An evidence-based assessment of the impact of the Olympic Games on population levels of physical activity

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Summary

Pre-Olympic Games predictions commonly include an increase in population-based physical activity in the host city, as often stated in the bid, but Post-Games effects on physical activity have not been summarised. In this paper we: (a) examine mentions of a physical activity legacy in pre-Olympic bid documentation; (b) analyse existing physical activity surveillance data collected before, during and after the Games in hosting areas around the world; and (c) evaluate *Google Trends* data surrounding the London 2012 Olympic Games as a case study of community interest in the topic of "exercise" around the Games. Before 2007 limited mention of physical activity was made in pre-Olympic documentation, but after that most documents had targets for population physical activity or sport participation. The synthesis of available surveillance data indicates no change in the prevalence of physical activity or sport participation, except for Beijing and Nagano, although the increase in participation in Nagano may not be attributable to the Games since there was no change in participation in winter sports. The *Google Trends* data showed an acute spike in "Olympic" searches immediately associated with the London Games period and sustained peri-Olympic increases in searches for the topic "exercise". The Olympic Games by themselves have not improved population-wide physical activity but may be an important missed public health opportunity. Realising such a legacy will require strategic planning and partnerships across the IOC, Olympic, sport and public health agencies and a thorough evaluation framework implemented throughout the pre- and post-Games period in the host country.

Introduction

Physical inactivity has been described as a global pandemic (1) that is responsible for a substantial burden due to non-communicable diseases (NCDs), 5.3 million deaths and billions of dollars every year (1,2). The World Health Organization Global Action Plan on Physical Activity 2018 – 2030 suggests that best-practice communication strategies linked with community-based programs and mass participation initiatives may be important contributors to increasing population physical activity levels (3). The Olympic Games is the pinnacle of human performance and an important global event to unite people from around the world through a shared passion for sport. The Olympic spirit of *de Coubertin* was originally described as the notion of *"taking part"* (rather than only focusing on elitism and obtaining medals), and this provides a public health leverage point for fostering community participation in sport and physical activity (4). The Olympic Games represents an important opportunity to promote population-level physical activity and the purpose of this paper is to provide an overview of the available evidence.

Planning for the Olympic Games includes consideration of legacies "bequeathed to the host city (to) benefit its inhabitants for many years" (5). The term 'legacy' was first used in the Melbourne bid for the 1956 Summer Games (6). Typically, Olympic Games legacies have achieved health service improvements, communicable disease control, air quality and environmental health benefits, urban health and regeneration, and sometimes improved transportation systems (5,7).

There is untapped potential to use mass events to promote health behaviour changes that reduce NCD risk, and the Olympics offers an opportunity for increasing physical activity

from a public health perspective (7). In the same way, aspirational public health goals for previous Olympic Games have sought to promote health through non-smoking and healthy food and beverage services (5,8,9). This promise of a 'physical activity / sport participation legacy' is not well evidenced (10,11,12). Although the Olympic Games contribute to sports facilities, sport education, and foster elite sports training programs (13), these effects only reach high-level athletes, and are different to legacies promoting health-enhancing physical activity and sport at the population level.

One mechanism through which Olympic elite sports are thought to increase population-level physical activity and sport participation is through the alleged 'trickle down' effect whereby elite sports participation is thought to lead to increased community interest and hence to more people engaging in sport and physical activity. However, there is no evidence supporting this 'trickle-down' effect (14). The potential for the Olympic Games to promote population health remains to be realised.

In this paper, we aim to provide a summary of the evidence of population physical activity participation following the Olympic Games by: 1) reviewing pre-Olympic Bid documents and identifying thematic mentions of physical activity and community sport participation; 2) examining participation in physical activity and sport around the Olympic period in host countries; and 3) exploring the temporal trends of population-level interest in 'exercise' using London 2012 as a case study. The first step in this legacy enquiry involved an audit of Olympic bid and policy documents regarding physical activity and community sport. For the second question we extracted existing and publicly available physical activity or sport participation population data from the host region or country to assess prevalence levels before and after the Olympic Games. The third question examined community searching

behaviour on the Google platform before and after the London 2012 Olympic Games, with time series modelling of the topic areas of "exercise" and "Olympics" to assess the temporal relationships between community interest in these topics and the Olympic Games.

Pre-Olympic bid documents

We examined pre-Olympic Games bid documents, Olympic Games reports (https://library.olympic.org/Default/accueil.aspx), International Olympic Committee (IOC) reports, Government policy documents and other relevant grey literature for mention of "legacy", "legacy plan", "physical activity", "sport", or "community participation" (Table 1). We noted no mention of community sport or physical activity in bid documents or post-Olympic Games reports until 2007/8 (15). The IOC had initiated an Olympic Games Global Impact project in 2001, which suggested that Olympic cities collect indicator data before and after the Games, that specifically included legacy information on grassroots sport participation. The Beijing 2008 Summer and the Vancouver 2010 Winter Olympic Games were the first to collect such information (16). The Beijing 2008, London 2012 and Tokyo 2020 bid information specifically mentioned community physical activity and sport participation. Specifically, the Beijing Olympic Committee proposed to use the Olympic Games as an inspiration to promote China's nation-wide mass participation in sport and fitness programs ("大众体育", "全民健身"), together with educational campaigns fostering the Olympic spirit. The London Olympics aspired to promote grassroots participation in physical activity to "inspire a (younger) generation". The Tokyo Olympics included specific strategies (e.g., opening corporate sports facilities to the general public and hosting a "Sports Day") with specific and measurable targets ("the number of people who regularly do exercise and sports"). Overall, increased mentions of community participation in physical activity and

sports reflect a positive change during the bidding process and planning for Summer Olympic Games. No such change has been observed with the Winter Olympics.

Population-level participation in physical activity and sports

We searched for available or published data from regular population surveys in recent Olympic host countries to examine temporal trends in physical activity and sport participation (population physical activity or sport data sources and measures are shown in the Supplementary Online file Appendix A). We selected population representative estimates that used consistent physical activity or sport participation measures within-country spanning the Olympic Game period in host cities, states or countries where data were available.

We present changes in participation rates for sport or physical activity, and the ratio of the average pre-Olympic rates to the post-Olympic rates for both Summer and Winter Olympics (Figure 1). Significance was not formally tested, but we report "non-substantial changes" in situations where the prevalence rate 95% confidence intervals overlapped in the reported estimates.

An earlier secondary report from the Barcelona 1992 Olympics provided information of a municipality-wide survey that suggested increases in the proportion of the population who did any physical or sporting activity at least weekly; but no reliable information regarding this survey were available (17).

Population data from the state of Georgia (Atlanta) showed a slight but not substantial increase in the years following the 1996 Olympics, as the 95% confidence limits for the post Games estimates overlapped with those pre-Games (18). Japanese information before and

after the Nagano Winter Olympics showed a substantial increase in reported sport participation, and an increase in mean step counts before the 1998 Games, but the mean step count declined in subsequent years (19). Further, the increase in sport participation in Nagano may not be attributable to the Games since there was no change in participation in winter sports which are more relevant to the winter Games.

Sydney city data showed no change in sport participation (Figure 1), and a previous report identified increases in community interest in exercise among Australian males following the Sydney Olympics (20), but no change in population survey measures of physical activity including sub-analyses confined to the state of New South Wales which includes Sydney (20). Salt Lake City showed no increases in participation (18). No population physical activity data were available for the Athens 2004 Olympics.

More recent data are shown in the middle and lower rows of Figure 1. Three large population surveys from adults in China indicated steady improvement in leisure-time physical activity with the percentage of participants meeting the recommendations for leisure-time physical activity increasing from 17.2% in 2000 to 22.8% in 2014 (21), with similar increases reported in all age groups under 55 years, and by gender and among urban/rural Chinese adults.

Increasing physical activity among children was a strong focus of the Vancouver 2010 Olympic Games, and especially surrounding the school setting (22). Data around the Vancouver 2010 Winter Games indicated no change in objective Canplay population step-count data among school-age children either nationally or in the province (British Columbia, BC) in which Vancouver is situated (23). Further, the proportion of children reporting

organised sport participation did not change over this period and no evidence of the anticipated 'trickle-down' effect was noted (23,24).

London reported data from serial Active People Surveys which showed an unchanged prevalence of adults meeting the physical activity guidelines across the twelve years measured. Data from the city of Rio de Janeiro suggest a small but non-substantial increase in physical activity participation following the Olympic Games, although there was some increase in Rio in the previous three years. Tokyo data are pre-Olympic Games, but do not yet indicate any positive trends in mean step counts, exercise habit or sport participation up to 2017.

The left-hand section of Figure 1 summarises the average post/pre Olympics physical activity prevalence ratio (with values larger than 1 indicating an increase from pre- to post-Olympics). Data on one (sport participation) of the 4 measures following Nagano 1998 (winter), and leisure-time physical activity following Beijing 2008 (summer) showed greater average prevalence rates following the Olympics, with no change in the other three measures following Nagano, and no change in the other five Olympic Games.

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Olympic Games and population participation in physical activity: what have we learned?

We found few examples of bid documents that included physical activity and sport participation strategies into the pre-Olympic planning process. Although mass events and mass campaigns to promote physical activity and sport are mentioned in the WHO Global

Action Plan on Physical Activity 2018 – 2030 (3), the global public health potential for raising community awareness about physical activity through the Olympics remains to be realised. Links to the concept of "Sport for All" and the promotion of community sporting programs for the general population are not evident.

National policy statements often allude to physical activity and sport such as the extensive policy framework preceding the London 2012 Olympics (Table 1). There was some evidence of increased and sustained interest in exercise, demonstrated through the search-term increases using Google Trends around the London Olympics, but the prevalence of meeting physical activity guidelines among adults in England remained unchanged before, during and after the London Games. This suggests that London's attempt to increase grassroots participation in physical activity and sport may have led to an overall improvement in public awareness and policy interest in physical activity, however, this did not translate in the medium-term into increased levels of participation. Other recent host cities also failed to demonstrate post-Olympics increases in participation, including self-report measures of sport participation (Vancouver) and physical activity (Sydney, Rio) and objective step-counts (Vancouver). Of note, there was an increase in population levels of "intention to be more active" seen immediately following the Sydney Olympics, suggesting increased community interest in being active, but this was not associated with any change in physical activity behaviour (20).

The Beijing 2008 Olympic Games appeared to use the Olympic opportunity to develop national policies that invested in physical activity participation. Between 2001, when Beijing won the bid, and 2008 when the event took place, comprehensive policies and guidelines on mass participation in physical activity and "Sports for All" were implemented at the national

and city level. This comprised community sporting infrastructure construction, educational campaigns and community sporting events, providing a "systems-level" integrated response that may have contributed to the observed increase in population participation in leisure-time physical activity, and to sustained sport policy development (25).

Physical Activity Legacy: Recommendations for future Olympic Games and Mass Sporting Events

The Olympic Games Global Impact report provided a framework for including sport participation and physical activity as a long-term legacy of the Olympic Games, but limited evidence is available to show that this vision has been implemented, or that such strategies have been effective. In order to achieve this vision, a comprehensive national physical activity and sport plan is needed, which starts well before the Olympic Games, and is continued beyond the end of the Games. To capitalise on a successful Olympics bid, countries should create strong inter-agency *partnerships* at multiple levels. This should include partnerships between the IOC, local Olympic committees and multiple sectors across the host national Government, and also between community organisations that deliver local opportunities for physical activity. These partnerships would deliver a comprehensive set of community programs leading up to the Olympic Games to strengthen the sport sector and to increase population physical activity levels. To date, Olympic planners seldom work in partnership with Public Health agencies and community sports groups throughout the peri-Games periods to produce real public health effects (26); rather there has been an expectation that the 'trickle-down effect' will inspire the community (10,27,28).

The Olympic Games could be a catalyst for action to promote physical activity at scale (29). One advantage of the Olympics is the huge investment over multiple years, which may allow

public health planning to be developed in tandem. This may be possible with other global sporting events, but is less likely with local sporting contests or single day physical activity events. In any case, concurrent mass communications are needed to promote the public health idea about physical activity. Messages should not only focus on the heroics of elite sports professionals but use the opportunity of the Olympics to raise awareness about everyday 'movement for all', at every level in a society, and to link community activity to the spirit of the Olympics. Mass reach messages need to carefully promote the 'moderate physical activity' message (3), otherwise low active people may be discouraged from starting to move more (30).

As noted in the Google Analytics modelling, the increased interest in sport and exercise around the Olympics may provide an opportunity for physical activity promotion. This hypothetical increase in community interest needs to be supported by peri-Olympics related changes to urban infrastructure, park and sports facility development, and public transport systems that will support incidental physical activity and community sport. This process was best realised around the Beijing Olympics in 2008, where Government commitment to facilities and community education continued throughout the peri-Olympic period. Non-Olympic nations should use the quadrennial opportunity of the Games to promote sport and activity in their countries. Similarly, community-wide social marketing should accompany other global mega-sporting events to create more active communities through role modelling.

This paper has focused on the Olympic Games, and a similar dearth of evidence exists for the effects of other 'mega-events', such as World Cup Football, and possibly Grand Slam tennis events on physical activity at the population level (31). A related area is mass community walking, cycling, running or other participation events, including those carried out by non-

Government Organisations or charities. These are usually ‘one off’ annual events and encourage social connection, charitable sponsorship and community spirit. Although they have large participant numbers, they often attract people who are already active (32-34), or attract highly selected participants (35). However, some mass events do attract large numbers of walkers or low active people, such as an annual mass event of 50,000 participants in Ireland (36). However, participation in activity may be maximal around the event, and relapse to low levels of activity is seen (33). It is possible that widescale adoption of regular weekly local events, such as *parkrun* (37) may better maintain participation within communities. Although few have been evaluated, these mass events have the potential for being natural experiments, to assess different reinforcement and support strategies at both the municipal and community-wide levels. This further evidence is necessary to determine whether inactive people develop sustained physically active lifestyles following community events.

Independent monitoring and evaluation frameworks are essential to assess the long-term evidence for integrated approaches around the hosting of the Olympic Games on population physical activity (29,38). If we assume that the Olympic Games has the potential to be ’a physical activity intervention at scale’, then it should be comprised of organizational, policy and communitywide changes. Figure 3 shows our chronological ’systems based’ logic model that describes the planning and evaluation actions required (3). A comprehensive process evaluation framework is needed to monitor policy implementation, the engagement of stakeholders and partnerships, and assess capacity-building for physical activity and community sport. Stable planning policy frameworks, rather than ‘shifting goalposts’ are required to maintain cross-sectoral and sustainable progress in community programs and infrastructure (26). Existing population surveillance systems could be adapted to better monitor physical activity and sport participation among adults and children.

Attribution of physical activity behaviour change to the Olympics remains a methodological challenge. Observed increases in physical activity around the Olympics may be due to other policy or programmatic initiatives. In Rio de Janeiro, several factors changed around 2010 including economic and social prosperity, leading to more private physical activity facilities and the scaled-up implementation of national and state physical activity programs (26,27), which may have influenced increases in pre-Games physical activity. These data demonstrate temporal correlation (i.e., occurrence) rather than causation and it is not possible to attribute changes directly to the Olympics as a "natural experiment"; however, the paucity of substantial increases in the years following the Olympics do suggest no direct Olympic Games effects to date.

Some of the allure of the Olympic Games relates to showcasing and profiling the host city and nation, while promising benefits to the populace. Politicians develop a "monument complex" (39) with the belief that the health and wellbeing of host cities will be substantively improved through hosting the Olympics. The Games may engender community enthusiasm, a 'festival' spirit and a transient sense of wellbeing in the host city (40). Achieving physical activity and sport participation improvements and realising the social and economic benefits that would result from reducing the 'physical inactivity pandemic' (1,41), require more focused and integrated efforts implemented over many years.

References

1. Kohl 3rd HW, Craig CL, Lambert EV, Inoue S, Alkandari JR, Leetongin G, Kahlmeier S, Lancet Physical Activity Series Working Group. The pandemic of physical inactivity: global action for public health. The lancet. 2012 Jul 21;380(9838):294-305.

2. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, Lancet Physical Activity Series Working Group. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. The lancet. 2012 Jul 21;380(9838):219-29.

3. World Health Organization. Global action plan on physical activity (GAPPA) 2018-2030: More active people for a healthier world. World Health Organization, Geneva; 2019 Jan 21.

4. Torres CR. Results or participation?: Reconsidering Olympism's approach to competition. Quest. 2006 May 1;58(2):242-54.

5. Dapeng J, Ljungqvist A, Troedsson H, eds. The health legacy of the 2008 Beijing Olympic Games : successes and recommendations. Geneva World Health Organization, 2010.

6. McIntosh MJ, The Olympic bid process as the starting point of the legacy development," in Moragas M, Kennett C, Puig N eds., The Legacy of the Olympic Games 1984-2000: International Symposium, Lausanne, 14th, 15th and 16th November 2002, International Olympic Committee, 2003, p.450-455

7. Weed M, Coren E, Fiore J, Wellard I, Chatziefstathiou D, Mansfield M, Dowse S. (2015) The Olympic Games and raising sport participation: a systematic review of evidence and an interrogation of policy for a demonstration effect, European Sport Management Quarterly, 15:2, 195-226, DOI: 10.1080/16184742.2014.998695

8. Panet-Raymond B, Cooper D. Public Health Legacy: Experiences from Vancouver 2010 and Sydney 2000 Olympic and Paralympic Games.2008. http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1217574183388

9. Tsouros AG, Efsathiou PA (Eds). Mass Gatherings and Public Health: The experience of the Athens 2004 Olympic Games. ISBN 9789289072885. World Health Organization, WHO / European Office, Copenhagen, 2007.

10. Murphy NM, Bauman A. Mass sporting and physical activity events—are they “bread and circuses” or public health interventions to increase population levels of physical activity?. Journal of physical activity and health. 2007 Apr 1;4(2):193-202.

11. Mahtani KR, Protheroe J, Slight SP, Demarzo MM, Blakeman T, Barton CA, Brijnath B, Roberts N. Can the London 2012 Olympics ‘inspire a generation’to do more physical or sporting activities? An overview of systematic reviews. BMJ open. 2013 Jan 1;3(1):e002058.

12. McCartney G, Thomas S, Thomson H, Scott J, Hamilton V, Hanlon P, Morrison DS, Bond L. The health and socioeconomic impacts of major multi-sport events: systematic review (1978-2008). BMJ. 2010 May 20;340:c2369.

13. Veal AJ, Toohey K, Frawley S. The sport participation legacy of the Sydney 2000 Olympic Games and other international sporting events hosted in Australia. Journal of policy research in tourism, leisure and events. 2012 Jul 1;4(2):155-84.

14. Hogan, K., & Norton, K. The 'price' of olympic gold. J Sci Med Sport, 2000,3(2), 203-218

15. IOC. Candidate Acceptance Procedure, 2007. Accessed 2020 at: https://protect-au.mimecast.com/s/Ix70CMwvLQTZYyQmTWREsi?domain=stillmed.olympic.org

16. Olympic Review 2006. Olympic Games Global Impact. IOC library https://stillmed.olympic.org/Documents/Reports/EN/en_report_1077.pdf

17. Morgagas M, Botella M Eds The keys to success: the social, sporting, ecnomic and communications impact of Barcelona 92. Centre d'Estudis Olimpics i de L'Esp;ort, Universitat Autonoma de Barcelona, Fundacio Barcelona Olimpica, 1995.

18. An R, Xiang X, Yang Y, Yan H. Mapping the prevalence of physical inactivity in US States, 1984-2015. PloS one. 2016;11(12).

19. Takamiya T, et al. (2019): Trends in step-determined physical activity among Japanese adults from 1995 to 2016. Med Sci Sports Exerc, 51, 1852-1859.

20. Bauman A, Bellew B, Craig CL. Did the 2000 Sydney Olympics increase physical activity among adult Australians?. Br J Sports Med. 2015 Feb 1;49(4):243-7.

21. Tian Y, Jiang C, Wang M, Cai R, Zhang Y, He Z, Wang H, Wu D, Wang F, Liu X, He Z. BMI, leisure-time physical activity, and physical fitness in adults in China: results from a series of national surveys, 2000–14. The Lancet Diabetes & Endocrinology. 2016 Jun 1;4(6):487-97.

22. International Olympic Committee: Final Report of the IOC Coordination Commission. XXI Winter Olympic Games, Vancouver 2010. International Olympic Committee; 2011. Available at http://www.olympic.org/ Documents/Games_Vancouver_2010/Vancouver-EN.pdf.; Accessed October 8, 2013.

23. Craig CL, Bauman AE. The impact of the Vancouver Winter Olympics on population level physical activity and sport participation among Canadian children and adolescents: population based study. International journal of behavioral nutrition and physical activity. 2014 Dec 1;11(1):107.

24. Potwarka LR, Leatherdale ST. The Vancouver 2010 Olympics and leisure-time physical activity rates among youth in Canada: any evidence of a trickle-down effect?. Leisure Studies. 2016 Mar 3;35(2):241-57.

25. Chen S, Preuss H, Hu X, Kenyon J, Liang X. Sport Policy Development in China: Legacies of Beijing's 2008 Summer Olympic Games and 2022 Winter Olympic Games. Journal of Global Sport Management. 2019 Feb 2:1-30.

26. Reis, AC, Frawley, S, Hodgetts, D, Thomson, A & Hughes, K 2017, 'Sport participation legacy and the Olympic games: the case of Sydney 2000, London 2012, and Rio 2016', Event Management 21: 2:139-158.

27. Cashman, R. The bitter sweet awakening: the legacy of the Sydney 2000 Olympic Games. Sydney: Centre for Olympic Studies 2006

28. Weed M, Coren E, Fiore J, Wellard I, Chatziefstathiou D, Mansfield L, Dowse S. The Olympic Games and raising sport participation: a systematic review of evidence and an interrogation of policy for a demonstration effect. European sport management quarterly. 2015 Mar 15;15(2):195-226.

29. Reis RS, Salvo D, Ogilvie D, Lambert EV, Goenka S, Brownson RC, Lancet Physical Activity Series 2 Executive Committee. Scaling up physical activity interventions worldwide: stepping up to larger and smarter approaches to get people moving. The lancet. 2016; 388(10051):1337-48.

30. Carter RV, Lorenc T. 2015. A qualitative study into the development of a physical activity legacy from the London 2012 Olympic Games. *Health Promotion International*, *30*(3):793-802.

31. Annear MJ, Shimizu Y, Kidokoro T. Sports mega-event legacies and adult physical activity: A systematic literature review and research agenda. EJSS (Champaign). 2019;19(5):671-85.

32. Bowles HR, Rissel C, Bauman A. Mass community cycling events: Who participates and is their behaviour influenced by participation?. International Journal of Behavioral Nutrition and Physical Activity. 2006 Dec;3(1):1-7.

33. Lane A, Murphy NM, Bauman A. (2012). Active for a day: predictors of relapse among previously active mass event participants. Journal of Physical Activity and Health, 9, 48-52.

34. Chatton, A. and B. Kayser (2013). Self-reported health, physical activity and socio-economic status of middle-aged and elderly participants to a popular road running race in Switzerland: better off than the general population? Swiss Medical Weekly 143: w13710.

35. Harrington RA, Arena R, Despres JP, Ciarochi A, Croll E, Bloch KD, et al. More than 10 million steps in the right direction: results from the first American Heart Association scientific sessions walking challenge. Prog Cardiovasc Dis. 2015;57(4):296-8.

36. Lane A, Murphy NM, Smyth P and Bauman A (2010). Do mass participation sporting events have a role in making populations more active? Research Report No. 2. The Irish Sports Council 2010.

37. Grunseit, A.C., Richards, J., Reece, L., Bauman, A. and Merom, D., 2020. Evidence on the reach and impact of the social physical activity phenomenon parkrun: a scoping review. Preventive Medicine Reports, p.101231.

38. Ogilvie D, Adams J, Bauman A, Gregg EW, Panter J, Siegel KR, Wareham NJ, White M. Using natural experimental studies to guide public health action: turning the evidence-based medicine paradigm on its head. J Epidemiol Community Health. 2020 Feb 1;74(2):203-8.

39. Horne J. The four ‘knowns’ of sports mega-events. Leisure Studies. 2007;1;26(1):81-96.

40. Dolan P, Kavetsos G, Krekel C, Mavridis D, Metcalfe R, Senik C, Szymanski S, Ziebarth NR. The host with the most? The effects of the Olympic Games on happiness. (2016). DIW Discussion Papers, No. 1599, Deutsches Institut für Wirtschaftsforschung (DIW), Berlin.

41. Ding D, Lawson KD, Kolbe-Alexander TL, Finkelstein EA, Katzmarzyk PT, Van Mechelen W, Pratt M, Lancet Physical Activity Series 2 Executive Committee. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. The Lancet. 2016 Sep 24;388(10051):1311-24.

453 **Table 1. Pre-Olympic policy statements about physical activity (PA), sport and related legacies**

Olympic Host City	Title of Olympic policy / planning document(s)	Physical activity/ sport policy statements / promise	Other legacies mentioned in pre- and post-Olympic documents relevant to sport or PA
Barcelona 1992 (Summer Games)	Official Report of the Games of the XXV Olympiad Barcelona 1992; Bid document 1986 (Candidature file)	No mention of physical activity or community participation; develop "amateur sport" (Bid p4).	Official post Games report only mentions "legacy" of sport infrastructure
Lillehammer 1994 (Winter Games)	Bid documentation (Candidature file) 1987	"legacy" term not used; no mention of physical activity or community sport participation	Not known
Atlanta 1996 (Summer Games)	https://www.georgiaencyclopedia.org/articles/sports-outdoor-recreation/olympic-games-1996 and Olympic Bid (Candidature file) 1990	No mention of physical activity or community sport participation.	Atlanta sporting facilities, pedestrianisation, housing and building projects; legacy of community sport events
Nagano 1998 (Winter Games)	Nagano Winter Olympics Bidding Committee. (1991) "1998 NAGANO JAPAN" (Official bid file); Nagano City. (1990) "1998 Olympic Winter Games Plan" Nagano City, Nagano. [In Japanese]	No mention of PA legacy; mention of sports facilities	"The athletic facilities will continue to be enjoyed by athletes and sports enthusiasts" (p.10, Bid file)
Sydney 2000 (Summer Games)	IOC Summer OG bid, 1993. IOC library (Bid : Candidature file)	No mention of PA or community sport participation	Mention of community sports facilities; mention of sporting facility and parklands legacy [Bid file vol 2:12.24:5] Legacy of transport [2:5,20,76]
Salt Lake City 2002 (Winter Games)	Olympic bid document 1990	No mention of physical activity or sport participation	Community program, "A Healthier You 2002."
Athens 2004 (Summer Games)	Official report of the Summer Olympic Games Athens 2004. ISBN 9608810175 (volume 1); 9608810183	No mention of PA or sport legacy	Public transportation legacy

	(volume 2)		
Turin 2006 (Winter Games)	https://www.olympic.org/news/how-turin-was-transformed-by-hosting-an-olympic-winter-games. ; Torino 2006 Olympic Bid Volumes1-3 in Watts compilation (2014)	No mention of physical activity or community sport in bid documents	Twenty-five "Olympic ring education initiatives" engaged over 600,000 schoolchildren
Beijing 2008 (Summer Games)	Bid document. Official report of the Beijing 2008 Olympic Games Vol 1; Dapeng et al 2010 ; Watts compilation: Beijing Bid 17:1	inspired China's nation-wide fitness program"…. "… young people can benefit from the Olympic experience and become promoters of the Olympic spirit."	Eco-friendly and energy saving; "athletes-centered" perspective in planning venues and facilities;
Vancouver 2010 (Winter Games)	Canadian Sport policy Federal/Provincial/Territory priorities for collaborative action 2007-2012 Vancouver 2010 Bid report , 2009	No mention of PA or community sport participation;	Create "sustainable legacies for athletes / sport development .... " ; (environmentally friendly) transport systems; Aboriginal and Youth sport legacy; Action Schools BC (a dissemination project for activity in schools).
London 2012 (Summer Games)	Series of Government Department policy documents 2007-2012 **	increase grass roots participation, particularly by young people ; to encourage the whole population to be more physically active [c,d]; …exploits of our elite athletes will inspire young people.. …to get into sport… long-term step change in the number of people who play sport, is to create a sporting habit amongst young people [e]	Urban transformation; Olympic Park a blueprint for sustainable living [a,b,d]; economic and community engagement [c,d]

Sochi 2014 (Winter Games)	IOC 2014 Evaluation Commission Report, XXII Olympic Winter Games 2014	No mention of physical activity or community sport participation	New infrastructure and transport; legacy for sports
Rio de Janeiro 2016 (Summer Games)	Caderno Legado Social (Social Legacy Report of the Rio 2016 Games) http://www.cesmac.edu.br/admin/wp-content/uploads/2014/11/cadernoLegadosSocial-1.pdf; Live your passion; Rio 2016 candidate city	expand the reach of sports and physical activity programs to citizens. No mention of physical activity or sport participation in "Live your passion" document	Municipalities and community-based organizations. Infrastructure and transport development; young athlete scholarships, training facilities; sport infrastructure
Pyeong-chang 2018 (Winter Games)	IOC PyeongChang report, Vol 1 (in Watts compilation)	No mention of physical activity or community sport	hub of winter sports in Asia, Olympic Legacy Development Fund (p25)
Tokyo 2020 (Summer Games)	The Tokyo Organising Committee of the Olympic and Paralympic Games. (2016) Tokyo 2020 Action and Legacy plan 2016	..increase in number of people who regularly do exercises and sports … (increase in sport participation), promotion of sports among employees and residents	Designated 'Sports Day'"; opening corporate sports facilities to the general public; pillar of sport and health

Legend:

** 2007 Dept Culture, Media and Sport (DCMS) Winning: Tourism Strategy for 2012 and Beyond [a] 2007 DCMS: Our Promise 2012 [b] 2008 DCMS: Before, During and After –making the most of London Games [c] , 2010 DCMS: Plans for OG legacy [d] , 2012 DCMS: Creating a sporting habit for life –new youth sport strategy [e], 2012 DCMS: Beyond 2012 –the London 2012 legacy story [f]

Notes: Olympic bid data from IOC library, Lausanne https://library.olympic.org/ or from a private curated compilation (accessed August 2020)
Watts T: https://issuu.com/thatsnotmypuppy

Figure 1. Trends in population sport or physical activity participation for host Olympic cities or nations

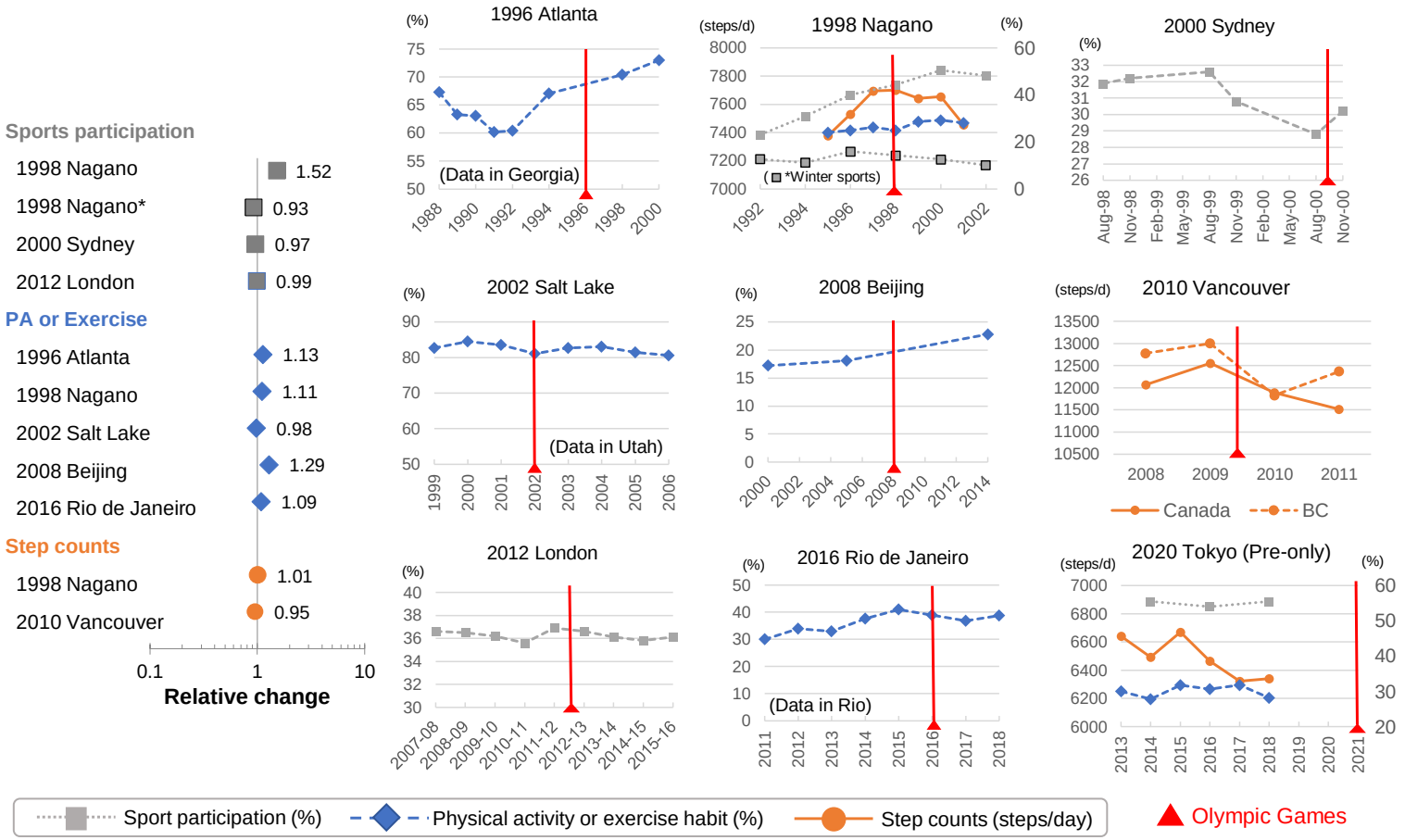


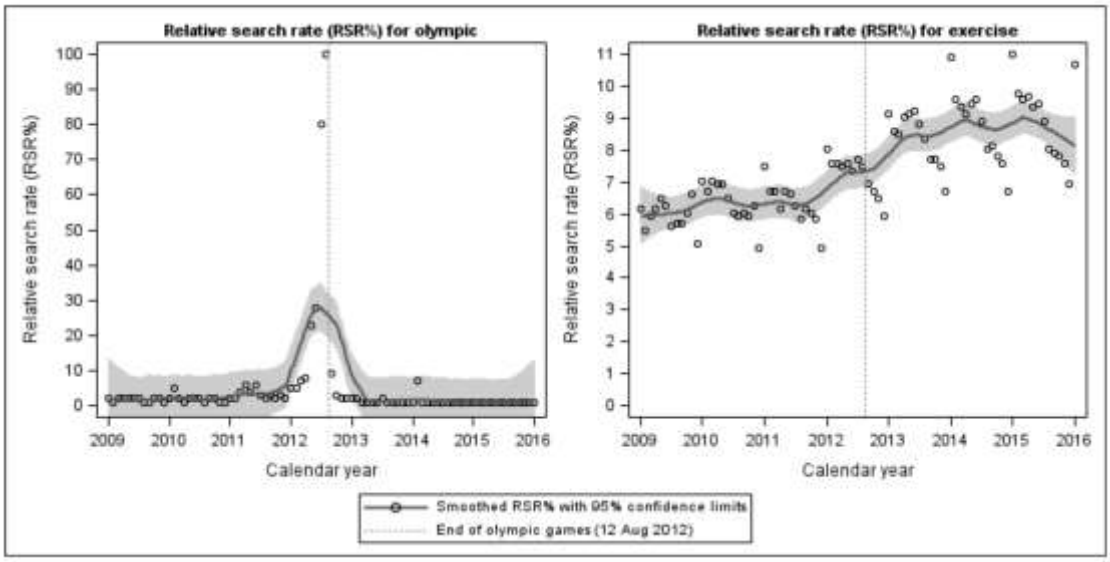
Figure: Population-level physical activity before and after the Olympic Games in the hosting countries.
PA: physical activity, BC: British Columbia. Physical activity data are from nationally representative samples unless otherwise stated. Relative change was obtained by dividing the post average by the pre average. Relative change greater than 1.0 indicates that population-level physical activity increased after the Olympic Games. *Winter sports participation. Detailed information about the measures for each country can be found in Supplementary Online file, Appendix B.

Panel 1. Population-level interest in physical activity during the 2012 London Olympic Games

In recent years, Google Trends has been recognised as an innovative and valuable tool for "infoepidemiology" and "infoveillance"[1], which has been successfully used to predict infectious disease outbreaks, evaluate tobacco control policies[2,3] and track community interest in physical activity and exercise during the pandemic of COVID-19 [4]. Not all Google trends data are accurate, and may overestimate influenza outbreaks. We used Google data in a different way, to assess subjective community interest in participating in exercise and physical activity during the Olympic Games period. We used this as a hypothesis generating analysis, to provide supplementary evidence to the prevalence data included in Figure 1, based on the assumption that changes in community interest, intention and information-seeking precede changes in behaviours. Previous population survey data in evaluating the Sydney Olympics showed an increase in community interest regarding exercise, but no change in physical activity prevalence. No such data were available for other Olympic Games, so we present this method as a tentative, but innovative approach to assessing changes in community interest.

We selected the 2012 Summer Olympic Games as a case study and modelled the population-level interest in "Olympic Games" in contrast to the topic of "exercise" between 2009 and 2016, before and after the London Olympics (see Supplementary Online Appendix B for methodology). Using Interrupted time series analysis, results show an acute surge in "Olympic" searches immediately associated with the Olympic Games period. The right hand panel shows a clear increase in search queries related to "exercise" immediately leading up to the London Olympics, and a continued (but not significantly different) post-Olympics increase in "exercise" until June 2013 [See Online Appendix B]. In conclusion, the UK population may have become more interested in exercise during the time of the 2012 London Olympic Games. While the skyrocketing interest in this mass sporting event was fleeting, the interest in physical activity-related behavioural change may have been more sustained. The purpose of this analysis is illustrative, to show how 'big data' can be used for real-time assessment of community interest around the Olympic Games. Data of the public's online searching behaviour may reflect community interest and does not translate to population-level increase in physical activity engagement and should always be triangulated against other information, such as that from long-term surveillance systems.

Figure 2. Trends in Google searches for the topics "Olympic" and "Exercise" around the London 2012 Olympic Games



References for (Text Box) Panel 1:

1 Mavragani A, Ochoa G. Google Trends in infodemiology and infoveillance: Methodology framework. *JMIR Public Health Surveill* 2019;5(2):e13439; [2] Troelstra SA et al Effect of tobacco control policies on information seeking for smoking cessation in the Netherlands: A Google Trends study. PLoS ONE 2016;11(2): e0148489; [3] Pelat C, Turbelin C, Bar-Hen A, Flahault A, Valleron AJ. More diseases tracked by using Google Trends. Emerging infectious diseases. 2009 Aug;15(8):1327; and Hay SI, George DB, Moyes CL, Brownstein JS. Big data opportunities for global infectious disease surveillance. PLoS med. 2013 Apr 2;10(4):e1001413; [4] Ding D, del Pozo Cruz B, Green MA, Bauman AE. Is the COVID-19 lockdown nudging people to be more active: a big data analysis. Brit J Sports Med , March 2020. {5} Lazer, D, et al (2014). The Parable of Google Flu: Traps in Big Data Analysis. Science 343(6176): 1203., also Lazar D. (2015) WIRED. https://www.wired.com/2015/10/can-learn-epic-failure-google-flu-trends/

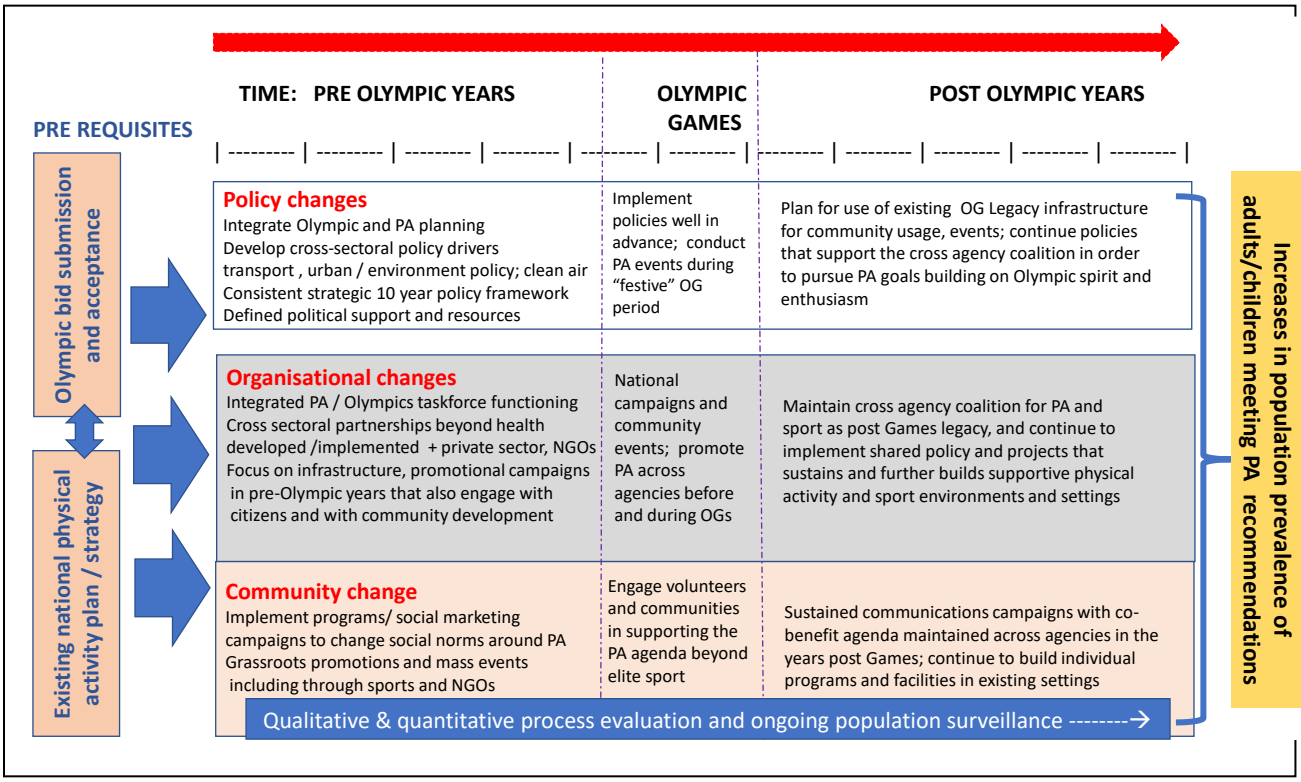


Figure 3. Multi-year conceptual framework (logic model) for assessing whether the Olympic Games influences population physical activity or sport participation