

An Effectiveness Hierarchy of Preventive Interventions: neglected paradigm or self-evident truth?

Simon Capewell MD DSc

Professor of Clinical Epidemiology

Ann Capewell FRCP FRCPE

Consultant Physician

Address:

Department of Public Health & Policy,
Institute of Psychology, Health & Society.
Whelan Building, Quadrangle,
University of Liverpool,
LIVERPOOL, L69 3GB
United Kingdom

Telephone: 0044 (0)151 794 5576

Fax: 0044 (0)151 794 5588

capewell@liverpool.ac.uk

Word counts:

Abstract: 135 words

Paper: 2950 words

Box 1 text: 110 words

An Effectiveness Hierarchy of Prevention Strategies: neglected paradigm or self-evident truth?

Abstract

Non-communicable disease prevention strategies usually target the four major risk factors of poor diet, tobacco, alcohol and physical inactivity. Yet, the most effective approaches remain disputed.

However, increasing evidence supports the concept of an effectiveness hierarchy. Thus, “downstream” preventive activities targeting individuals (such as 1:1 personal advice, health education, “nudge” or primary prevention medications) consistently achieve a smaller population health impact than interventions aimed further “upstream” (for instance, smoke-free legislation, alcohol minimum pricing or regulations eliminating dietary trans-fats). These comprehensive, policy-based interventions reach all parts of the population and do not depend on a sustained “agentic” individual response. They thus tend to be more effective, more rapid, more equitable and also cost-saving.

This effectiveness hierarchy is self-evident to many professionals working in public health. Previously neglected in the wider world, this effectiveness hierarchy now needs to be acknowledged by policy makers.

An Effectiveness Hierarchy of Prevention Strategies:

neglected paradigm or self-evident truth?

Background

This *Perspective* briefly summarises the growing evidence for a public health “effectiveness hierarchy”, and examines the policy implications for future preventive health strategies.

The global burden of disease and disability is now mainly caused by non-communicable diseases (NCDs), notably heart disease, stroke, dementia, diabetes, and cancer.^{1,2}

NCD prevention strategies are now prioritising four major risk factors: tobacco, poor diet, physical inactivity and alcohol.^{1,2,3} However, there is debate about the most effective approaches to prevention. Many countries have prioritised “downstream” approaches targeting individuals (such as screening to detect high risk patients, personal advice, primary prevention medications and “nudge”).³ These highly visible strategies are politically less challenging than “upstream” population-wide policy interventions (such as legislation, regulation, taxation or subsidies.^{1,2,3}) However, the growing effectiveness evidence clearly points “upstream”.⁴

*(The apocryphal story illustrating the “upstream /downstream” metaphor is summarised in **Box 1**)*

Effectiveness Hierarchy: Neglected paradigm or self-evident truth?

Most public health practitioners intuitively accept an effectiveness hierarchy as an obvious, self-evident truth.^{5,6,7,8} Thus Frieden proposed a five tier “Health Impact Pyramid” in 2010.⁹ This explicitly suggests that “upstream” interventions addressing socioeconomic determinants of health have the greatest potential population impact, and counselling and health education the least.⁹

Some enlightened clinicians have also highlighted the potentially large role of policies to prevent cardiovascular disease^{8,10} or cancer,¹¹ and advocated using “the longest lever possible”.¹²

However, in the wider world, most politicians and policy makers, pundits and ordinary people appear unaware or indifferent to this effectiveness hierarchy. They thus risk over-looking the best strategies for maximising the future health of their families and friends.^{4,7}

We therefore now propose to briefly review the evidence for this **effectiveness hierarchy**.

Evidence supporting the effectiveness hierarchy

The evidence supporting a hierarchy of effectiveness now appears relatively extensive for all four of the major NCD risk factors: tobacco, diet, physical inactivity and alcohol.^{1,2} This evidence is briefly summarised below.

Tobacco control

Systematic reviews of tobacco control strategies consistently suggest that larger scale, comprehensive population-based approaches are more effective than individual approaches or local community strategies.^{13,14,15} The relative power of these different tobacco control interventions has been usefully summarised and quantified by a variety of scales including the US Tobacco Control Index and the European Tobacco Control Scale (TCS).¹⁶ The TCS illustrates a clear **effectiveness hierarchy** for tobacco control interventions. From a total of 100 points, 30 points are allocated to tobacco price, 22 points to *comprehensive* smokefree legislation (but only 10 points if limited to workplaces), 10 points for health warnings on cigarette packs, 6 points for nationwide cessation services for individuals and only 2 points for individual patients accessing telephone quitline advice¹⁶ (Figure 1).

Poor Diet

A similar **effectiveness hierarchy** is becoming apparent in diverse interventions to improve diet. Our BMJ Analysis summarised the growing evidence for reducing dietary salt consumption in populations.¹⁷ A gradient was clearly apparent. Advice to individuals or social marketing was generally weak. The UK programme of sustained pressure for industry reformulation reinforced by media messaging was more powerful. Furthermore, comprehensive “upstream” strategies including regulation and marketing control (as in Finland and Japan) have been yet more powerful, achieving even greater reductions in daily salt consumption.^{17,18} (Figure 2)

Similar hierarchies of effectiveness are apparent for interventions to *reduce* the dietary intake of industrial trans fats, saturated fats and sugars, and also for interventions to *increase* the consumption of fresh fruit and vegetables. For instance, the biggest reductions in industrial trans fat intake have been seen in Denmark (and soon perhaps in the USA), as the consequence of progressive and comprehensive policy interventions culminating in legislation.^{19,20} (Figure 3)

Likewise, the largest country-wide reductions in saturated fat intake were achieved in Finland (reflecting comprehensive and sustained strategies to progressively reduce the production and consumption of animal and dairy fats), and in Mauritius (following a regulation banning palm oil imports). Mean blood cholesterol levels subsequently fell dramatically, by 1.0 mmol/l and by 0.8mmol/l respectively.^{21,22}

Physical activity /inactivity

Recent NICE reviews have summarised the growing evidence demonstrating a similar **effectiveness hierarchy** in individuals and in populations (Figure 4). First prize goes to Cuba's 37% increase in physically active adults because of active travel, this being a rapid and unintended consequence of the major economic crisis commencing in 1989.²³ As GDP plummeted by 80% and fuel became scarce, the government needed to dramatically reduce private transport, promote public transport and also distribute a million bicycles.²³

Between 1972 and 2002, Finland implemented comprehensive national policies promoting walking, cycling and leisure activities. These policies substantially increased the proportion of physically active adults, by approximately 27% in women and by some 11% in men.²⁴ In contrast, more limited transport and exercise policies further "downstream", typically achieve smaller increases in physical activity, such as media campaigns, or time-limited active travel schemes promoting walking and cycling. In general, least has been achieved by targeting individuals for advice, information leaflets or exercise prescription.^{25,26} Furthermore, those modest benefits typically then diminish over time.^{26,27} (Figure 4)

Alcohol control and cost-effectiveness

Anderson and colleagues recently reviewed the growing evidence for reducing alcohol consumption in populations.²⁸ This provided considerable additional support for a hierarchy of effectiveness and, crucially, also of **cost-effectiveness**. Thus, brief interventions advising individuals cost approximately \$2,700 per disability adjusted life year (DALY) saved. Interventions targeted further "upstream" become increasingly cost-effective, with a 50% excise tax increase costing much less, only \$330 per DALY saved.²⁸

Wider cost-effectiveness: an emerging hierarchy of interventions

Health economists with NICE have identified increasing evidence of a similar hierarchy in the effectiveness and cost-effectiveness of diverse preventive interventions. Most are now easily compared using the standard NICE metric: Cost per QALY. Owen and colleagues recently reviewed the cost-effectiveness estimates for some 200 public health interventions, most being relatively “downstream”.²⁹ Thus, preventive interventions in individuals requiring statin medication often cost many thousands of pounds per QALY, while individual advice on behaviour changes, (for instance, exercise on prescription or mass media campaigns promoting healthy eating) usually only cost a few hundred pounds per QALY.²⁹

In contrast, **“upstream” population-wide policy interventions are generally *cost-saving***, such as regulations to control tobacco or alcohol, or to reduce dietary salt or trans fats; likewise subsidies to promote fresh fruit.³⁰ Reassuringly similar results come from economic analyses in the UK, USA and Australia.^{31,32} The systematic review by Masters et al likewise recently observed an effectiveness hierarchy in over 50 diverse public health interventions.³¹ Interventions implemented locally typically gained a return on investment averaging £4 for every pound spent. “Upstream” nation-wide public health interventions typically demonstrated even larger benefits with a median return on investment of £27 for each pound invested.³¹

Some interventions may even be cost-positive, ie revenue raising. Taxes on soda, and tobacco, for example, could actually serve to fund targeted interventions for those individuals in most need, and thus potentially improve health equity.

Secondary benefits of prevention

Many of the same interventions designed to prevent unhealthy behaviours can also serve to “treat” those who partake in behaviours which undermine their health. Taxes may prevent initiation of

cigarettes, but also may increase/improve quit attempts for price sensitive smokers. Likewise, banning the sale of tobacco products in pharmacies also decreases overall tobacco retailer density, thus discouraging smoking in adolescents and potentially decreasing relapse in smokers trying to quit.^{33,34} Furthermore, evidence to support this **effectiveness hierarchy** paradigm is also steadily emerging in other arenas including climate change, road safety, crime prevention and social policy.⁴

(Box 2)

Discussion

Main findings of this study

Increasing evidence supports the concept of an effectiveness hierarchy. Thus, “downstream” preventive activities targeting individuals (such as 1:1 personal advice, health education, “nudge” or primary prevention medications) consistently achieve a smaller health impact than interventions aimed further “upstream” (for instance, smoke-free legislation, alcohol minimum pricing or regulations eliminating dietary trans-fats). These comprehensive, policy-based interventions reach all parts of the population and do not depend on a sustained “agentic” individual response. They thus tend to be more effective, more equitable and also cost-saving.

The proposed concept of an **effectiveness hierarchy** raises several important issues. These include the underlying theoretical and ethical frameworks, equity and durability. Also crucial are the challenges of overcoming vested interests, wider political feasibility and operationalizing the policy evidence into interventions which are then effectively implemented.

What is already known on this topic

Geoffrey Rose famously demonstrated the simple mathematical principle: that a small improvement in the whole population (for instance dietary salt reduction to modestly lower average blood pressure) consistently generates larger net benefits than more intensive interventions just

targeting those fewer individuals at higher risk (for instance using medications for hypertension).³⁵ (Individual approaches typically have higher delta, but on far fewer people and with a higher per-person expense).

Dahlgren and Whitehead's "layers of influence" rainbow model then helped to better conceptualise the "upstream" political, economic, cultural and environmental influencing factors through to "downstream" factors acting directly on communities and individuals.³⁶

More recently, McLaren and colleagues have usefully observed that all preventive interventions sit on a "structural/agentive continuum": starting from fiscal or legislative actions which change the environment ("structural" interventions) through to information leaflets and advice which are completely "agentive", being totally dependent on an individual's active response.³⁷

The latter point being recently emphasised by Adams et al.³⁸

The Nuffield Bioethics review suggested that public health interventions should be proportional to the hazard.³⁷ Their useful Ladder of Interventions specified actions escalating from "doing nothing" (for a minimal risk), through progressive restrictions of an individual's freedom of choice and culminating in the "elimination of choice" (for instance Danish regulations to eradicate industrial trans fats from food).¹⁹

Equity effects

Individual preventive approaches depend mainly on agency-a person's active response.^{35,36} Such interventions therefore tend to favour affluent and educated groups, hence potentially increasing inequalities.^{35,36} Conversely, "structural" population-wide approaches which make the environment healthier generally benefit all individuals.^{35,36} They may thus sometimes narrow the inequalities gap.^{36, 37, 38,39,40}

Durability and sustainability issues

Interventions attempting behaviour change in individuals typically diminish over time: smokers relapse, statin adherence decreases, healthy diets drift and joggers give up.^{25,26,27} In contrast, the benefits of legislation tend to be *durable* (reflecting the persistent effect of an intervention, removing the need to reapply it), and also *self-sustaining*. Thus, once smoking is eliminated from bars, or arsenic or industrial transfats eliminated from food, these health hazards are seldom permitted to return.

Implementation can also become more effective over time, as illustrated by seatbelt legislation or smokefree environments: political resistance fades, younger cohorts inherit the new “social norms” and public support actually increases.^{4,6,38}

Some interventions are sustainable over time without the need for additional resources or upkeep. However, others like water fluoridation will require upkeep. However that cost is modest when compared with treating individuals with dental decay.

Political feasibility and “upstream” approaches

Translating evidence into policy is neither simple nor linear. Decision making by planners and policy makers is complex, reflecting many factors often considered more powerful than scientific evidence.^{44,45,46} Many hurdles exist, because the political and scientific arenas differ in terms of their perspectives, aims, values and practices. Neither can legislation offer a “quick fix”. In liberal democracies, successful laws generally only follow extensive public debate and growing support.^{18,33}

Happily, there is a long history of governments legislating to protect their citizens’ health. These regulatory successes include clean water, sanitation, air pollution, immunisation, seatbelts and smokefree statutes.⁴⁷ Such legislative public health proposals are typically supported by the political centre and left; but often initially opposed by the libertarian right and commercial interests.⁴⁷

Framing is also crucially important. Thus, smoke free policies were framed to protect non-smokers, where public smoking infringed on their rights. Likewise strategies framed to protect youth - for example, from being exposed to marketing of tobacco products or junk food.

There are also many political levers to use, from taxes or zoning (to prevent tobacco and alcohol retailers from locating near schools), to licensing (alcohol retailers, tobacco retailers), or frank prohibition of signage or product usage.

Applying the logic of an **effectiveness hierarchy** would clearly favour regulation and fiscal interventions at the highest levels – national, regional and global. The Framework Convention for Tobacco Control (**FCTC**) represents a notable global success now signed by over 160 countries.⁴³ Similar approaches have therefore been subsequently suggested to control other harmful products such as alcohol, dietary trans fats or sugars.^{48,49} The recent UN High Level Meeting on NCD prevention and control was thus potentially powerful, with the WHO subsequently agreeing a “25x25” target: a 25% reduction in NCD deaths by the year 2025.^{1,2}

However, many hurdles remain. The FCTC was only achieved in 2005, *five decades* after clear scientific evidence of tobacco harm, and only after two decades of sustained advocacy and activism.⁴¹ In reality, any such concerted global actions will be predictably and energetically opposed and obstructed by commercial vested interests.⁴⁸⁻⁵⁴ As suppliers of unhealthy commodities, “Big Tobacco”, “Big Alcohol” and “Big Food” companies obviously prioritise profit, not public health.⁴⁸⁻⁵⁶ Furthermore, these “disease promoting industries” use remarkably similar tactics intended to delay, dilute or demolish effective regulation.⁴⁸⁻⁵⁶ For instance, claiming that “nanny state” policies erode individual autonomy or harm economic growth.^{47,49}

Similarly obstructive commercial lobbying has recently been seen at the US federal level, frustrating public health regulation to combat child obesity.⁴⁸⁻⁵⁰ In contrast, over 25 individual states and US metropolitan areas have successfully implemented “soda taxes” on sugary drinks,

most recently Berkeley, San Francisco, Philadelphia, Oakland, Boulder and Chicago.⁵⁴ Similarly, over 30 cities and states have now enacted protective legislation on smoke-free public spaces.^{55,56,57}

Similarly in Europe, public health progress has often been similarly sabotaged at the European Union level. For instance, the recent Tobacco Products Directive was systematically weakened by sustained lobbying, and the EU proposal for front-of-pack food labelling to effectively inform consumers was derailed by massive food industry opposition.^{55,56} Happily however, individual European member countries have been politically more agile, (much like leading US cities and states^{57,58}). They have successfully achieved effective regulation and taxation to control tobacco,^{15,16} alcohol,⁵¹ trans fats,^{19,20} salt^{17,18} and sugar.^{53,54}

The failure of “nudge” and partnership approaches

In stark contrast to healthy policies, non-regulatory voluntary agreements and “partnerships” with industry have consistently proven weak or ineffective, not least by de-emphasising upstream issues. For example, “responsibility deals” which depend on “nudge” and non-specific “pledges” from industry have received increasingly devastating criticism in the UK, Europe and the USA.⁵⁹⁻⁶⁴ (Box 3)

Limitations of this study

This brief review has many limitations. Firstly, the scientific evidence still remains relatively sparse, and might be selectively quoted. However, recently emerging results are supportive, notably recent systematic reviews of policies to reduce the dietary intake of salt, and trans fats,^{18,20} and the economic return on investment of diverse public health interventions.³¹ A more comprehensive programme of primary research and systematic reviews should therefore now formally test the effectiveness hierarchy paradigm in a wider range of specific areas.⁶⁵ Looking

beyond the classical four NCD risk factors will also be important and potentially exciting (Box 3).⁴

Secondly, demanding the medical “gold-standard” of randomised trials is easy when assessing patient therapies, but seldom feasible for evaluating upstream national policy interventions. Thus most policy effect sizes represent estimates based on analyses of natural experiments interrupted time-series or observational cohorts.^{66,67} Furthermore, these effect sizes have been quantified using a variety of outcome metrics. This heterogeneity limits comparisons of effectiveness and highlights the value of promoting a standard methodology, such as costs per QALY or DALY.^{26,29}

Thirdly, needing to acknowledge the potential for unintended consequences of population wide interventions. Thus, if population wide policies are enduring, sustainable and wide reaching, they should be fully evaluated for unintended effects prior to general implementation. For example, the 1920s US prohibition of alcohol fuelling crime, or media campaigns on obesity resulting in shaming, bullying, stigma or negative mental health consequences.

Fourthly, considering any policy intervention in isolation is slightly artificial. Preventive interventions in the messy real world are delivered in a wider social, cultural and economic context which may be supportive, neutral or obstructive. Thus, in tobacco control, combinations of interventions within comprehensive strategies can produce additive or even synergistic benefits.⁶⁸ Therefore “upstream” interventions banning advertising typically create a more favourable environment which will then support the individual advised by their doctor to stop smoking. A *systems approach* involving a comprehensive, multi-level, multi-sectorial strategy may thus achieve “the maximum possible sustained public health gains”.

^{6,7,8,9,18,20, 66,68,69} Furthermore, benefits which can often occur surprisingly rapidly, within months rather than decades.⁷⁰

The public and policy implications of a preventive effectiveness hierarchy

As the emerging evidence strengthens, so the implications become increasingly clear.

- 1. Future strategies proposed for non-communicable disease prevention should strive to prioritise “upstream” approaches using regulation, taxation, subsidies and comprehensive approaches.** Policy makers and politicians will therefore need to champion these “upstream” interventions at the highest international levels (including the World Bank, United Nations, World Health Organisation, World Trade Organisation, and Codex Alimentarius).
- 2. Interventions further “downstream” and closer to the individual generally become progressively weaker and more expensive.** They therefore merit greater scepticism from planners and policy makers.
- 3. High income countries can fudge the choice between population-wide and individual approaches to prevention.** They can afford both, and might therefore portray these strategies as “complementary”. However, low and middle income countries face limited budgets and starker choices. They cannot quite so easily dismiss the emerging evidence on effectiveness and cost-effectiveness summarised here.
- 4. Opposition by commercial vested interests might be anticipated.** Because corporations will routinely resist any proposed public health regulation which might threaten their profits. However, the health of the public tends to triumph, eventually.⁴⁷

In conclusion, most policy makers and planners are facing growing disease burdens and shrinking healthcare budgets. Thus when considering future prevention strategies, they will increasingly need to prioritise those upstream policies which would most benefit their entire populations. They can no longer afford to neglect the public health effectiveness hierarchy.

Acknowledgements

We thank many friends for their constructive suggestions and support, notably Martin McKee, Martin O’Flaherty, Margaret Whitehead and colleagues in the University of Liverpool; and also anonymous referees at JPH and a prior journal.

Contributors and Sources

This article summarises analysis and prolonged reflection, refined by extensive discussions with the colleagues thanked above. The evidence has been progressively gathered by a combination of scoping reviews and more detailed searches. A series of well resourced systematic reviews are now proposed as the logical next stage in the process.

Conflicts of interest

None.

The apocryphal story about “upstream” and “downstream” prevention

While walking by the river, a philosopher came upon people drowning in the turbulent water. He observed a young man pulling each drowning individual out of the river. The young man cried "*Come and help me!*"

But instead, the philosopher walked further upstream. Nearing the town, he discovered a narrow footbridge - crowded, unfenced and unsafe. Thus many people were falling off the bridge into the river.

The philosopher persuaded the town authorities to fit a simple handrail to the bridge.

After that, people no longer fell in and drowned.

Downstream, the exhausted young man could then return home and feed his family.

Evidence supporting the effectiveness hierarchy paradigm

Extensive evidence

- Tobacco control
- Diet interventions
- Physical activity
- Alcohol control

Emerging Evidence

- Air pollution
- Breast feeding
- Clean water
- Climate change
- Crime prevention
- Drug addiction
- Fire prevention
- Gun Control
- Injury prevention
- Mental health
- Poverty
- Road safety
- Unemployment

References

1. World Health Organisation . Noncommunicable diseases. WHO Fact sheet 2016
<http://www.who.int/mediacentre/factsheets/fs355/en/>
2. Beaglehole R, Bonita R, Ezzati M, Alleyne G, Dain K, Kishore S P, Horton R. NCD Countdown 2025: accountability for the 25 × 25 NCD mortality reduction target
www.thelancet.com Published online July 7, 2014 [http://dx.doi.org/10.1016/S0140-6736\(14\)61091-6](http://dx.doi.org/10.1016/S0140-6736(14)61091-6)
3. Smith SC, A Collins, R Ferrari, DR. Holmes, S Logstrup, DV McGhie, J Ralston, RL Sacco, H Stam, K Taubert, DA Wood and WA Zoghbi. Our Time: A Call to Save Preventable Death from Cardiovascular Disease (Heart Disease and Stroke).
Circulation 2012; Print ISSN: 0009-7322. Online ISSN: 1524-4539
4. Coote A & Harris M. The Prevention Papers. Upstream investment and early action to prevent harm: building knowledge and breaking down barriers. *New Economics Forum* 2013.
<http://www.neweconomics.org/publications/the-prevention-papers>
5. Oliver A & Nutbeam D. Addressing health inequalities in the United Kingdom: a case study.
J Public Health 2003; 25 (4): 281-287. doi: 10.1093/pubmed/fdg091
6. Wanless D. Securing Good Health for the Whole Population. HM Treasury, 2004.
http://webarchive.nationalarchives.gov.uk/+http://www.hm-treasury.gov.uk/consultations_and_legislation/wanless/consult_wanless04_final.cfm
7. Wildner, M. Prevention at the Interface between Politics and Practice.
Gesundheitswesen 2012; 74; (4) 229-233 DOI: 10.1055/s-0032-1308976
8. Labarthe DR. & Dunbar SB. Global Cardiovascular Health Promotion and Disease Prevention : 2011 and Beyond . *Circulation* 2012;125:2667-2676.
Doi: 10.1161/CIRCULATIONAHA.111.087726
9. Frieden T R. A Framework for Public Health Action: The Health Impact Pyramid.
Am. J. Public H. 2010; 100 (4): 590-595 DOI: 10.2105/AJPH.2009.185652
10. Pearson T A. Public Policy Approaches to the Prevention of Heart Disease and Stroke.
Circulation 2011;124 (23): 2560-2571 DOI: 10.1161/CIRCULATIONAHA.110.968743
11. Isle LB, Plescia M, La Porta M, Shepherd W. In conclusion: looking to the future of comprehensive cancer control. *Cancer Causes & Control* 2010; 21, (12): 2049-2057.
12. Jarris P. Strategies for Public Health in a Transforming Health System.
J Public Health Management Practice, 2013, 19(1), 93–96.

13. Gornall, J. Slaying the dragon: how the tobacco industry refuses to die.
BMJ 2015;350:h2052 doi: 10.1136/bmj.h2052
14. Bunnell, R; O'Neil, D; Soler, R. Fifty Communities Putting Prevention to Work:
Accelerating Chronic Disease Prevention Through Policy, Systems and Environmental Change.
J Community Health. 2012 Oct;37(5):1081-90. doi: 10.1007/s10900-012-9542-3.
15. Jepson R, Harris F, MacGillivray S, Kearney N, Rowa-Dewar N: A Review of the effectiveness
of interventions, approaches and models at individual, community and population level that are
aimed at changing health outcomes through changing knowledge, attitudes and behaviour.
NICE, London 2006. <http://www.nice.org.uk/nicemedia/live/11868/44521/44521.pdf>
16. Joossens L & Raw M. The Tobacco Control Scale: a new scale to measure country activity.
Tob Control 2006 15: 247-253
17. Cappuccio F P, Capewell S, Lincoln P, McPherson K. Population salt reduction to prevent
cardiovascular disease: identifying policy options. BMJ 2011; 343: d4995 PMID: 21835876
18. L Hyseni, A Elliot Green, F Lloyd-Williams, et al. P48 Systematic review of dietary salt reduction
policies: evidence for an “effectiveness hierarchy”? J Epid Comm H 2016;70:Suppl 1 A74-A75
doi:10.1136/jech-2016-208064.147
19. T Bech-Larsen & J Aschemann-Witzel. A Macromarketing Perspective on Food Safety Regulation
The Danish Journal of Macromarketing. 2012; 32(2) 208-219
20. L Hyseni, H Bromley, F Lloyd-Williams, et al. OP73 Systematic review of dietary trans-fat
reduction policies: evidence for an effectiveness hierarchy?
J EpidComm H 2016;70:Suppl 1 A41 doi:10.1136/jech-2016-208064.73
21. Dowse GK, Gareeboo H, Alberti KGMM, Zimmet P, Tuomilehto J, Purran A, Fareed D,
Chitson P, Collins VR, Hemraj F. Changes in population cholesterol concentrations and
other cardiovascular risk factor levels after five years of the non-communicable disease
intervention programme in Mauritius. BMJ 1995; 311: 1255-1259.
22. Puska, P. Fat and Heart Disease: Yes We Can Make a Change - The Case of North Karelia
(Finland). Annals Nutrition & Metabolism 2009; 54: 33-38. DOI: 10.1159/000220825.
23. Franco M, Ordunez P, Caballero B, Granados JAT, Lazo M, Bernal JL, Guallar E, Cooper R S.
Impact of Energy Intake, Physical Activity, and Population-wide Weight Loss on
Cardiovascular Disease and Diabetes Mortality in Cuba, 1980–2005. Am J Epid 2007; 166;
1374-9.
24. Vuori I, Lankenau B, Pratt M. Physical activity policy and program development: the experience
in Finland. *Public H Reports* 2004;**119**:331-45.
25. Philipe de Souto Barreto. Why are we failing to promote physical activity globally?
Bull World Health Organ 2013;91:390–390A | doi: <http://dx.doi.org/10.2471/BLT.13.120790>
26. NICE Public Health Guidance 41. Walking and cycling: local measures to promote walking and
cycling as forms of travel or recreation. www.guidance.nice.org.uk/ph41
27. Pavey, TG; Taylor, AH; Fox, KR; Hillsdon, M; Anokye, N; Campbell, JL; Foster, C;

- Green, C; Moxham, T; Murie, N; Searle, J; Trueman, P; Taylor, RS. Effect of exercise referral schemes in primary care on physical activity and improving health outcomes: systematic review and meta-analysis. *Br Med J* 2011; 343: d6462.
28. Anderson P, Chisholm D, Fuhr DC. Alcohol and Global Health 2. Effectiveness and cost-effectiveness of policies and programmes to reduce the harm caused by alcohol. *Lancet* 2009; 373: 2234–46.
 29. Owen L, Morgan A, Fischer A, Ellis S, Hoy A, Kelly MP. The cost-effectiveness of public health interventions. *J Public H* 2011; 34 (1); 37–45. doi:10.1093/pubmed/fdr075
 30. Barton P, Andronis L, Briggs A, McPherson K, Capewell S. Effectiveness and cost-effectiveness of CVD prevention in whole populations. *BMJ* 2011; 343:d4044:
 31. R Masters, E Anwar, B Collins, R Cookson, S Capewell, The return on investment of public health interventions: a systematic review. *J Epidemiol Community Health* 2017;0:1–8. doi:10.1136/jech-2016-208141
 32. Cobiac LJ; Magnus A; Lim S. Which Interventions Offer Best Value for Money in Primary Prevention of Cardiovascular Disease? *PLoS ONE* 2012; 7 (7) e41842
 33. Hudmon, KS, Fenlon, CM, Corelli, RL,); Prokhorov, AV, Schroeder, SA. Tobacco sales in pharmacies: time to quit. *TOBACCO CONTROL*; 2006; 15 (1): 35-38 DOI: 10.1136/tc.2005.012278
 34. Schleicher, NC, Johnson, TO, Fortmann, SP, Henriksen, L. Tobacco outlet density near home and school: Associations with smoking and norms among US teens. *PREVENTIVE MEDICINE* 2016; 91: 287-293. DOI: 10.1016/j.ypmed.2016.08.027
 35. Rose G. Sick individuals and sick populations. *Int J Epidemiol* 1985;14:32–8
 36. Dahlgren G & Whitehead M. Policies and Strategies to Promote Equity in Health. Copenhagen: Institute for Future Studies. 1991
 37. McLaren L, McIntyre L & Kirkpatrick S. Rose’s population strategy of prevention need not increase social inequalities in health. *Int J Epidemiology* 2010;39:372–377.
 38. Adams J, Mytton O, White M, Monsivais P (2016) Why Are Some Population Interventions for Diet and Obesity More Equitable and Effective Than Others? The Role of Individual Agency. *PLoS Med* 13(4): e1001990. doi:10.1371/journal.pmed.1001990
 39. Nuffield Council on BioEthics. Public health: ethical issues. 2007 London. www.nuffieldbioethics.org
 40. Tugwell P. Staircase Tugwell P, de Savigny D, Hawker G, Robinson V. Applying clinical epidemiological methods to health equity: the equity effectiveness loop. *BMJ*2006;332:358-61.
 41. Capewell S & H Graham. Will cardiovascular disease prevention widen health inequalities? *PLoS Medicine* 2010; 7(8): e1000320.

42. McGill R, Anwar E, Orton L, et al. Are interventions to promote healthy eating equally effective for all? Systematic review of socioeconomic inequalities in impact. *BMC Public Health* 2015 , 15:457. DOI: 10.1186/s12889-015-1781-7 <http://www.biomedcentral.com/1471-2458/15/457>
43. Mackay, J. Implementing tobacco control policies. *Br Med Bulletin* 2012; 102 (1): 5-16. DOI: 10.1093/bmb/lds007
44. K Oliver, S Innvar, T Lorenc, J Woodman, J Thomas. A systematic review of barriers to and facilitators of the use of evidence by policymakers. *BMC Health Services Research* 2014, 14:2
45. Orton L, Taylor Robinson D, Moonan M, O’Flaherty M, Capewell S. The Use of Research Evidence in Public Health Decision Making Processes: Systematic Review. *PLoS ONE* 2011. 6 (7): e21704
46. Macintyre S. Evidence in the development of health policy. *Public Health* 2012; 126: 217-219.
47. S Capewell. Are nanny states healthier states? *BMJ* 2016;355:i6341 doi: 10.1136/bmj.i6341
48. Stuckler D; Nestle M. Big food, food systems, and global health. *PLoS Medicine* 2012; **9** (6): e1001242
49. Moodie R, Stuckler D, Monteiro C & Lancet NCD Action Group. Profits and pandemics: prevention of harmful effects of tobacco, alcohol, and ultra-processed food and drink industries. *Lancet* 2013; 381 (9867): 670-679 DOI: 10.1016/S0140-6736(12)62089-3.
50. Brownell KD, Warner K. The perils of ignoring history: big tobacco played dirty and millions died: How similar is big food? *Milbank Q* 2009;87:259-94.
51. Gilmore AB, Savell E, Collin J. Public health, corporations and the new responsibility deal: promoting partnerships with vectors of disease? *J Public H* 2011;33:2-4. doi:10.1093/pubmed/fdr008 PMID:21289060
52. Hastings G. Why corporate power is a public health priority. *BMJ* 2012; 345: e5124 DOI: 10.1136/bmj.e5124
53. Yale Rudd Center for Food Policy & Obesity. Tax information http://yaleruddcenter.org/what_we_do.aspx?id=366
54. J Gornall. Sugar: Spinning a web of influence. *BMJ* 2015;350:h231 doi: 10.1136/bmj.h231 (Published 11 February 2015)
55. ANRF. American Nonsmokers’ Rights Foundation. Summary of 100% Smokefree State Laws and Population Protected by 100% U.S. Smokefree Laws. <http://www.no-smoke.org/pdf/SummaryUSPopList.pdf>
56. Lhachimia SK, Cole KJ, Nusselder WJ, Smite HA, Bailif P, Bennett K, Pomerleau J, McKee M, Charlesworth K, Kulika MC, Mackenbach JP, Boshuizen H. Health impacts of increasing alcohol prices in the European Union: A dynamic projection. *Preventive Med* 2012;55 (3): 237-243.

57. ChangeLab Solutions. Tobacco Control. Reducing retailer density.

<http://www.changelabsolutions.org/tobacco-control>

58. Luke, DA, Sorg, AA, Combs, T, Robichaux, CB, Moreland-Russell, S, Ribisl, KM, Henriksen, L. Tobacco retail policy landscape: a longitudinal survey of US states. TOBACCO CONTROL 2016; 25: i44-i51 DOI: 10.1136/tobaccocontrol-2016-053075

59. Lloyd-Williams F, Bromley H, Orton L, et al. Smorgasbord or symphony? Assessing public health nutrition policies across 30 European countries using a novel framework. BMC Public Health.2014, 14:1195.
<http://www.biomedcentral.com/1471-2458/14/1195>
60. Bonell, C. One nudge forward, two steps back. BMJ 2011;342:d401
61. Evaluation of The European Platform For Action On Diet, Physical Activity And Health. European Commission. Directorate General Health and Consumers Directorate C “Health and Risk Assessment” Brussels, Belgium. Final report July 2010
http://ec.europa.eu/health/nutrition_physical_activity/docs/evaluation_frep_en.pdf
62. Sharma L, Teret SP, Brownell KD. The Food Industry and Self-Regulation: Standards to Promote Success and to Avoid Public Health Failures. Am J Public H 2010; 100 (2): 240-246 DOI: 10.2105/AJPH.2009.160960
63. Knai, C., Petticrew, M., Durand, M.A., Scott, C., James, L., Mehrotra, A., Eastmure, E., Mays, N., 2015. The Public Health Responsibility deal: has a public–private partnership brought about action on alcohol reduction? Addiction. <http://dx.doi.org/10.1111/add.12892>.
64. C. Knai, M. Petticrew, M.A. Durand, E. Eastmure, L. James, A. Mehrotra, C. Scott, N. Mays. Has a public–private partnership resulted in action on healthier diets in England? An analysis of the Public Health Responsibility Deal food pledges. Food Policy 2015; 54: 1–10.
65. Threlfall, AG, Meah, S, Fischer, AJ, Cookson, R, Rutter, H, Kelly, MP. The appraisal of public health interventions: the use of theory. Journal Of Public Health 2015; 37 (1): 166-171
66. Rutter H, Glonti K. Towards a new model of evidence for public health Lancet 2016; 388, S7, 32243-7. DOI: [http://dx.doi.org/10.1016/S0140-6736\(16\)32243-7](http://dx.doi.org/10.1016/S0140-6736(16)32243-7)
67. Neumann P & Cohen J. NEJM Perspective on “The Cost-Effectiveness of Environmental Approaches to Disease Prevention” The CEA Registry Blog. July by CEA Registry Team 7/26/2012. <https://research.tufts-nemc.org/cear4/Resources/CEARegistryBlog/tabid/69/EntryId/246/NEJM-Perspective-on-The-Cost-Effectiveness-of-Environmental-Approaches-to-Disease-Prevention.aspx>
68. Green, LW, Kreuter, MW. Evidence Hierarchies *versus* Synergistic Interventions. Am J Public H 2010; 100 (10): 1824-1825.
69. NICE Public Health Guidance 25. CVD prevention in populations. NICE, London, 2010. www.guidance.nice.org.uk/ph25
70. Capewell S & O’Flaherty M. Mortality falls can rapidly follow population-wide risk factor changes. Lancet, 2011; 378 752-753.

FIGURE LEGENDS+

Figure 1 Tobacco Control Score (TCS):
Estimated effects of different policy options

Figure 2 Dietary Salt Reduction:
Estimated effects of different policy options

Figure 3 Dietary Industrial Transfat Reduction:
Estimated effects of different policy options

Figure 4 Interventions Increasing Physical Activity:
Estimated effects of different policy options

APPENDICES: Data for figures, available in Online Supplement

eTable 1
Interventions for reducing population tobacco consumption

eTable 2
Interventions for reducing population dietary salt intake

eTable 3
Interventions for reducing population dietary intake of industrial trans fats

eTable 4
Interventions for increasing population physical activity levels