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Opinion

Public health research on physical activity and COVID-19: Progress and updated priorities

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1. Introduction

Before coronavirus disease 2019 (COVID-19) became a global health emergency in early 2020, there was substantial evidence of physical activity's (PA's) multiple benefits with direct relevance to reducing the harms of the pandemic: improved immune functioning and reduced inflammation to lessen severity of infections, enhanced efficacy of vaccines, especially among high-risk older adults, and stress reduction.[1] The World Health Organization recommended PA to reduce impacts of the pandemic, but few countries incorporated PA promotion as part of their pandemic control efforts.[2] As PA researchers and advocates, we were concerned that, in most countries, PA was not being recommended at a time when very few tools were available to combat the disease. We were further concerned that some of the infection control strategies being implemented would create major barriers to being active by closing most of the indoor and some of the outdoor locations where people are commonly active. We hypothesized one reason why PA was not being promoted was the lack of evidence showing its benefits were directly applicable to COVID-19. Thus, we considered research on PA and COVID-19 to be a global priority and developed a public health-oriented research agenda. The paper describing our 7 recommended research priorities was published in the *Journal of Sport and Health Science* and released online in May 2020.[3]

The purpose of the current opinion article was to provide a selective narrative summary of PA-related topics that (a) have been well studied during the pandemic, (b) have not been well studied, and (c) are emerging research priorities. We rely on review papers whenever possible. To conclude, we recommend improved efforts to place PA on the research and application agendas for the continuing COVID-19 pandemic and future health crises.

2. Well-studied PA and COVID-19 topics

2.1. PA's COVID benefits

A sizeable but little-noticed literature on PA's influence on immune functioning provided evidence of mechanisms by which PA could directly impact COVID-19 outcomes. Early in the pandemic this pre-existing literature was meta-analyzed and showed physically active people were less likely to have community-acquired infections, had better functioning immune systems, and had stronger antibody responses to vaccines.[4] Research on these and similar mechanisms increased during the pandemic and both confirmed previous findings and identified additional benefits related to infectious diseases.

The top research priority in our 2020 paper[3] was to evaluate whether PA protected COVID-19 patients from severe outcomes, which would be expected based on the existing evidence of mechanisms. By 2022 it was possible to conduct a meta-analysis of 16 observational studies involving about 1.8 million participants.[5] Physically active adults had an 11% lower risk of being infected, a 36% lower risk of hospitalization for COVID-19, and a 43% lower risk of dying.[5] Thus, PA researchers quickly built a strong evidence base that physically active people appeared to be protected from severe COVID-19 outcomes to a substantial extent.

2.2. Effects of COVID on PA and sedentary behavior

Government orders to close most of the common indoor, and often outdoor, locations for PA, sports, and exercise were

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widespread in the early months of the pandemic. These locations included fitness centers, schools, parks, and trails. Some countries prohibited or severely limited going outdoors. Thus, it was expected PA would decline during the pandemic, and sedentary behavior would increase since people were spending much more time at home. Numerous studies quantified these impacts, and the results were fairly consistent, though effect size estimates were limited by the variety of study designs and self-reported measures. A 2021 review[6] summarized 64 studies. The vast majority of 45 studies of adults reported decreases in PA, and all 26 studies of sedentary behavior showed increases. Among youth, all 6 studies showed decreases in PA, and all 5 studies showed increases in sedentary behavior.[6] By contrast, Buehler and Pucher[7] found cycling for transportation increased between 2019 and 2020 in most cities across Europe, North America, and Australia. They explained the encouraging pattern by noting many cities expanded safe bicycling infrastructure, and some people who stopped riding public transport started bicycling.[7]

2.3. PA, restricted use of green space, and mental health

There is considerable evidence the disruption to daily lives brought about by COVID-19 negatively impacted mental health, and PA played a contributing role.[8] A study of 5 U.S. cities described a bi-directional, cyclical relation between PA and mental health disorders during the pandemic, identifying PA as a protective factor that could reduce mental health impacts of current and future pandemics.[9] A review[10] of 31 studies showed higher PA during the pandemic was associated with fewer negative mental health symptoms across the lifespan. However, there was no consensus on PA level, frequency, or types for mitigating negative mental symptoms.[10] A review[11] of 21 observational studies conducted in 2020 showed higher total time in PA was associated with 12%−32% lower chances of having depressive symptoms and 15%−34% of anxiety symptoms. It would be useful to examine why PA was not recommended to relieve widespread mental health problems during the pandemic despite its well-documented mental health benefits.

In the early days of the pandemic, public parks, green spaces, and trails were closed. These restrictions contributed to increased adverse physical and mental health outcomes, which, in turn, may be negatively associated with how well people can fight COVID-19 infections.[12]

3. PA and COVID-19 topics that were not well-studied

3.1. PA interventions during COVID-19

One priority topic in our 2020 PA and COVID-19 proposed research agenda was to develop and evaluate PA interventions during COVID-19, both for examining the effects of PA on COVID-19 outcomes (i.e., PA as the intervention), and for improving PA participation during pandemic-induced lockdown periods (i.e., PA as the outcome). Unfortunately, very few PA intervention studies were published during the pandemic. According to Google Scholar, up until April 4, 2023, 236 publications cited the PA and COVID-19 research agenda article,[3] and among them, only 6 (2.5%) were of intervention studies (experimental and quasi-experimental study designs). Three of these studies were telehealth, ehealth or mhealth interventions (telephone, app-based, or internet-based interventions) to promote PA (e.g., McDonough et al.[13]). While this limited review of citations of the research agenda paper is not a substitute for a systematic search, it reflects a lack of progress in this area.

A PubMed search conducted on April 4, 2023, for "physical activity or exercise interventions to improve COVID-19 recovery outcomes" revealed a similar pattern. Only a handful of trials were conducted during the pandemic testing the effectiveness of PA for optimizing COVID-19 recovery (e.g., Li et al.[14]).

Importantly, all of the identified studies reported positive findings. These few studies provided suggestive evidence that virtual and telehealth strategies can increase or maintain PA during periods of restricted mobility like a pandemic. The need to identify effective interventions for promoting PA in times of crisis remains a priority, especially given realistic threats of future pandemics and climate-related emergencies.

3.2. Activity-supportive environments for COVID-19 mitigation

Extensive international research indicates residents of walkable, higher-density, mixed land use, and pedestrian-oriented communities with access to green space are more physically active for transportation and recreation purposes and have lower risks of multiple non-communicable diseases than residents of lower-density suburban-style neighborhoods. In the early stages of the pandemic, news reports claimed population density increased spread of the virus. Some government leaders and prominent commentators promoted suburban sprawl to save lives during the pandemic.[15] Since 2020, a handful of studies investigated the relation between the built environment and COVID-19. Studies early in the pandemic focused on population density and produced conflicting results, with findings of no association, negative association, and positive association with COVID-19 mortality.[16] Only a couple of studies examined other features of activity-supportive environments, such as mixed land use and green space. Both studies reported activity-supportive environments had favorable associations with COVID-19 mortality, partly explained by PA (active transport) and overweight/obesity.[17,18] Since non-communicable diseases are responsible for 74% of deaths worldwide every year,[19] we argue it would be misguided to recommend reducing density and increasing sprawl to improve health based on a once-in-a-century pandemic. The role of built environments in infectious diseases deserves further study.

3.3. Contribution of PA disparities to COVID disparities

Another topic that was not extensively studied was the relation of PA disparities to the well-documented inequities of COVID-19 infection and outcomes. Especially for economically disadvantaged groups, one main driver of regular PA is economic necessity, through active transport and active

labor.[20] Even prior to the pandemic, opportunities for choice-based PA (i.e., during leisure-time or active transport in safe and enjoyable environments) tended to be more common among more privileged groups, and the pandemic could be expected to widen these inequities.[21] During the pandemic, low-income individuals, who generally rely more on necessity-driven PA, were also those at higher risk for COVID-19 infection, as they were more likely to have "essential" jobs. Lower income individuals also were more likely to live in crowded households and neighborhoods with fewer activity-promoting assets.[20] Studies documented that these environmental and employment inequities amplify pre-existing PA disparities,[22,23] but more work is needed to understand how PA inequities contribute to inequities in infectious disease outcomes.

4. Emerging PA-related topics and updated priorities

4.1. Role of PA in long COVID

Long COVID describes new or enduring symptoms after the acute phase of COVID-19 infection. Though the optimal management of long COVID is yet to be developed, PA may have a role due to its benefits for many symptoms of long COVID.[24] However, evidence from observational studies suggests PA has the potential to both improve and worsen long COVID symptoms. In a qualitative study,[25] some long COVID patients reported improved mental health with outdoor activities and walking, but others reported worsening symptoms. At least 2 studies[26,27] reported a large majority of long COVID patients reported PA worsened their symptoms or stimulated relapses. Studies are needed to examine whether exercise protocols with minimal acute side effects can be devised, for which subgroups of long COVID patients exercise might not be indicated, and whether exercise may yield longer term benefits.

4.2. PA as a vaccine adjuvant

Prior to the pandemic there was a modest literature on chronic or acute exercise as an adjuvant for vaccinations for a variety of viral and bacterial diseases. The main outcome was antibody titers, which are a mechanism of vaccine effectiveness. The rationale is that PA's multiple effects on the immune system prepare the body to mount a more effective, and perhaps longer-lasting, response to vaccines. A meta-analysis of 6 studies reported an overall significant but modest effect, but there was variation by disease.[4] An earlier review[28] of 20 studies with varied designs also reported encouraging results. The second review highlighted PA may be particularly effective among older adults, who typically have less efficient immune systems and weaker vaccine responses (immunosenescence).[28] Despite this pre-pandemic evidence and experience of fairly rapid declines in COVID-19 vaccine effectiveness, we found few studies on PA as a vaccine adjuvant during the pandemic. One paper reported evaluations of 1 COVID-19 vaccine and 2 influenza vaccines, with and without 90 min of light-to-moderate intensity PA immediately following vaccination. The PA stimulated a much stronger antibody response to all vaccines 1 week after both a first dose and second dose, without any increase in vaccination side effects.[29] We recommend studies of PA as an adjuvant be routinely conducted with new vaccines in diverse population groups.

4.3. Reasons for limited application of PA during the pandemic

Neither the pre-pandemic evidence of PA's benefits for immune function and infectious diseases nor the substantial evidence produced during the pandemic seems to have been incorporated into pandemic control discussions or recommendations in most countries. Although the World Health Organization recommended PA early in the pandemic and publicized relevant findings,[30] as did the United Kingdom and perhaps a few other countries, pandemic advice in most countries allowed exercise as an "essential activity", but did not explicitly recommend it for COVID-19 prevention and control. In our observations, the PA evidence related to COVID-19 was essentially ignored by public health and infectious disease leaders. For example, a news article[31] reporting on the strong results of a meta-analysis of pre-diagnosis PA on COVID-19 outcomes[5] included responses from 2 infectious disease experts. They questioned the measurement of PA and mentioned the lack of clarity about mechanisms of action and optimal dose of PA. There were no comments on the public health significance of a 43% lower mortality among active adults, and the experts advised it was too early to act on the evidence. Thus, it would be valuable to examine the perceptions of infectious disease and public health investigators and leaders about PA and COVID-19 studies to understand reasons for not incorporating the apparently powerful preventive effects in public health actions.

5. Conclusion

The conclusion of our 2020 research agenda paper[3] still applies 3 years later: "PA has multiple well-documented benefits directly related to reducing impact of the COVID-19 infection itself, as well as helping the global population cope with the isolation and stress caused by the pandemic. Yet, PA is not being strategically nor systematically promoted to reduce harm from the current pandemic. Thus, there is an urgent need for research that can inform more effective PA policies and practices in the short-term and prepare global public health for better responses to future crises."[3] The PA research community worldwide responded to the pandemic quickly with a burst of creative research on a range of topics. Among other findings, this research demonstrated PA has the potential to substantially reduce the risk of severe COVID-19 outcomes,[5] and restrictions to reduce transmission among individuals clearly decreased PA and increased sedentary behavior across the age range.[6] However, this evidence has been generally ignored, with the prominent exception of the World Health Organization, and very few countries incorporated PA into pandemic recommendations. The combination of failing to promote PA and creating barriers to being active likely had a detrimental impact on public health. The absence of PA

education and promotion in response to the current pandemic makes it likely preparations for future infectious disease epidemics and pandemics will also fail to take advantage of the multiple benefits of PA in public health practice. Research to date has not led to the application of PA to limit harm during the COVID-19 pandemic, so PA researchers may need to rethink our research objectives, methods, partners, and approaches to communicating research to those who can translate research findings into more effective policy and practice, if not for the continuing COVID-19 situation, then for future pandemics and crises generated by climate change.

Authors' contributions

All authors agreed on the outline of the piece, drafted sections, and critically edited the full manuscript draft. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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