


PERSPECTIVES | *Integrative Cardiovascular Physiology and Pathophysiology*

Social isolation during the COVID-19 pandemic can increase physical inactivity and the global burden of cardiovascular disease

 **Tiago Peçanha,^{1,*} Karla Fabiana Goessler,^{1,2,*} Hamilton Roschel,^{1,2} and Bruno Gualano^{1,2,3}**

¹Applied Physiology and Nutrition Research Group, School of Physical Education and Sport, Faculdade de Medicina FMUSP, Universidade de São Paulo, São Paulo, Brazil; ²Rheumatology Division, Hospital das Clínicas HCFMUSP, Faculdade de Medicina, Universidade de São Paulo, São Paulo, Brazil; and ³Food Research Center, University of São Paulo, São Paulo, Brazil

Submitted 17 April 2020; accepted in final form 12 May 2020

Peçanha T, Goessler KF, Roschel H, Gualano B. Social isolation during the COVID-19 pandemic can increase physical inactivity and the global burden of cardiovascular disease. *Am J Physiol Heart Circ Physiol* 318: H1441–H1446, 2020. First published May 15, 2020; doi:10.1152/ajpheart.00268.2020.—Emerging data indicate a substantial decrease in global physical activity levels during the period of social isolation adopted worldwide to contain the spread of the coronavirus disease 2019 (COVID-19). Confinement-induced decreases in physical activity levels and increases in sedentary behavior may provoke a rapid deterioration of cardiovascular health and premature deaths among populations with increased cardiovascular risk. Even short-term (1–4 wk) inactivity has been linked with detrimental effects in cardiovascular function and structure and increased cardiovascular risk factors. In this unprecedented and critical scenario, home-based physical activity programs arise as a clinically relevant intervention to promote health benefits to cardiac patients. Many studies have demonstrated the feasibility, safety, and efficacy of different models of home-based exercise programs in the primary and secondary prevention of cardiovascular diseases and major cardiovascular events among different populations. This body of knowledge can inform evidence-based policies to be urgently implemented to counteract the impact of increased physical inactivity and sedentary behavior during the COVID-19 outbreak, thereby alleviating the global burden of cardiovascular disease.

cardiac diseases; coronavirus; exercise; sedentary behavior

Coronavirus disease 2019 (COVID-19) is an infectious disease of pandemic proportions, with more than 4,000,000 cases and approximately 278,000 deaths reported worldwide as of May 12, 2020 (50). COVID-19 is a public health emergency of international concern (51), and as such, it requires coordinated, protective responses from national and supranational entities around the world. The absence of specific preventive or therapeutic medical interventions for COVID-19 infection, alongside its rapid transmission rate and apparently substantial undocumented contamination and transmission numbers, has led to the scientifically sound recommendation that individuals must stay home to avoid social interactions and restrain the disease spread, thereby reducing pressure on health systems worldwide. Despite being effective for infection control, this strategy has potential behavioral and clinical repercussions.

Home isolation is likely to result in a profound decrease in moderate-to-vigorous physical activity levels and increase in sedentary behavior, e.g., “any waking behavior characterized by an energy expenditure of ≤ 1.5 MET while in a sitting or reclining posture” (48). Although the actual impact of worldwide isolation on physical activity levels remains to be shown, Fitbit, Inc., an American company that develops wearable devices that track an individual’s physical activity level, has recently shared physical activity data from 30 million users that demonstrates a substantial reduction (ranging from 7% to 38%) in average step counts in almost all countries during the week ending March 22, 2020, as compared with the same period last year (20). This preliminary evidence suggests that quarantine may provoke a substantial decline in physical activity levels, similar to that which is observed in other confined conditions, such as spaceflight exploration and incarceration (1, 5). Several levels of evidence, from epidemiology to molecular sciences, suggest that the potential increase in physical inactivity induced by the pandemic may have substantial repercussions for cardiovascular health.

The seminal study by Morris et al. (35) showing increased cardiovascular mortality in bus drivers (inactive) compared with bus conductors (active) from the London double-decker buses encouraged a number of epidemiological studies that demonstrated the links between physical inactivity and cardiovascular risk. Of interest is that the adjusted relative risks of coronary heart disease and overall mortality associated with physical inactivity are 1.16 (1.04–1.30) and 1.28 (1.21–1.36), respectively (32). More recently, evidence from clinical trials and mechanistic studies have demonstrated that physical inactivity can lead to cardiovascular abnormalities as well as their molecular mechanisms. Data from bed rest studies, a model of muscle unloading and inactivity, have demonstrated that a few weeks of immobilization promote cardiac atrophy and dysfunction (41), luminal narrowing of peripheral vessels (38), arterial stiffening (36), and impairment of endothelium-dependent function in the macro- (36, 44) and microcirculation (11). Even less severe models of physical inactivity have shown similar outcomes. For instance, Teixeira et al. (45) observed a large reduction in popliteal artery flow-mediated dilation ($\sim 56\%$ decline) after 1 wk of reduced daily physical activity (from $>10,000$ to $<5,000$ steps/wk). Using a similar step reduction model, Boyle et al. (8) observed a reduction in the brachial artery diameter and an increase in markers of vascular apoptosis and activation within 3–5 days of inactivity. There is

* T. Peçanha and K. F. Goessler contributed equally to this work.
Correspondence: B. Gualano (gualano@usp.br).

evidence that the detrimental effects of inactivity on cardiovascular function take place in an even shorter period. Studies have shown that 3–6 h of uninterrupted sitting is sufficient to cause significant deterioration of vascular function (9, 46, 47). Figure 1A summarizes the detrimental effects of physical inactivity on cardiovascular health.

Mechanisms underlying inactivity-induced cardiovascular dysfunction may involve alterations at different levels. Hypokinesia has been linked with increased autophagy (33) and reduced rates of cardiac muscle protein turnover (4), leading to myocardial cell atrophy (33). These alterations may superimpose on increased oxidative stress and inflammation, which have also been shown to increase as physical activity level decreases (43). As for the vasculature, inactivity reduces mean and antegrade shear rates (46, 47) and increases oscillatory shear levels (47), creating a proatherogenic environment (9, 30). Importantly, inactivity-induced increases in cardiovascular risk may be exacerbated by other inactivity-induced alterations, such as muscle wasting, increased visceral fat, hyperglycemia, and dyslipidemia (6, 28, 29).

Achieving minimum physical activity levels (i.e., 150 min of moderate to vigorous physical activity, 75 min/wk of intensive physical activity, or a combination of both) and reducing sedentary behavior in times of social isolation have become a challenge and, at the same time, a necessity for everyone. Over the last decades, several studies have demonstrated the cardiovascular benefits promoted by exercise in cardiac individuals, who are often physically inactive (25, 39). With the necessary closure of gyms, athletic centers, and parks as part of social distancing measures adopted worldwide (which potentially adds to the decline in physical activity), the use of easily implemented, home-based exercise programs becomes relevant to mitigate the deleterious effects of increased inactivity. Importantly, home-based physical activity interventions have been demonstrated to be feasible, safe, and effective for people with cardiovascular disease (Table 1). These interventions may be highly relevant to restore preisolation physical activity levels and to counteract the negative effects of inactivity on the cardiovascular system. In this scenario, remotely supervised home-based interventions have been shown to significantly

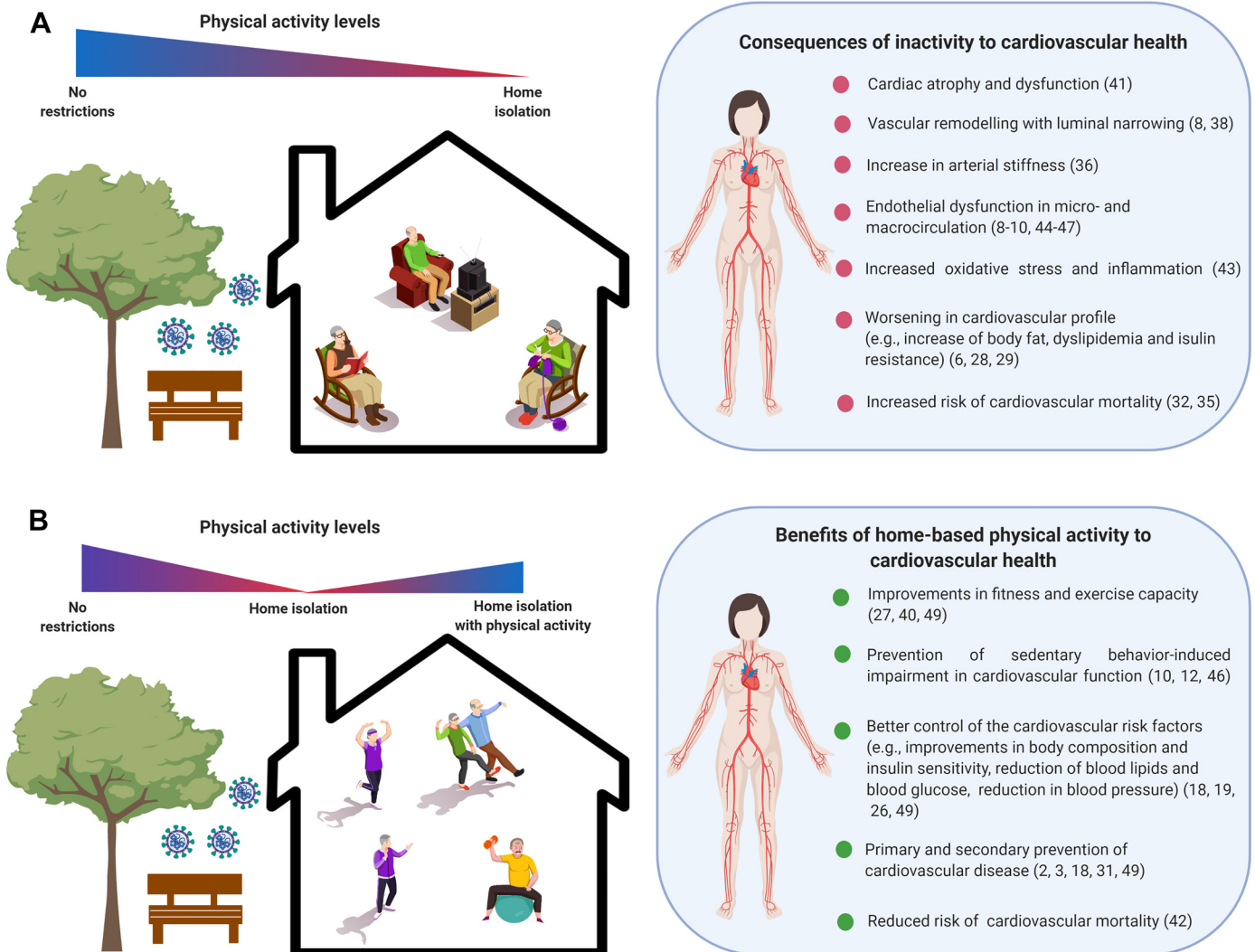


Fig. 1. Consequences of physical inactivity induced by home isolation on cardiovascular health (A) and the benefits of home-based physical activity in offsetting cardiovascular disturbances induced by inactivity (B). Free vectors provided by macrovector/FreePik.

Table 1. Overview of interventions to potentially counteract physical inactivity and sedentary behavior in cardiac patients subjected to social isolation during the COVID-19 outbreak

Population Studied	Intervention Protocols	Monitoring	Main Findings	Strengths	Limitations
<i>Supervised home-based exercise interventions</i>					
Post-MI (49), HF (27, 40, 42), HTN (26)	Frequency: 1 (42), 3 (27, 42) 4 (26, 42), and 5 (40, 42, 49) days/wk Intensity: Light (26, 40, 42), moderate (27, 40, 42, 49), and high (42) Type: aerobic (26, 27, 40, 42, 49), resistance (42), and stretching (27) Time: 15 (40, 42), 30 (27, 40, 42, 49), and 45 (40) min Duration: 6 (49), 8 (27, 40), and 12 (26, 42) wk	Type: m-Health/e-Health applications (40, 49), mentoring sessions, web consultation, phone call (26, 27, 42), email (26, 42), wearable devices (42), logbook (26) Frequency: daily (49), once/wk (27, 42), 3 times/wk (26)	SBP: ↔ (49) ↓ (26) DBP: ↔ (49) ↓ (26) LDL: ↔ (49) HDL: ↔ (49) Body composition: ↓ (49) Exercise capacity: ↑ (27, 40) 6MWT: ↑ (27, 40, 49) Quality of life: ↑ (27, 49)	<ul style="list-style-type: none"> ● HB programs are as effective as CB to maintain exercise capacity and cardiovascular health ● High intervention adherence ● Effective alternative for patients unable to attend traditional CR program ● Access to a health coach may improve communication, social support, education, and adherence to exercise ● HB exercises can be easily integrated with regular home routine 	<ul style="list-style-type: none"> ● Long-term effects of HB are largely unknown ● Applicable only to stable cardiac patients ● Safety of HB interventions in high risk patients is unknown ● Worse control of exercise intensity ● Protocols using subjective monitoring methods (i.e., logbooks) may be not reliable to measure patient's progress over training ● Lack of standardization of HB programs
<i>Non-supervised home-based exercise interventions</i>					
HTN (18, 19), CHF (31), MI (7), CAD (7)	Frequency: 3 (7, 18, 19, 31) days/wk Intensity: light (7) and moderate (7, 18, 19) Type: aerobic (7, 18, 19), resistance (31), and stretching (18, 19) Time: 30 min (7, 18, 19) Duration: 2 (19), 4 (19), 6 (7), 8 (18), 12 (31), and 16 (18) mo	None	Body composition: ↓ (18, 19) SBP: ↓ (18, 19) DBP: ↓ (18, 19) Total Cholesterol: ↓ (19) HDL: ↑ (19) Triglycerides: ↓ (19) Glucose: ↓ (19) Exercise capacity: ↔ (compliant*) (7) ↓ (noncompliant*) (7) Walking capacity: ↑ (31) Quality of life: ↑ (31)	<ul style="list-style-type: none"> ● Low-cost (i.e., do not require health professional, expensive materials and/or monitors); ● Easy to implement at daily routine; ● Applicable for low income patients and in low income countries; ● Empowerment of the patient to self-monitor and regulate exercise intensity; ● Do not need follow-up of physician, physiotherapist or physical trainer. 	<ul style="list-style-type: none"> ● Lack of control of exercise adherence and attendance ● Worse control of exercise intensity ● Adherence is totally dependent of patient's self-regulation ● Not applicable for high risk or unstable/uncontrolled patients
<i>Interventions to reduce sedentary behavior</i>					
Pre-HTN (34), HTN (23, 34), stroke (15)	Type: educational behavioral program (23); counselling session (15); sit less messages (15), and e-Health intervention (34) Duration: 7 (15) and 12 (23, 34) wk	Weekly group meeting (23), home-visit (15), phone call (15), and e-Health alert application messages (34)	Body composition: ↔ (23) SBP: ↓ (23, 34) DBP: ↓ (23, 34) Pain and spasticity (VAS): ↓ (15) Sitting time: ↓ (15) Standing time: ↑ (15) Stepping: ↑ (15)	<ul style="list-style-type: none"> ● Can be safely applied across a range of cardiovascular conditions ● Simple daily reminders to break up sitting time are feasible and low-cost and have positive impacts on CV health ● Possibility to replace sedentary time with simple daily life activities 	<ul style="list-style-type: none"> ● Long-term effects of SB are largely unknown ● Motivation and adherence to intervention may be insufficient ● Low long-term compliance

CAD, coronary artery disease; CB, center-based; CHF, coronary heart failure; CR, cardiac rehabilitation; CV, cardiovascular; DBP, diastolic blood pressure; eHealth, digital health; HB, home based; HDL, high-density lipoprotein; HTN, hypertension; HF, heart failure; LDL, low-density lipoprotein; mHealth, mobile health; MI, myocardial infarction; 6MWT, 6-min walk test; SBP, systolic blood pressure; VAS, visual analogue scale for pain. ↑, Increase; ↓, decrease; ↔, no change. *Groups were classified as compliant (completed ≥3 days/wk of unsupervised exercise after CR discharge) and noncompliant (not completed the unsupervised program after discharge).

improve physical fitness in coronary artery disease and heart failure patients (2, 3, 40, 42) and to be equally effective in center-based interventions for secondary prevention (2). This type of training has shown to be safe for stable low-to-moderate risk cardiac patients and hypertensive individuals

(26, 40, 42, 49). Technological advancements over recent years have boosted the emergence of a multitude of tools, such as physical activity trackers and applications for smartwatches and phones, that can help to improve the delivery of supervised physical activity interventions. These advancements may also

be relevant to expand the reach of such interventions to populations that are unable to attend face-to-face counseling. However, the lack of standardization of home-based exercise intervention to cardiovascular disease populations remains a matter of concern that should be addressed over the next years.

Unsupervised, self-regulated interventions may also offer a viable option to increase physical activity levels and to improve cardiovascular health in populations with stable cardiovascular disease or at increased cardiovascular risk. For instance, Lans et al. (31) observed that 12 mo of home-based low-intensity resistance exercise was effective in improving exercise capacity and quality of life in patients with chronic heart failure, with improvements observed as early as within 3 mo of implementation. Similarly, 4 mo of unsupervised home exercise was reported to improve cardiovascular risk profile in hypertensive individuals (19). Adherence to nonsupervised interventions may be a matter of concern; however, preliminary evidence indicates acceptable adherence levels (~50–80%) (31), which could be further increased by patient education and enhanced social support alongside the intervention (21). The use of these behavioral strategies is yet to be tested in the context of home-based unsupervised exercise programs in cardiovascular disease populations. Figure 1B summarizes the benefits promoted by home-based physical activity on cardiovascular health.

Further to home-based exercise training programs, interventions focused on breaking up sedentary behavior are clinically relevant, given that time spent in sedentary activities has been reported to be a strong risk factor for all-cause mortality and that this is independent of physical inactivity. A large-scale, prospective study using isothermal substitution modeling has demonstrated 24% lower risk of mortality from cardiovascular causes when 30 min/day of sedentary time is replaced with 30 min/day of light-intensity physical activity (13). Data from laboratory studies substantiate the preventive role of breaking sedentary time on cardiometabolic health. For instance, 3- to 5-min bouts of low-intensity walking or body weight resistance exercises every 30–60 min can prevent sitting-associated impairment to vascular and metabolic function in different populations, including obese and type 2 diabetic patients (10, 12, 46). A 4-day intervention targeting the replacement of sitting time with walking and standing improved insulin sensitivity and reduced 24-h glucose levels in type 2 diabetic patients (14). Reducing sedentary time is also of interest to populations undergoing cardiac rehabilitation; in stroke patients, for example, the clinical improvements promoted by exercise and rehabilitation programs may be lost if patients spend too much time sitting (16). Unfortunately, there is less information on the cardiovascular effects of long-term chronic interventions to reduce sedentary behavior. The use of smartwatch and physical activity trackers have shown to be feasible and effective in reducing sedentary time and improving cardiovascular parameters in populations with increased cardiovascular risk (24). However, questions remain about the acceptability and long-term adherence to these strategies in populations with cardiovascular disease (24). Multicomponent behavioral interventions aimed at reducing sedentary time and increasing physical activity levels have also shown promising results in different populations (22); however, the cardiovascular benefits of such

strategies are yet to be comprehensively tested in populations with cardiovascular disease or risk factors.

Social isolation due to the COVID-19 outbreak potentially increases physical inactivity, which may seriously increase the global burden of cardiovascular disease. Using population attributed fractions (PFA), researchers concluded physical inactivity to be responsible for 9% of all-cause mortality, corresponding to ~5.3 million deaths in 2018. This makes physical inactivity a risk factor for poor health outcomes comparable with obesity and smoking (17, 37). Prior to the COVID-19 pandemic, the global prevalence of physical inactivity among patients with coronary heart diseases (CHD) varied from 22.3 to 40.5% across the world (32). Eliminating physical inactivity was estimated to avert 399,000 CHD deaths. We used the same estimates provided by these authors to calculate that all-cause and CHD deaths may scale up by ~535,000, ~1.3 million, and ~2.7 million and by ~42,000, ~105,000, and ~210,250 if inactivity hypothetically increases by 10, 25, or 50%, respectively, during the COVID-19 pandemic (Fig. 2). It is also possible to conjecture that the deleterious effects of inactivity on cardiovascular health will be proportional to the period of inactivity to which individuals will be exposed. As cardiac patients are considered a vulnerable group, it is possible that they may be required to undergo more extreme forms of physical distancing, known as “cocooning,” throughout the pandemic, potentially exacerbating the deleterious effects of physical inactivity on cardiovascular outcomes. Moreover, hospitalized individuals due to COVID-19 will likely face a long road to recovery after prolonged bed rest in the intensive care unit or after being on a ventilator. It is also possible to speculate that physical impairments due to hospitalization may be difficult to resolve in some individuals, predisposing them to a poorer cardiovascular prognosis and scaling up morbimortality.

To avoid premature deaths related to physical inactivity, health care professionals and public health agencies should act together in promoting physical activity during quarantine. Although home-based programs involving low- or moderate- to vigorous-intensity exercises have been shown to be safe and effective for patients with stable cardiovascular diseases, caution should be exercised when prescribing home-based training for high-risk patients. For those, closer remote supervision using telecommunication might be necessary. This is indeed a

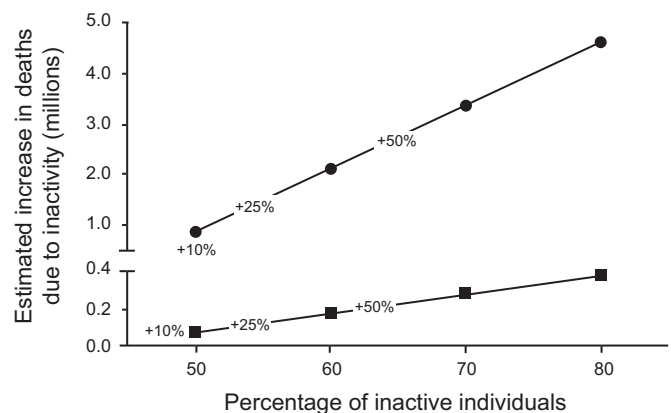


Fig. 2. Potential increases in total (●) and coronary heart disease (CHD; ■) deaths as a function of increases in physical inactivity (32).

challenge for low- and middle-income countries and vulnerable populations, with less (if any) access to internet and technological tools (e.g., wearable devices, health monitors, and physical activity apps). In such a case, the use of text messages and phone calls might be an effective and feasible contact channel between health care professionals and patients. Government actions should reinforce physical activity promotion at a population level as a health care priority, with particular emphasis on vulnerable individuals, who may require more restrictive and longer-duration isolation measures to avoid virus transmission, such as elders and patients with cardiovascular diseases. Scientific societies, including the American Heart Association, the American College of Sports Medicine, and the World Health Organization, have launched practical materials to educate people on the relevance of home-based exercises. This initiative needs to be widely spread to society and quickly assimilated by health care professionals managing cardiac patients.

The recognition of the impact of physical inactivity on the burden of cardiovascular disease and the evidence-based interventions to counteract it is of paramount relevance to inform coordinated public health actions aimed at tackling both COVID-19 and inactivity pandemics simultaneously.

ACKNOWLEDGMENTS

We thank Dr. Eimear Dolan for reviewing the manuscript.

GRANTS

This work was supported by the Sao Paulo Research Foundation Grants 2017/13552-2, 2019/07150-4 and 2019/18039-7, National Council for Scientific and Technological Development Grants 406196/2018-4 and 428242/2018-9, and Coordination for the Improvement of Higher Education Personnel (CAPES-PROEX; Finance Code 001).

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

T.P., K.F.G., H.R., and B.G. conceived and designed research; T.P. and B.G. prepared figures; T.P. and K.F.G. drafted manuscript; H.R. and B.G. edited and revised manuscript; T.P., K.F.G., H.R., and B.G. approved final version of manuscript.

REFERENCES

- Arries EJ, Maposa S. Cardiovascular risk factors among prisoners: an integrative review. *J Forensic Nurs* 9: 52–64, 2013. doi:10.1097/JFN.0b013e31827a59ef.
- Avila A, Claes J, Goetschalckx K, Buys R, Azzawi M, Vanhees L, Cornelissen V. Home-based rehabilitation with telemonitoring guidance for patients with coronary artery disease (short-term results of the TRICH Study): randomized controlled trial. *J Med Internet Res* 20: e225, 2018. doi:10.2196/jmir.9943.
- Batalik L, Dosbaba F, Hartman M, Batalikova K, Spinar J. Benefits and effectiveness of using a wrist heart rate monitor as a telerehabilitation device in cardiac patients: a randomized controlled trial. *Medicine (Baltimore)* 99: e19556, 2020. doi:10.1097/MD.00000000000019556.
- Bederman IR, Lai N, Shuster J, Henderson L, Ewart S, Cabrera ME. Chronic hindlimb suspension unloading markedly decreases turnover rates of skeletal and cardiac muscle proteins and adipose tissue triglycerides. *J Appl Physiol (1985)* 119: 16–26, 2015. doi:10.1152/jappphysiol.00004.2014.
- Belavý DL, Gast U, Daumer M, Fomina E, Rawer R, Schiebl H, Schneider S, Schubert H, Soaz C, Felsenberg D. Progressive adaptation in physical activity and neuromuscular performance during 520d confinement. *PLoS One* 8: e60090, 2013. doi:10.1371/journal.pone.0060090.
- Bienso RS, Ringholm S, Kiilerich K, Aachmann-Andersen NJ, Krogh-Madsen R, Guerra B, Plomgaard P, van Hall G, Treebak JT, Saltin B, Lundby C, Calbet JA, Pilegaard H, Wojtaszewski JFP. GLUT4 and glycogen synthase are key players in bed rest-induced insulin resistance. *Diabetes* 61: 1090–1099, 2012. doi:10.2337/db11-0884.
- Borges JP, Mediano MF, Farinatti P, Coelho MP, Nascimento PM, Lopes GO, Kopiler DA, Tibiriçá E. The effects of unsupervised home-based exercise upon functional capacity after 6 months of discharge from cardiac rehabilitation: a retrospective observational study. *J Phys Act Health* 13: 1230–1235, 2016. doi:10.1123/jpah.2016-0058.
- Boyle LJ, Credeur DP, Jenkins NT, Padilla J, Leidy HJ, Thyfault JP, Fadel PJ. Impact of reduced daily physical activity on conduit artery flow-mediated dilation and circulating endothelial microparticles. *J Appl Physiol (1985)* 115: 1519–1525, 2013. doi:10.1152/jappphysiol.00837.2013.
- Carter S, Hartman Y, Holder S, Thijssen DH, Hopkins ND. Sedentary behavior and cardiovascular disease risk: mediating mechanisms. *Exerc Sport Sci Rev* 45: 80–86, 2017. doi:10.1249/JES.0000000000000106.
- Carter SE, Draijer R, Holder SM, Thijssen DH, Hopkins ND. The effect of breaking up prolonged sitting on cerebral blood flow. *Med Sci Sports Exerc* 48: 311, 2016. doi:10.1249/01.mss.0000485937.04381.e7.
- Demiot C, Dignat-George F, Fortrat JO, Sabatier F, Gharib C, Larina I, Gauquelin-Koch G, Hughson R, Custaud MA. WISE 2005: chronic bed rest impairs microcirculatory endothelium in women. *Am J Physiol Heart Circ Physiol* 293: H3159–H3164, 2007. doi:10.1152/ajpheart.00591.2007.
- Dempsey PC, Sacre JW, Larsen RN, Straznicki NE, Sethi P, Cohen ND, Cerin E, Lambert GW, Owen N, Kingwell BA, Dunstan DW. Interrupting prolonged sitting with brief bouts of light walking or simple resistance activities reduces resting blood pressure and plasma noradrenaline in type 2 diabetes. *J Hypertens* 34: 2376–2382, 2016. doi:10.1097/HJH.0000000000001101.
- Dohrn IM, Kwak L, Oja P, Sjöström M, Hagströmer M. Replacing sedentary time with physical activity: a 15-year follow-up of mortality in a national cohort. *Clin Epidemiol* 10: 179–186, 2018. doi:10.2147/CLEP.S151613.
- Duvivier BM, Schaper NC, Hesselink MK, van Kan L, Stienen N, Winkens B, Koster A, Savelberg HH. Breaking sitting with light activities vs structured exercise: a randomised crossover study demonstrating benefits for glycaemic control and insulin sensitivity in type 2 diabetes. *Diabetologia* 60: 490–498, 2017. doi:10.1007/s00125-016-4161-7.
- English C, Healy GN, Olds T, Parfitt G, Borkoles E, Coates A, Kramer S, Bernhardt J. Reducing sitting time after stroke: A phase II safety and feasibility randomized controlled trial. *Arch Phys Med Rehabil* 97: 273–280, 2016. doi:10.1016/j.apmr.2015.10.094.
- Ezeugwu VE, Manns PJ. Sleep duration, sedentary behavior, physical activity, and quality of life after inpatient stroke rehabilitation. *J Stroke Cerebrovasc Dis* 26: 2004–2012, 2017. doi:10.1016/j.jstrokecerebrovasdis.2017.06.009.
- Ezzati M, Lopez AD. Estimates of global mortality attributable to smoking in 2000. *Lancet* 362: 847–852, 2003. doi:10.1016/S0140-6736(03)14338-3.
- Farinatti P, Monteiro WD, Oliveira RB. Long term home-based exercise is effective to reduce blood pressure in low income brazilian hypertensive patients: a controlled trial. *High Blood Press Cardiovasc Prev* 23: 395–404, 2016. doi:10.1007/s40292-016-0169-9.
- Farinatti PT, Oliveira RB, Pinto VL, Monteiro WD, Francischetti E. [Home exercise program: short term effects on physical aptitude and blood pressure in hypertensive individuals]. *Arq Bras Cardiol* 84: 473–479, 2005. doi:10.1590/S0066-782X2005000600008.
- Fitbit, Inc. *The Impact of Coronavirus on Global Activity* (Online). <https://blog.fitbit.com/covid-19-global-activity/> [25 March 2020].
- Franklin NC. Technology to promote and increase physical activity in heart failure. *Heart Fail Clin* 11: 173–182, 2015. doi:10.1016/j.hfc.2014.08.006.
- Gardner B, Smith L, Lorencatto F, Hamer M, Biddle SJ. How to reduce sitting time? A review of behaviour change strategies used in sedentary behaviour reduction interventions among adults. *Health Psychol Rev* 10: 89–112, 2016. doi:10.1080/17437199.2015.1082146.
- Gerage AM, Benedetti TRB, Cavalcante BR, Farah BQ, Ritti-Dias RM. Efficacy of a behavior change program on cardiovascular parameters in patients with hypertension: a randomized controlled trial. *Einstein (Sao Paulo)* 18: eAO5227, 2020. doi:10.31744/einstein_journal/2020AO5227.

24. Hickey AM, Freedson PS. Utility of consumer physical activity trackers as an intervention tool in cardiovascular disease prevention and treatment. *Prog Cardiovasc Dis* 58: 613–619, 2016. doi:10.1016/j.pcad.2016.02.006.
25. Hirai DM, Musch TI, Poole DC. Exercise training in chronic heart failure: improving skeletal muscle O₂ transport and utilization. *Am J Physiol Heart Circ Physiol* 309: H1419–H1439, 2015. doi:10.1152/ajpheart.00469.2015.
26. Hua LP, Brown CA, Hains SJ, Godwin M, Parlow JL. Effects of low-intensity exercise conditioning on blood pressure, heart rate, and autonomic modulation of heart rate in men and women with hypertension. *Biol Res Nurs* 11: 129–143, 2009. doi:10.1177/1099800408324853.
27. Karapolat H, Demir E, Bozkaya YT, Eyigor S, Nalbantgil S, Durmaz B, Zoghi M. Comparison of hospital-based versus home-based exercise training in patients with heart failure: effects on functional capacity, quality of life, psychological symptoms, and hemodynamic parameters. *Clin Res Cardiol* 98: 635–642, 2009. doi:10.1007/s00392-009-0049-6.
28. Knudsen SH, Hansen LS, Pedersen M, Dejgaard T, Hansen J, Hall GV, Thomsen C, Solomon TP, Pedersen BK, Krogh-Madsen R. Changes in insulin sensitivity precede changes in body composition during 14 days of step reduction combined with overfeeding in healthy young men. *J Appl Physiol* (1985) 113: 7–15, 2012. doi:10.1152/jappphysiol.00189.2011.
29. Krogh-Madsen R, Thyfault JP, Broholm C, Mortensen OH, Olsen RH, Mounier R, Plomgaard P, van Hall G, Booth FW, Pedersen BK. A 2-wk reduction of ambulatory activity attenuates peripheral insulin sensitivity. *J Appl Physiol* (1985) 108: 1034–1040, 2010. doi:10.1152/jappphysiol.00977.2009.
30. Ku DN, Giddens DP, Zarins CK, Glagov S. Pulsatile flow and atherosclerosis in the human carotid bifurcation. Positive correlation between plaque location and low oscillating shear stress. *Arteriosclerosis* 5: 293–302, 1985. doi:10.1161/01.ATV.5.3.293.
31. Lans C, Cider A, Nylander A, Brudin L. Peripheral muscle training with resistance exercise bands in patients with chronic heart failure. Long-term effects on walking distance and quality of life; a pilot study. *ESC Heart Fail* 5: 241–248, 2018. doi:10.1002/ehf2.12230.
32. 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. *Lancet* 380: 219–229, 2012. doi:10.1016/S0140-6736(12)61031-9.
33. Liu H, Xie Q, Xin BM, Liu JL, Liu Y, Li YZ, Wang JP. Inhibition of autophagy recovers cardiac dysfunction and atrophy in response to tail-suspension. *Life Sci* 121: 1–9, 2015. doi:10.1016/j.lfs.2014.10.023.
34. Mainsbridge C, Ahuja K, Williams A, Bird ML, Cooley D, Pedersen SJ. Blood pressure response to interrupting workplace sitting time with non-exercise physical activity: results of a 12-month cohort study. *J Occup Environ Med* 60: 769–774, 2018. doi:10.1097/JOM.0000000000001377.
35. Morris JN, Heady JA, Raffle PAB, Roberts CG, Parks JW. Coronary heart-disease and physical activity of work. *Lancet* 262: 1053–1057, 1953. doi:10.1016/S0140-6736(53)90665-5.
36. Nosova EV, Yen P, Chong KC, Alley HF, Stock EO, Quinn A, Hellmann J, Conte MS, Owens CD, Spite M, Grenon SM. Short-term physical inactivity impairs vascular function. *J Surg Res* 190: 672–682, 2014. doi:10.1016/j.jss.2014.02.001.
37. Olshansky SJ, Passaro DJ, Hershow RC, Layden J, Carnes BA, Brody J, Hayflick L, Butler RN, Allison DB, Ludwig DS. A potential decline in life expectancy in the United States in the 21st century. *N Engl J Med* 352: 1138–1145, 2005. doi:10.1056/NEJMs043743.
38. Palombo C, Morizzo C, Baluci M, Lucini D, Ricci S, Biolo G, Tortoli P, Kozakova M. Large artery remodeling and dynamics following simulated microgravity by prolonged head-down tilt bed rest in humans. *BioMed Res Int* 2015: 1–7, 2015. doi:10.1155/2015/342565.
39. Piepoli MF. Exercise training in chronic heart failure: mechanisms and therapies. *Neth Heart J* 21: 85–90, 2013. doi:10.1007/s12471-012-0367-6.
40. Piotrowicz E, Zieliński T, Bodalski R, Rywik T, Dobraszkiewicz-Wasilewska B, Sobieszczkańska-Malek M, Stepnowska M, Przybylski A, Browarek A, Szumowski Ł, Piotrowski W, Piotrowicz R. Home-based telemonitored Nordic walking training is well accepted, safe, effective and has high adherence among heart failure patients, including those with cardiovascular implantable electronic devices: a randomised controlled study. *Eur J Prev Cardiol* 22: 1368–1377, 2015. doi:10.1177/2047487314551537.
41. Platts SH, Martin DS, Stenger MB, Perez SA, Ribeiro LC, Summers R, Meck JV. Cardiovascular adaptations to long-duration head-down bed rest. *Aviat Space Environ Med* 80, Suppl: A29–A36, 2009. doi:10.3357/ASEM.BR03.2009.
42. Safiyari-Hafizi H, Taunton J, Ignaszewski A, Warburton DE. The health benefits of a 12-week home-based interval training cardiac rehabilitation program in patients with heart failure. *Can J Cardiol* 32: 561–567, 2016. doi:10.1016/j.cjca.2016.01.031.
43. Shanely RA, Nieman DC, Henson DA, Jin F, Knab AM, Sha W. Inflammation and oxidative stress are lower in physically fit and active adults. *Scand J Med Sci Sports* 23: 215–223, 2013. doi:10.1111/j.1600-0838.2011.01373.x.
44. Sonne MP, Højbjerg L, Alibegovic AC, Nielsen LB, Stallknecht B, Vaag AA, Dela F. Endothelial function after 10 days of bed rest in individuals at risk for type 2 diabetes and cardiovascular disease. *Exp Physiol* 96: 1000–1009, 2011. doi:10.1113/expphysiol.2011.058511.
45. Teixeira AL, Padilla J, Vianna LC. Impaired popliteal artery flow-mediated dilation caused by reduced daily physical activity is prevented by increased shear stress. *J Appl Physiol* (1985) 123: 49–54, 2017. doi:10.1152/jappphysiol.00001.2017.
46. Thosar SS, Bielko SL, Mather KJ, Johnston JD, Wallace JP. Effect of prolonged sitting and breaks in sitting time on endothelial function. *Med Sci Sports Exerc* 47: 843–849, 2015. doi:10.1249/MSS.0000000000000479.
47. Thosar SS, Bielko SL, Wiggins CC, Wallace JP. Differences in brachial and femoral artery responses to prolonged sitting. *Cardiovasc Ultrasound* 12: 50, 2014. doi:10.1186/1476-7120-12-50.
48. Tremblay MS, Aubert S, Barnes JD, Saunders TJ, Carson V, Latimer-Cheung AE, Chastin SF, Altenburg TM, Chinapaw MJ; SBRN Terminology Consensus Project Participants. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act* 14: 75, 2017. doi:10.1186/s12966-017-0525-8.
49. Varnfield M, Karunanithi M, Lee CK, Honeyman E, Arnold D, Ding H, Smith C, Walters DL. Smartphone-based home care model improved use of cardiac rehabilitation in postmyocardial infarction patients: results from a randomised controlled trial. *Heart* 100: 1770–1779, 2014. doi:10.1136/heartjnl-2014-305783.
50. World Health Organization. *Coronavirus Disease (COVID-19) Outbreak Situation* (Online). <https://www.who.int/emergencies/diseases/novel-coronavirus-2019> [12 May 2020].
51. World Health Organization. *Statement on the Second Meeting of the International Health Regulations (2005) Emergency Committee Regarding the Outbreak of Novel Coronavirus (2019-nCoV)*. [https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-\(2005\)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-\(2019-ncov\)](https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov)) [12 May 2020].