The purpose of this study was to establish when there was enough evidence for public health action to scale-up these signs across the community

**Methods used, why we used them, and what they showed**

The first step was to identify all published research studies that have investigated the effectiveness of signs in encouraging stair use (Bauman et al., 2017). This involved undertaking a systematic search of the published literature using two electronic databases, Scopus and Medline. Studies were eligible for inclusion if they used “point of decision” signs (including posters and stair rise banners) to encourage stair use, and reported the number of observations, and either the odds ratio with 95% confidence intervals or the number and percentage of people observed to use the stairs at baseline and post intervention. The reported denominator in these studies was total observations of both stair and escalator/elevator use, and the primary outcome was the proportion of stair usage pre-post intervention. Due to the non-randomised pre-post design in these evaluations, the widespread use of objective measures (mainly direct observation of stairs vs escalator use), and in the interests of maximising inclusivity of evidence, no formal assessment of study quality was undertaken.

We identified 50 studies for inclusion in the review, with the first study being conducted in 1980. We initially conducted a traditional meta-analysis to calculate the pooled effect size for stair use interventions across all included studies. The results indicated that the likelihood of using the stairs increased by 52% following the installation of a promotional sign (pooled odds ratio, OR=1.52, 95% CI 1.37-1.70).

We then undertook a sequential meta-analysis (trial sequential analysis) of the studies, to determine the point at which there was sufficient evidence that stair signs are an effective intervention. Initial results showed that even the earliest studies showed significant increases in stair use. However, due to the low volume of pedestrian traffic (events), the evidence base lacked statistical power. Over time, as more studies were accumulated, the strength of the evidence grew and by 2006 a threshold was reached whereby it could be concluded that stair sign interventions definitively lead to significant increases in stair use. Further studies published beyond that date did not further contribute to the evidence base for stair use effectiveness, although at least 30 such studies have been conducted.

**Section summary**:

- Sequential meta-analysis is a statistical approach to pooling data from sequential studies to determine when there is sufficient evidence for certainty regarding the effectiveness of the intervention
- Our analyses revealed a significant increase in stair use and by 2006, enough was known so that no further studies were needed
- The application of sequential meta-analysis to public health interventions has the potential to reduce wasteful research into interventions of proven effectiveness.

**What the results of our study mean**

Installing stair signs is a low cost intervention, which is easy to implement and leads to significant increases in stair use. This simple intervention therefore has considerable potential for promoting active lifestyles and decreasing the burden of ill-health due to inactivity. However, the potential of stair use interventions can only be realised if they are scaled-up to the population level. This would mean replication of hundreds of stair use signage interventions across many settings such as public transport, shopping centres, office buildings, and even potentially hotels and airports. The research agenda, we would argue, should be focusing on identifying barriers and facilitators to implementing stair use signage across these many settings, and then testing and evaluating solutions to those concerns, such that stair use interventions can be tested and implemented at scale. Despite strong evidence on the effectiveness of stair signs by 2006, scale-up of this type has been rarely reported in the research literature. This highlights a gap between what is known from research evidence and the challenges to implementation for policymakers and in real-world practice.

**Implications, reflections, lessons learned for researchers**

Sequential meta-analysis provides a method for identifying the point in time in which there is sufficient evidence on the effectiveness of an intervention, after which it should be scaled-up in practice. The methods we used were derived from clinical epidemiology and clinical trial research, but have been applied in our study to preventive programs in community settings. The translation of research methods involved adapting meta-analytic methods to consider single group (pre-post) designs to calculate the contribution of each intervention to the overall evidence. The results show

that there has been good evidence of the effectiveness of stair promotion signs since 2006, yet the implementation of this intervention in practice has still not occurred at scale.

There are several important lessons from this research. Firstly, it demonstrates that sequential meta-analysis can be applied to real-world public health interventions, even those not using randomised trial designs. Secondly, it demonstrates the usefulness of the approach in determining when a volume of evidence is 'sufficient'. Thirdly, it indicates that much research has been conducted in this area since 2006, which has not contributed further to the evidence base and is therefore wasteful use of resources. Fourth, it highlights the research-practice gap, whereby interventions do not necessarily get scaled-up in practice, despite strong research evidence of effectiveness. We conclude that there is no further need for small-scale stair use evaluations, but there is a real need for dissemination and advocacy to ensure the translation of research evidence into community prevention practice.

Stair signs are just one example of a public health intervention that has repeatedly been tested in relatively small-scale research studies. From the research methods perspective, there is potential to apply sequential meta-analysis methods to other interventions to determine whether a threshold of evidence has been reached. This could help in reducing wasteful research into interventions of known effectiveness and legitimise a shift in focus towards wider population-level scale-up.

TEXT BOX

**What has happened since the publication of our review?**

Numerous further typical small-scale studies on stair promotion signs have been published. These include stair signs in university settings (Crozier et al., 2019; Engelen 2017; Ly et al., 2019), metro stations (Allias et al., 2017), an airport (Bellettiere et al., 2017), and a city centre office building (Bennett et al., 2018). These studies have continued to reinforce that the magnitude of change in stair use following the installation of a sign is broadly consistent with what has been reported in previous studies. A multi-building University study suggested that signage effects might be smaller than was observed in previous decades (Engelen 2017). One recent study identified the need to add social media supports to a stair-based signage intervention, and this interaction with social and e-media may be necessary for effective future interventions (Engelen 2019).

One example of a larger and more generalizable intervention was conducted in New York City between May 2008 and August 2012 (Lee et al., 2012). The initiative successfully distributed more than 30,000 stair prompts to building owners/managers of over 1000 buildings. In 2019 the authors published some reflections on the lessons learned from implementing this population-wide intervention (Lee et al., 2019). Keys to success included multi-sector partnerships between NYC's Health Department and non-health government agencies and organizations, a designated outreach coordinator, and outreach strategies targeting building owners and managers. More research like this, exploring the potential of implementing in wider settings, and then delivering and evaluating “at scale” would move the research field from small studies to much-needed community- or population-wide implementation. Given that the evidence base on the effectiveness of stair signs is well established and now perhaps is even ‘over-researched’, both researchers and practitioners need to focus on the problem in population settings.

## Classroom Discussion Questions

1. Discuss how the research methods that come from one discipline might be used in another discipline, perhaps with reference to this paper (and how this paper achieved that). Think of examples from your own experience or other examples from your reading of the literature where this might have occurred.

2. Consider issues of research translation in health or public health interventions. Can you identify any other areas where there is evidence for an effective approach that is already known, and discuss whether it has or has not been translated or scaled-up to a wider population level.

3. Public health interventions generate a lot of published evidence in the literature each year. What is different about this paper in terms of research methods used and evidence generated, and what does this paper suggest is needed for public health action in this particular area?

## Multiple Choice Quiz Questions

1. The primary purpose of the meta-analysis in this paper is to:

    A) identify how much change in stair use is likely in interventions?

    B) combine data to calculate a pooled effect size of stair interventions so that their average effect will be known?

    C) track studies over time to assess when there is sufficient evidence to recommend and scale-up stair signage interventions? CORRECT

2. This study was designed particularly to be of relevance to:

    A) policymakers and governments identifying the settings for action?

    B) practitioners, to understand the effects of stair promoting interventions?

    C) researchers involved in conducting stair sign interventions? CORRECT

3. Results of this study enabled practitioners to identify:

    A) which types of signs and messages are most effective in promoting stair use?

    B) that stair interventions need replicating and evaluating at scale? CORRECT

    C) how to design and test optimal stair use interventions?

## Declaration of Conflicting Interests

The Authors declares that there is no conflict of interest.

## Further Reading

[Insert list of up to six further readings here]

## Web Resources

[Insert links to up to six relevant web resources here]

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