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REVIEW ARTICLE (META-ANALYSIS)

Differential Effects of the COVID-19 Pandemic on Physical Activity Involvements and Exercise Habits in People With and Without Chronic Diseases: A Systematic Review and Meta-analysis

Tommy K.Y. Ng, PT, MSc,[a] Chris K.C. Kwok, PT, MSc,[a] Gabriel Y.K. Ngan, PT, MSc,[a] Horace K.H. Wong, PT, MSc,[a] Fadi Al Zoubi, PT, MSc, PhD,[a] Christy C. Tomkins-Lane, PhD,[b] Suk-Yu Yau, BSc, MPhil, PhD,[a] Dino Samartzis, DSc,[c] Sabina M. Pinto, PT, MSc,[a] Siu-Ngor Fu, PT, PgD, MPhil, PhD,[a] Heng Li, PhD,[d] Arnold Y.L. Wong, PT, MPhil, PhD[a]

From the [a]Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong, China; [b]Department of Health and Physical Education, Mount Royal University, Calgary, Canada; [c]Department of Orthopedic Surgery, Rush University Medical Center, Chicago, IL; and [d]Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China.

Abstract

Objective: To conduct a systematic review and meta-analysis to summarize evidence regarding differential changes in physical activity (PA) involvements and exercise habits in people with and without chronic diseases during the COVID-19 outbreak.

Data Sources: MEDLINE, Embase, SPORTDiscus, Cumulative Index to Nursing and Allied Health, PsycINFO, Cochrane Library, and Physiotherapy Evidence Database were searched from November 2019 to May 2021.

Study Selection: Two reviewers independently screened cross-sectional and longitudinal studies that investigated changes in PA-related outcomes in people with and without chronic diseases during the pandemic.

Data Extraction: PA-related outcomes and sedentary time were extracted from the included studies. Relevant risk of bias were assessed. Meta-analyses were conducted for each PA-related outcome, if applicable. Quality of evidence of each PA-related outcome was evaluated by Grading of Recommendations Assessment, Development, and Evaluation.

Data Synthesis: Of 1226 identified citations, 36 articles (28 with and 8 without chronic diseases) with 800,256 participants were included. Moderate evidence from wearable sensors supported a significant reduction in pooled estimates of step count (standardized mean differences [SMD]=−2.79, P<.01). Very limited to limited evidence substantiated significant decreases in self-reported PA-related outcomes and significant increases in sedentary behaviors among people with and without chronic diseases. Specifically, pooled estimates of metabolic equivalent-minute per week (SMD=−0.16, P=.02) and PA duration (SMD=−0.07, P<.01) were significantly decreased, while sedentary time (SMD=0.09, P=.04) showed significant increases in the general population (small to large effects). Very limited evidence suggested no significant PA changes among people in a country without lockdown.

Conclusions: During the pandemic, objective and self-reported assessments showed significant reductions in PA in people with and without chronic diseases globally. This mainly occurred in countries with lockdowns. Although many countries have adopted the "live with the coronavirus" policy, authorities should implement population-based strategies to revert the potential lockdown-related long-term deleterious effects on people's health.

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The COVID-19 pandemic posed a menacing threat to global public health. After the first COVID-19 case reported in Wuhan, China, in December 2019,[1] the disease has rapidly plagued the globe, inflicting unprecedented negative effects on the global

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socioeconomic and health care systems. As of September 2021, a total of 221 countries had been struck by COVID-19, resulting in more than 248 million infected cases and over 5 million deaths.[2] Countries with lower national income and suboptimal medical services are more vulnerable to the negative consequences of the COVID-19 pandemic, including changes in health behaviors such as physical activity (PA) participation.[3]

Given the escalating number of confirmed COVID-19 cases and overburdened health care systems, the World Health Organization (WHO) declared the COVID-19 outbreak as a pandemic.[2] Most governments implemented stringent measures, including travel ban, nationwide quarantine, social distancing, and lockdowns to suppress the outbreak.[2] Approximately 4 billion people were confined to their homes, while more than 90 countries or regions had imposed lockdowns by April 2020.[4]

Prolonged lockdowns have a negative effect on people's physical, psychological, and social health.[5-39] Reduced PA or exercise participation, alongside increased sedentary behaviors, could compromise the physical and mental health of many individuals.[40,41] The WHO recommends adults to perform 150-300 minutes of moderate intensity or 75-150 minutes of vigorous intensity aerobic PA every week.[42] People with chronic diseases, who are recommended to do regular exercises to delay their disease progression,[43,44] may be more susceptible to the adverse effect of reduced PA. Reduced PA in these patients not only may affect their disease progression but also increases their risk of developing additional inactivity-related diseases. Regular moderate to vigorous PA (MVPA) can boost immunity against community-acquired infectious diseases and increase potency of vaccination. Although an earlier systematic review has summarized the preliminary effects of the COVID-19 pandemic lockdown on PA changes of the public,[45] it was limited by small representative samples and lack of assessments of evidence or meta-analyses regarding the effects of the pandemic on various PA-related outcomes among people with and without chronic diseases in countries with or without lockdowns. Because PA changes measured by wearable sensors may differ from those collected from self-reported PA questionnaires, comprehensive meta-analyses of various PA-related outcomes can better inform policy makers in developing tailored strategies to revert the adverse effects of physical inactivity in vulnerable subgroups during and after the pandemic. The current systematic review and meta-analysis addressed this gap to summarize the evidence regarding effects of the COVID-19 pandemic on PA-related outcomes in the people with and without chronic diseases who did not contract COVID-19.

Methods

The study protocol was registered on PROSPERO (CRD42021234936). The Preferred Reporting Items of Systematic Reviews and Meta-Analyses guidelines[46] were adopted to report this review.

List of abbreviations:

IPAQ	**International Physical Activity Questionnaire**
MET	**metabolic equivalent task**
MVPA	**moderate to vigorous physical activity**
PA	**physical activity**
SMD	**standardized mean difference**
T2D	**type 2 diabetes**
WHO	**World Health Organization**

Search strategy

A systematic literature search was conducted on 7 databases (MEDLINE, EMBASE, SPORTDiscus, Cumulative Index to Nursing and Allied Health, PsycINFO, Cochrane Libraries, Physiotherapy Evidence Database) to identify articles published between November 1, 2019, and May 31, 2021, without any language restrictions. We searched these databases using a combination of 2 sets of keywords: ['COVID' OR 'cov*' OR 'corona*' OR 'severe acute respiratory syndrome coronavirus 2' OR 'SARS*'] AND ['physical activit*' OR 'activity level' OR 'exercise habit*' OR 'exercise routine*' OR 'lifestyle'] (appendix 1). Additional relevant articles were searched from the reference lists of the included studies. Forward citation tracking was conducted using Scopus. The corresponding authors of the included articles were contacted by emails to identify any additional relevant publications.

Selection criteria

Cross-sectional and longitudinal studies that investigated PA-related outcomes during the COVID-19 pandemic were included. Articles were excluded if the participants were actively or previously infected with COVID-19. Commentaries, letters to editors, reviews, conference proceedings, and qualitative studies were also excluded.

Study selection

All citations identified from database searches were exported to EndNote X9 (Clarivate).[a] After removing duplicates, 2 reviewers (K.Y.N., K.H.W.) independently screened the titles and abstracts following the selection criteria. They piloted on 100 abstracts to align discrepancy. They then independently screened the remaining references. Abstracts deemed relevant were included for full-text screening. The process was repeated for the full-text screening. Reviewers met to reach a consensus about the eligible articles. If disagreements persisted, a third reviewer (K.C.K.) arbitrated the disagreements. The interrater agreement was calculated using Cohen's κ.[47]

Data extraction

Two independent reviewers (K.Y.N., K.H.W.) used a standardized form to extract data related to authors, year of publication, study location, study design, data collection methods, response and attrition rate, participants' demographics, definitions of PA and sedentary behaviors, changes in PA-related outcomes, and the corresponding statistics.

Risk of bias assessments

Two independent reviewers (K.Y.N., K.H.W.) used 2 separate tools to assess the quality of the included studies. Specifically, the methodological quality of cross-sectional studies was assessed by the 20-item Appraisal Tool for Cross-Sectional Studies.[48] The tool only provides descriptive assessments without numeric scores. It is flexible for researchers to use it based on their priorities. Therefore, we rearranged the items into 6 domains: objectives and design, study participation, handling of nonrespondents, outcome measures, statistical analysis, and reporting.[49] Similar to our previous reviews,[49,50] each domain was ranked as low, moderate, or high based on the criteria listed in appendix 2. The Quality in Prognosis Studies tool was used to assess the methodological quality of longitudinal studies.[51,52] The Quality in Prognosis Studies tool comprises 6 domains: study participation, study attrition, prognostic factor measurement, outcome measurement, study confounding, and statistical analysis and reporting.[52] Each domain was rated as low, moderate, or high.[52] From the quality of each domain, the overall methodological quality was graded as low, moderate, or high[52] (see appendix 2).

Data synthesis

PA-related outcomes extracted from the included studies were categorized into 2 pairs of subgroups: (1) the people with and without chronic diseases and (2) countries with and without lockdown. If 2 or more included studies reported changes in a particular PA-related outcome during the pandemic in a given subgroup, the respective standardized mean differences (SMDs) were pooled for a meta-analysis using a random-effects model. All meta-analyses were performed using the Comprehensive Meta-analysis Version 3.3 software.[b] Statistical heterogeneity of the included studies was assessed by I^2 statistics and classified as low (I^2<40%), moderate (I^2=40%-59%), substantial (I^2=60%-74%), and considerable (I^2>75%) heterogeneity.[53] The potential sources of heterogeneity of each meta-analysis were explained if substantial or considerable statistical heterogeneity was observed.[53]

Quality of evidence

The quality of evidence of each PA-related outcome was rated by the Grading of Recommendations Assessment, Development, and Evaluation.[54] The Grading of Recommendations Assessment, Development, and Evaluation framework consists of 7 domains, 5 of which could downgrade the quality of evidence regarding the estimated effect size, while the other 2 domains could increase the confidence in the estimated effect size. The synthesized data was ranked as very limited, limited, moderate, or high quality of evidence regarding how the true effect lays close to the estimated effect (see appendix 2).[55]

Results

The literature search identified 1226 publications, while 13 records were identified through other sources (fig 1). After removing 103 duplicates, 1136 studies were eligible for the title and abstract screening. Of the 95 screened full-text articles, 36 articles were included.[5-39,56] Fifty-nine full-text articles were excluded because they did not investigate PA changes (n=40); they included confirmed COVID-19 cases (n=6); or they were commentaries, letters or reviews (n=13). Our κ coefficients showed substantial (κ=0.75) and almost perfect (κ =0.93) agreements between the 2 reviewers (K.Y.N., K.H.W.) during the title/abstract screening and full-text screening, respectively.[47]

Characteristics of the included studies

The 36 included studies recruited 800,256 participants from Asia, Africa, Australia, Europe, and North and South America. Thirty-five studies were conducted in countries or regions with lockdowns,[5-39] while a Swedish study was conducted without lockdown.[56] The participants' mean ages ranged from 7.3-74.0 years. Table 1 summarizes participants' demographics in the included studies. Twenty-three studies adopted a cross-sectional design,[6,7,9-12,14,15,17,18,21-25,27,28,30-32,37,38,56] while 13 adopted a retrospective design.[5,8,13,16,19,20,26,29,33-36,39]

Twenty-eight studies investigated changes in PA in people without chronic diseases.[6-8,10-22,24-26,28,30-32,35-38,56] Notably, 20 of them focused on adults,[6-8,10,12-15,18,22,24-26,28,31,32,35,36,38,56] 2 on older people,[21,37] 4 on students,[11,17,19,20] and 2 on children and adolescents.[16,30] Eight studies investigated changes in PA among people with chronic diseases.[5,9,23,27,29,33,34,39] Specifically, 4

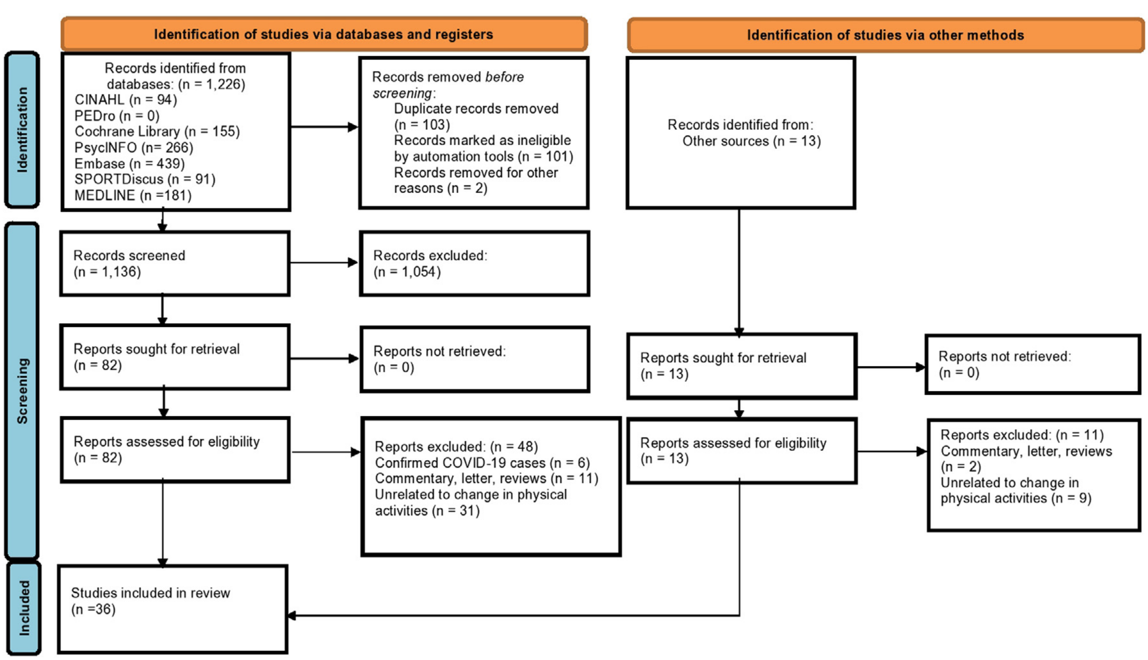

Fig 1 Flowchart of the systematic review according to Preferred Reporting Items of Systematic Reviews and Meta-Analyses guidelines.Abbreviations: CINAHL, Cumulative Index to Nursing and Allied Health; PEDro, Physiotherapy Evidence Database.

Table 1 Characteristics of the included studies

Author	Country; Lockdown Policy	Study Sample Characteristics; % Male; Age (y)	Study Population	Definitions of PA or Exercises	PA-Related Variables	Outcome Measurement Tools (Validation)	Statistical Test
Cross-sectional studies							
Ammar et al[6]	Multiple countries; lockdown	N=1047; 46% men; Age: 18-35 y: 55.1% 36-55 y: 35.1% >55 y: 9.8%	Healthy adults	PA as defined by IPAQ*	IPAQ score	IPAQ-Short Form (validated)	Paired *t* test
Arturo et al[7]	Mexico; lockdown	N=37; 59% men; Age: 27.8 y±6.1	Healthy adults (Teachers)	PA as defined by IPAQ*	PA in MET-min/wk Change in PA levels in participants	IPAQ (validated)	Student *t* test Descriptive statistics
Blom et al[55]	Sweden; no lockdown	N=5599; 50% men; Age: 46.3 y±11.0	Healthy adults	Daily activity and exercise	Proportion of participants reported change in PA levels Proportion of participants reported change in exercise Proportion of participants reported change in sedentary time	Customized questionnaire (unvalidated)	Descriptive statistics
Chague et al[9]	France; lockdown	N=124; 60.5% men; Age: 71.0 y±14.0	Patients with congestive heart failure	Not defined	Proportion of participants reported change in PA levels Proportion of participants reported change in sedentary time	Customized questionnaire (unvalidated)	Descriptive statistics
Cooper et al[10]	United States; lockdown	N=1607; 43% men; Age: 38.0 y±12.9	Healthy adults	Overall PA, walking for at least 30 min/d, PA as defined by IPAQ*	Proportion of participants reported change in PA levels Proportion of participants reported change in sedentary time	IPAQ-Short Form (validated)	Descriptive statistics
Deng et al[11]	Wuhan, China; lockdown	N=1607; 64.8% men; Age: <18 y: 1.2% 18-22 y: 97.9% >22 y: 0.9%	Healthy students (university and college)	Regular exercise as defined as ≥3 times/wk and ≥60 min each time	Proportion of participants reported change in PA levels Proportion of participants reported change in exercise habit	Customized questionnaire (unvalidated)	Descriptive statistics

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Table 1 (*Continued*)

Author	Country; Lockdown Policy	Study Sample Characteristics; % Male; Age (y)	Study Population	Definitions of PA or Exercises	PA-Related Variables	Outcome Measurement Tools (Validation)	Statistical Test
Di Renzo et al[12]	Italy; lockdown	N=3533; 23.9% men; Age: 40.0 y±13.5	Healthy adults (internet users)	Sports training eg, walking; gym/run/swimming/soccer/volleyball/basketball/CrossFit/dance/yoga/aerobic fitness/martial arts/tennis/aerial gymnastics	Proportion of participants reported change in exercise habit	Customized questionnaire (unvalidated)	Descriptive statistics
Đogaš et al[14]	Croatia; lockdown	N=3027; 20.3% men; Median age: 40 y	Healthy adults	Not defined	Duration of PA	Customized questionnaire (unvalidated)	Paired *t* test
Duncan et al[15]	United States; lockdown	N=3971; 30.8% men; Age: 50.4 y±16.0	Healthy adults (identical and same-sex fraternal twins)	Not defined	Proportion of participants reported change in PA levels	Customized questionnaire (unvalidated)	Descriptive statistics
Galle et al[17]	Italy; lockdown	N=2125; 37.2% men; Age: 22.5 y±0.1	Undergraduate students	Not defined	Proportion of participants reported change in PA levels	Customized questionnaire (unvalidated)	Descriptive statistics
Hu et al[18]	China; lockdown	N=1033; 51.7% men; Age: 18-30 y: 61.7% 31-40 y: 27.2% >41 y: 11.1%	Healthy adults	Exercise (such as running and dancing)	Proportions of participants reported change in exercise habit Proportion of participants reported change in sedentary time	IPAQ (validated)	Descriptive statistics
Lehtisalo et al[21]	Finland; lockdown	N=613; 51.2% men; Age: 67.9 y±4.6	Older adults	Leisure time physical activity, housework or cleaning, gardening	Proportion of participants reported change in PA levels	Customized questionnaire (unvalidated)	Descriptive statistics
Lesser et al[22]	Canada; lockdown	N=1098; 19.6% men; Age: 42.0 y±15.0	Healthy adults	Walking/jogging/running/biking/cycling/weight training/online video/classes/yoga/home workout/hiking/home/yard work/other	Proportion of participants reported change in PA levels	Behavioral regulations in exercise (validated) Godin Leisure Questionnaire (validated)	Descriptive statistics

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Table 1 (*Continued*)

Author	Country; Lockdown Policy	Study Sample Characteristics; % Male; Age (y)	Study Population	Definitions of PA or Exercises	PA-Related Variables	Outcome Measurement Tools (Validation)	Statistical Test
Minsky et al[23]	Israel; lockdown	N=279; 30.8% men; Age: 53.0 y±13.0	Adults with obesity	Not defined	Proportion of participants reported change in PA levels	Customized questionnaire (unvalidated)	Descriptive statistics
Orlandi et al[24]	Italy; lockdown	N=2218; 34.3% men; Age: 38.2 y±14.9	Healthy adults	PA as defined by IPAQ*	PA in MET-min/wk (converted from PA in MET-h/wk)	IPAQ (validated)	Paired *t* test
Paltrinieri et al[25]	Italy; lockdown	N=2816; 23.2% men; Age: 18-44 y: 44.8% 45-64 y: 44.0% >65 y: 10.6%	Healthy adults	Not defined	Proportion of participants reported change in PA levels	Customized questionnaire (unvalidated)	Descriptive statistics
Persiani et al[27]	Italy; lockdown	N=292; 49% men; Age: <35 y: 10.3% 35-50 y: 23% 50-70 y: 57.2% >70 y: 9.6%	Patients with musculoskeletal pain	Not defined	Change in PA levels in participants Proportion of participants reported change in sedentary time	Customized questionnaire (unvalidated)	Descriptive statistics
Rodríguez-Nogueira et al[28]	Spain; lockdown	N=472; 40% men; Age: 46.4 y±11.2	Healthy adults	Aerobics, strength exercise, and others	Change in PA levels in participants	Standardized Nordic Questionnaire (validated)	Descriptive statistics
Ruíz-Roso et al[30]	Italy; lockdown	N=726; 39.8% men; Age: 10-15 y: 45.7% 16-19 y: 54.3%	Adolescents	Active: PA ≥300 min/wk	Change in PA levels in participants	IPAQ (validated)	Descriptive statistics
Sonza et al[31]	Brazil and Europe; lockdown	N=3194; 32.9% men; Age: 38.4 y±13.6	Healthy adults	Aerobics, resistance and strength exercise	Change in PA levels in participants Proportion of participants reported change in sedentary time	Physical exercise level before and during social isolation questionnaire (validated)	Descriptive statistics
Stanton et al[32]	Australia; lockdown	N=1491; 32.6% men; Age: 50.5 y±14.9	Healthy adults	PA as defined by Active Australia Survey†	Duration of PA Proportion of participants reported change in PA levels	Active Australian Survey (validated)	Descriptive statistics Wilcoxon signed-rank test
Yamada et al[37]	Japan; lockdown	N=1600; 50% men; Age: 74.0 y±5.6	Older adults	PA as defined by IPAQ*	Duration of PA	IPAQ-Short Form (validated)	Wilcoxon signed-rank test
Zhu et al[38]	China; lockdown	N=889; 39% men; Age: 31.9 y±11.4	Healthy adults	Step counts	Step counts Duration of sedentary time	Customized questionnaire (unvalidated)	Paired *t* test

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Table 1 (*Continued*)

Author	Country; Lockdown Policy	Study Sample Characteristics; % Male; Age (y)	Study Population	Definitions of PA or Exercises	PA-Related Variables	Outcome Measurement Tools (Validation)	Statistical Test
Retrospective studies							
Al Fagih et al[5]	Saudi Arabia; lockdown	N=82; 64.6% men; Median age: 65 y	Patients with heart failure	Defined by algorithms of a cardiac implantable electronic device	Duration of PA	Cardiac implantable electronic devices	Wilcoxon signed-rank test
Barrea et al[8]	Italy; lockdown	N=121; 33.5% men; Age: 44.9 y±13.3	Healthy adults	≥30 min/d of aerobic exercise	Change in exercise habit in participants	Dichotomous questions (unvalidated)	χ^2 test
Di Sebastiano et al[13]	Canada; lockdown	N=2338; 9.8% men; Age: 18-65 y: 92% >65 y: 8%	Healthy adults	MVPA: defined by a device specific definition, or ≥100 steps/min Light PA: <100 steps/min	Duration of light PA Duration of MVPA Step counts	Wearable devices or smartphone inbuilt accelerometer	1-way repeated-measures ANOVA
Dunton et al[16]	United States; lockdown	N=211; 47.4% men; Age: 8.7 y±2.6	Healthy children	11 types of school-based PA enlisted in Active Where survey	Proportion of participants reported change in sedentary time	Active Where survey (validated)	Descriptive statistics
Jia et al[19]	China; lockdown	N=10,082; 28.3% men; Age: 19.8 y±2.3	High school, college, and graduate students	PA as defined by IPAQ*	Duration of MVPA Duration of sedentary time	IPAQ (validated)	Paired *t* test
Keel et al[20]	United States; lockdown	N=90; 12.2% men; Age: 19.45 y±1.3	Undergraduate students	Not defined	Proportion of participants reported change in PA levels	Customized questionnaire (unvalidated)	Descriptive statistics
Pépin et al[26]	Multiple countries; lockdown	N=742,200; 62% men; Mean age: 43.4 y	Healthy adults	Step counts	Step counts	Wearable pedometer	Wilcoxon signed-rank test
Rowlands et al[29]	United Kingdom; lockdown	N=165; 55% men; Age: 64.2 y±8.3	Patients with T2D	Defined by accelerometer	Duration of MVPA Step counts (converted from acceleration in milligravitation units)[‡] Frequency of continuous PA Duration of sedentary time	Wearable accelerometer	Paired *t* test

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Table 1 (*Continued*)

Author	Country; Lockdown Policy	Study Sample Characteristics; % Male; Age (y)	Study Population	Definitions of PA or Exercises	PA-Related Variables	Outcome Measurement Tools (Validation)	Statistical Test
Van Bakel et al[33]	Netherlands; lockdown	N=1565; 73.1% men; Age: ≤65 y: 756 >65 y: 677	Patients with cardiovascular disease	MVPA determined by work, transportation, household, and leisure time	Duration of MVPA Duration of sedentary time	Short Questionnaire to Assess Health-enhancing Physical Activity (validated)	Mann-Whitney *U* test
Vetrovsky et al[34]	Czech Republic; lockdown	N=26; 69.2% men; Age: 58.8 y±9.8	Patients with heart failure	Step counts	Step counts	Wearable accelerometer	Paired *t* test
Wang et al[35]	China; lockdown	N=3544; 65.4% men; Age: 51.6 y±8.9	Healthy adults	Step counts	Step counts	Smartphone inbuilt accelerometer	Generalized Estimating Equation
Weaver et al[36]	United States; lockdown	n=362; 47.8% men; Age: 46.5 y±16.0	Healthy adults	PA as defined by IPAQ*	PA in MET-min/wk Duration of sedentary time	IPAQ-Short Form (validated)	Paired *t* test
Zorcec et al[39]	Macedonia; lockdown	N=72; 12.5% men; Age: 7.3 y±2.9	Children with chronic respiratory diseases	Not defined	Change in PA levels in participants	Customized questionnaire (unvalidated)	Descriptive statistics

Abbreviation: ANOVA, analysis of variance.
* Definition of PA according to IPAQ: refer to appendix 3.
† Definition of PA according to Active Australian Survey: refer to appendix 4.
‡ Interpretation of acceleration in milligravitation units: refer to appendix 5.

focused on patients with cardiovascular diseases,[5,9,33,34] 1 on type 2 diabetes (T2D),[29] 1 on musculoskeletal pain,[27] 1 on adults with obesity,[23] and 1 on children with chronic respiratory diseases.[39]

Risk of bias assessments

One study was rated as having low risk of bias,[29] 31 as moderate,[6-26,28,32-39,56] and 4 as high.[5,27,30,31] Of the 23 cross-sectional studies, the most common risks of bias were no sample size justification[6,7,9-12,14,15,18,21-25,27,30-32,37,38,56] and no description of nonresponders' characteristics[6,7,9-12,14,15,17,18,21-25,27,28,30-32,37,38,56] (appendix 3). All the 13 retrospective studies did not provide information regarding the dropout participants nor accounted for potential confounders (appendix 4).[5,8,13,16,19,20,26,29,33-36,39]

PA and sedentary time

The included studies used diverse definitions of PA (appendices 5-7, table 2). Five studies used accelerometers and/or pedometers to quantify PA levels.[13,26,29,34,35] Eight studies used the International Physical Activity Questionnaire (IPAQ) to categorize PA into different levels.[6,7,10,18,19,24,36,37] Fourteen studies had miscellaneous definitions of PA (eg, regular exercise for different durations or different leisure time PA),[5,8,11-13,16,18,21,22,28,30,31,33,56] whereas 9 studies did not clearly define PA.[9,14,15,17,20,23,25,27,39] For the 12 studies that investigated sedentary behaviors,[9,10,16,18,19,27,29,31,33,36,38,56] 1 used accelerometers to record sedentary time,[29] 4 used self-reported screen time,[9,10,18,19] and 4 used self-reported sitting and/or couch time.[10,16,27,36] However, 3 studies only mentioned sedentary behaviors without definitions.[31,33,38]

Thirteen PA-related variables were reported in the included studies. Of them, 12 were reported in studies involving people without chronic diseases (appendix 8), while 8 were reported in studies involving people with chronic diseases (appendix 9). Those studies conducted in regions involving lockdowns reported 12 PA-related variables (see appendices 8 and 9), whereas the Swedish study (without lockdown) reported 3 PA-related variables in people without chronic diseases (see appendix 8).

Quality of evidence regarding changes in PA during the pandemic in people without chronic diseases

The included studies investigating changes in PA of people without chronic diseases were conducted in countries with[5-39] and without[56] lockdowns. These changes in PA-related variables are summarized in fig 2 and table 2).

Step counts (per d/wk)

Moderate evidence from 4 studies consistently showed significant decreases in step counts after the outbreak as measured by accelerometers, pedometers, or a self-reported questionnaire.[13,26,35,38] The meta-analysis showed a significant reduction in step counts with a large effect size (pooled SMD=−2.79, P<.01, I^2=100%).

Durations of light PA and MVPA

Very limited evidence from 1 Canadian study revealed a significant reduction (12.6%) in the duration of light PA as measured by accelerometers during the pandemic.[13] Likewise, very limited evidence from 2 studies suggested reduced durations of MVPA.[13,19] Specifically, 1 study used accelerometers to detect significant decreases in the duration of MVPA (9.3%) after the outbreak.[13] Another study used IPAQ to reveal a significant reduction in time spent on MVPA after lockdown.[19]

Duration of PA

Very limited evidence substantiated decreases in self-reported weekly PA duration.[14,32,37] However, because 1 included study did not present the relevant statistical data,[32] it was excluded from the meta-analysis. The meta-analysis showed a significant reduction in PA duration per week with a small effect size (pooled SMD=−0.07, P<.01, I^2=0%).[14,37]

Proportion of participants reporting changes in PA levels

There was inconsistent evidence regarding the proportion of people reporting changes in PA levels during the outbreak. Five studies used customized questionnaires to evaluate changes in PA during lockdowns, although PA was not defined.[15,17,20,21,25] They found that 20.7%-61.5% of participants reported decreases, 13.6%-53.2% reported no change, and 5.3%-48.6% reported increases in PA levels.[15,17,20,21,25] Similarly, 3 included studies used validated questionnaires to evaluate changes in PA levels during lockdowns.[10,22,32] They showed that 20.7%-33.9% of participants reported decreases, 25.1%-30.5% reported no change, and 35.7%-49.1% reported increases in PA levels.[10,22,32] A Swedish study (without lockdown) used a customized questionnaire to reveal that 63.0% of participants reported no change in PA levels, and only 26.0% reported decreases in PA levels during the outbreak.[56]

Changes in number of participants involving in different PA categories

There was very limited evidence supporting the adoption of an inactive lifestyle during lockdowns.[28,30,31] Although 3 studies revealed that more people were classified into the low PA category after the outbreak,[28,30,31] 1 of them reported approximately 30% increase in the number of people being categorized into "never performed PA" or "frequently performed PA" during the COVID-19 outbreak.[28]

Proportion of participants reported changes in their exercise duration

Limited evidence from 2 included studies supported that people living in countries with lockdowns reported either no change or decreases in their exercise duration, while only 17.8%-20.0% of people reported increases in their exercise duration.[11,18] Conversely, up to 26% of participants reported increases in exercise in a country without lockdown.[56]

Proportion of participants reported doing regular exercise

There was conflicting evidence regarding the proportion of people participating in regular exercises.[8,12] One included study reported no significant changes in the proportion of participants involved in regular exercise training after the outbreak,[12] while another study revealed a 19% drop in the number of participants who exercised regularly.[8] However, both studies used unvalidated questionnaires.

Metabolic equivalent-minute per week

Very limited evidence supported reduced estimated metabolic equivalent task (MET)-minute per week as measured by IPAQ.[7,24,36] The PA reduction ranged from 23.8%-69.8%.[7,24,36] The meta-analysis from 3 studies showed a significant reduction in MET-minute per week with a small effect size (pooled SMD=−0.16, P=.02, I^2=77%).[7,24,36]

Table 2 Summary of results on PA-related variables in people without chronic diseases

Author	Study Sample Size	Study Population	Definition of PA-Related Outcomes	Statistical Test	Results	Level of Significance	Effect Size	Level of Evidence
Countries with lockdown measures								
Step counts (per d or per wk) (N=4)								
Di Sebastiano et al[13]	N=2338	Healthy adults	Step count/wk as measured by wearable devices or a smartphone inbuilt accelerometer	1-way repeated-measures ANOVA	Decreased from 48,625±745 steps/wk to 43,395±705 steps/wk (by 10.8%)	$P<.001$	Large	Moderate
Pépin et al[26]	N=742,200	Healthy adults	Step count/d as measured by a pedometer	Wilcoxon signed-rank test	Decreased from 5326±479 steps/d to 4752±925 steps/d (by 10.8%)	$P<.001$		
Wang et al[35]	N=3544	Healthy adults	Step count/d as measured by a smartphone in-built accelerometer	Generalized Estimating Equation	Decreased from 8097±4793 steps/d to 5440±4571 steps/d (by 32.8%)	Not reported		
Zhu et al[38]	N=889	Healthy adults	Step count/day as measured by an unvalidated self-developed questionnaire	Paired *t* test	Decreased from 6247±4374 steps/d to 2714±3542 steps/d (by 56.6%)	$P<.001$		
Duration of light PA (N=1)								
Di Sebastiano et al[13]	N=2338	Healthy adults	Light PA as measured by an accelerometer: <100 steps/min	1-way repeated-measures ANOVA	Decreased from 1000.5±17.0 min/wk to 874.1±15.6 min/wk (by 12.6%)	$p<0.001$		Very limited
Duration of MVPA (N=2)								
Di Sebastiano et al[13]	N=2338	Healthy adults	MVPA: defined by heart rate ≥60% heart rate maximum by a built-in monitor, or ≥100 steps/min measure by an accelerometer	1-way repeated-measures ANOVA	Decreased from 194.2±5.2 min/wk to 176.7±5 min/wk (by 9.3%)	$P<.001$		Very limited
Jia et al[19]	N=10,082	High schools, colleges, and graduate schools students	PA as defined by IPAQ*	Paired *t* test	From 0.7±2.0 d/wk to 0.7±2.0 d/wk	$P<.05$		
Duration of PA (N=3)								
Đogaš et al[14]	N=3027	Healthy adults	Not defined	Paired *t* test	Decreased from 162.1 min/wk to 132.9 min/wk (by 18%)	$P<.001$	Small	Very limited
Stanton et al[32]	N=1491	Healthy adults	PA as defined by Active Australian Survey†	Wilcoxon signed-rank test	Decreased to 312.5±363.5 min/wk	Not reported		
Yamada et al[37]	N=1600	Healthy adults	PA as defined by IPAQ*	Wilcoxon signed-rank test	Decreased from 245 min/wk to 180 min/wk (by 27%)	$P<.001$		
Proportion of participants reporting changes in PA levels (N=8)								
Cooper et al[10]	N=1607	Healthy adults	PA as defined by IPAQ*	Descriptive statistics	Overall PA: n=413 reported decrease (25.7%) n=404 reported no change (25.1%) n=790 reported increase (49.1%) Low PA level: n=565 reported decrease (35.2%) n=574 reported no change (35.7%) n=468 reported increase (29.2%) Moderate PA level: n=519 reported decrease (32.3%) n=806 reported no change (50.2%) n=282 reported increase (17.6%) High PA level: n=566 reported decrease (35.2%) n=736 reported no change (45.8%) n=306 reported increase (19.0%)	NA		Conflicting
Duncan et al[15]	N=3971	Healthy adults (identical and same-sex fraternal twins)	Not defined	Descriptive statistics	n=1048 reported decrease (26.4%) n=1183 reported no change (29.8%) n=1740 reported increase (43.8%)	NA		
Galle et al[17]	N=2125	Undergraduate students	Not defined	Descriptive statistics	n=453 reported decrease (21.3%) n=640 reported no change (30.1%) n=1032 reported in increase (48.6%)	NA		
Keel et al[20]	N=90	Undergraduate students	Not defined	Descriptive statistics		NA		

(*continued on next page*)

Table 2 (*Continued*)

Author	Study Sample Size	Study Population	Definition of PA-Related Outcomes	Statistical Test	Results	Level of Significance	Effect Size	Level of Evidence
					n=54 reported decrease (61.5%) n=12 reported no change (13.6%) n=22 reported increase (24.9%)			
Lehtisalo et al[21]	N=2816	Healthy adults	Leisure time physical activity, housework or cleaning, and gardening as measured by an unvalidated self-reported questionnaire	Descriptive statistics	n=91 reported decreased (34%) n=287 reported no change (50%) n=193 reported increased (16%)	NA		
Lesser et al[22]	N=1098	Healthy adults	Walking/jogging/running/biking/cycling/weight training/online video/classes/yoga/home workout/hiking/home/yard work/other as measured by the Behavioral Regulations in Exercise Questionnaire and Godin Leisure-Time Questionnaire	Descriptive statistics	n=372 reported decrease (33.9%) n=334 reported no change (30.4%) n=392 reported increase (35.7%)	NA		
Paltrinieri et al[25]	N=2816	Healthy adults	Not defined	Descriptive statistics	n=641 reported decrease (35.1%) n=972 reported no change (53.2%) n=97 reported increase (5.3%) n=116 were missing data (6.4%)	NA		
Stanton et al[32]	N=1491	Healthy adults	PA as defined by Active Australian Survey†	Descriptive statistics	n=308 reported decrease (20.7%) n=454 reported no change (30.5%) n=729 reported increase (48.9%)	NA		
Changes in number of participants involving in different PA categories (N=3)								
Rodríguez-Nogueira et al[28]	N=472	Healthy adults	Aerobics, strengthening exercise, others, and no exercise, as well as the frequency of doing exercise as measured by an unvalidated self-developed questionnaire Occasionally carry out PA: some d/mo Frequently carry out PA: 7 d/wk	Descriptive statistics	Never carry out PA: increased from n=86 to n=113 (by 31%) Occasionally carry out PA: decreased from n=272 to n=213 (by 21.7%) Frequently carry out PA: increased from n=114 to n=146 (by 28.3%)	NA		Very limited
Ruíz-Roso et al[30]	N=726	Adolescents	Active: PA ≥300 min/wk as measured by IPAQ	Descriptive statistics	Active population: decreased from n=206 to n=135 (by 34.5%) Inactive population: increased from n=86 to n=157 (by 82.5%)	NA		
Sonza et al[31]	N=3194	Healthy adults	Aerobics, resistance, and strength exercise as measured by the Physical Exercise Level Before and During Social Isolation Questionnaire Level of activity reported by participants	Descriptive statistics	"A bit active" population: increased from n=866 to n=1086 (from 27.1% to 34%) Active population: decreased from n=1412 to n=1044 (from 44.2% to 32.7%) Very active population: decreased from n=527 to n=265 (from 16.5% to 8.3%)	NA		
MET-min/wk (N=3)								
Arturo et al[7]	N=37	Healthy adults	PA as defined by IPAQ*	Student *t* test	Decreased from 1826 MET-min/wk to 552 MET-min/wk (by 69.8%) Low PA: increased 18.2% in MET-min/wk Moderate PA: increased 10.1% in MET-min/wk High PA: decreased 22.3% in MET-min/wk	*P*=.005	Small	Very limited
Orlandi et al[24]	N=2218	Healthy adults	PA as defined by IPAQ*	Paired *t* test	Decreased from 2269.2 MET-min/wk to 1728 MET-min/wk (by 23.8%)	*P*=.001		
Weaver et al[36]	N=362	Healthy adults	PA as defined by IPAQ*	Paired *t* test	Decreased from 2205±3342.7 MET-min/wk to 1616±2176.6 MET-min/wk (by 26.7%)	*P*<.001		

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Table 2 (*Continued*)

Author	Study Sample Size	Study Population	Definition of PA-Related Outcomes	Statistical Test	Results	Level of Significance	Effect Size	Level of Evidence
IPAQ scores (N=1)								
Ammar et al[6]	N=1047	Healthy adults	PA as defined by IPAQ*	Paired *t* test	Decreased from 5.04±2.51 to 3.83±2.84 (by 24%)	*P*<.001		Very limited
Proportion of participants reported changes in exercise duration (N=2)								
Deng et al[11]	N=1607	Healthy adults	Time spent on exercise during COVID-19 (including web-based physical education) as measured by an unvalidated self-developed questionnaire	Descriptive statistics	n=826 reported less time (51.4%) n=460 reported the same (28.6%) n=321 reported more (20.0%)	NA		Limited
Hu et al[18]	N=1033	Healthy adults	Exercise as defined by IPAQ (eg, dancing and running) at 4 mo before COVID-19 and 4 mo after COVID-19 as measured by an unvalidated self-developed questionnaire	Descriptive statistics	n=195 reported decrease (18.9%) n=654 reported no change (63.3%) n=184 reported increase (17.8%)	NA		
Proportion of participants reported doing regular exercise (N=2)								
Barrea et al[8]	N=121	Healthy adults	≥30 min/d of aerobic exercise	χ^2 test	Decreased from n=62 (51.2%) to n=39 (32.2%)	*P*=.004		Conflicting
Di Renzo et al[12]	N=3533	Healthy adults	At least once/wk of training (eg, walking/gym/run/swimming/soccer/volleyball/basketball/Cross Fit/dance/yoga/aerobic fitness/martial arts/tennis/aerial gymnastics)	Descriptive statistics	Reported training: increased from n=2173 to n=2198 (by 1.2%) Reported no training: decreased from n=1360 to n=1335 (by 1.8%)	NA		
Duration of sedentary time (N=3)								
Jia et al[19]	N=10,082	High school, college, and graduate school students	Screen time as measured by IPAQ	Paired *t* test	Increased from 4.9±1.9 h/d to 5.6±2.2 h/d (by 14.3%)	*P*<.001	Small	Very limited
Weaver et al[36]	N=362	Healthy adults	Sitting time as measured by IPAQ-Short Form	Paired *t* test	Increased from 460.9±281.6 min/d to 494.5±211.5 min/d (by 7.4%)	*P*<.001		
Zhu et al[38]	N=889	Healthy adults	Sedentary time as measured by an unvalidated self-developed questionnaire	Paired *t* test	Increased from 5.3±2.7 h/d to 6.6±3.1 h/d (by 24.5%)	*P*<.001		
Proportion of participants reported changes in sedentary time (N=4)								
Cooper et al[10]	N=1,607	Healthy adults	Screen and sitting time as measured by IPAQ-Short Form	Descriptive statistics	Screen time: n=79 reported decrease (4.9%) n=662 reported no change (41.2%) n=866 reported increase (53.9%) Sitting time: n=91 reported decrease (5.7%) n=577 reported no change (35.9%) n=939 reported increase (58.5%)	NA		Limited
Dunton et al[16]	N=211	Healthy children	Sitting time as measured by the Active Where questionnaire	Descriptive statistics	n=8 reported decrease (4%) n=87 reported increase (41%) n=116 no results available (55%)	NA		
Hu et al[18]	N=1033	Healthy adults	Screen time as measured by IPAQ	Descriptive statistics	n=80 reported decrease (7.8%) n=247 reported no change (23.9%) n=706 reported increased (68.3%)	NA		
Sonza et al[31]	N=3194	Healthy adults	Sedentary behavior as measured by the Physical Exercise Level Before and During Social Isolation Questionnaire	Descriptive statistics	Sedentary population increased from n=390 (12.2%) to n=799 (25.0%)	NA		

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Table 2 (*Continued*)

Author	Study Sample Size	Study Population	Definition of PA-Related Outcomes	Statistical Test	Results	Level of Significance	Effect Size	Level of Evidence
Countries without lockdown measures								
Proportion of participants reported changes in PA (N=1)								
Blom et al[55]	N=5599	Healthy adults	Daily activity as measured by an unvalidated self-developed questionnaire	Descriptive statistics	n=1456 reported decrease (26.0%) n=3527 reported no change (63.0%) n=616 reported increase (11.0%)	NA		Very limited
Proportion of participants reported changes in exercise duration (N=1)								
Blom et al[55]	n=5599	Healthy adults	Time spent on exercise during COVID-19 as measured by an unvalidated self-developed questionnaire	Descriptive statistics	n=1567 reported decrease (28%) n=3303 reported no change (59%) n=728 reported increase (13%)	NA		Very limited
Proportion of participants reported changes in sedentary time (N=1)								
Blom et al[55]	N=5599	Healthy adults	Sitting time as measured by an unvalidated self-developed questionnaire	Descriptive statistics	n=448 reported decrease (8%) n=3695 reported no change (66%) n=1456 reported increase (26%)	NA		Very limited

Abbreviations: ANOVA, analysis of variables; NA, not applicable.
* Definition of PA according to IPAQ: refer to appendix 3.
† Definition of PA according to Active Australian Survey: refer to appendix 4.

IPAQ scores

Very limited evidence from 1 study reported a 24.0% decrease in IPAQ scores, although it was described in MET-minutes.[6]

Sedentary time

Very limited evidence suggested approximately 7.4%-24.5% increases in sedentary time (defined by screen time, sitting, and sedentary activities) in the general public as measured by IPAQ[19,36] or a self-developed questionnaire.[38] Our meta-analysis showed a significant increase in sedentary time with a small effect size (pooled SMD=0.09, P=.04, I^2=84%).[19,36,38]

Proportions of participants reported changes in sedentary time

There was limited evidence that a relatively larger proportion of participants reported increases in sedentary time in countries imposing lockdowns.[10,16,18,31] Approximately 41.0%-68.3% of participants reported increases in their sedentary time.[10,16,18] One study also found that the proportion of participants being classified as the "sedentary" category increased from 12.2% to 25.0%.[31] All these studies adopted validated questionnaires to quantify sedentary time.[10,16,18,31] Conversely, very limited evidence suggested that Swedish participants (without lockdown) were less likely to adopt a sedentary lifestyle.[56] Only 26.0% of Swedish participants reported increased sitting time, while 66.0% reported no change.[56]

People with chronic diseases

Step counts (per d/wk)

Very limited evidence suggested significant decreases in step counts by 7.6% in patients with T2D.[29] Similarly, there was very limited evidence that patients with cardiovascular diseases had approximately 16.4% reduction in step counts.[34]

Duration of MVPA

Very limited evidence supported no significant change in the duration of MVPA in patients with T2D as quantified by accelerometers.[29] Conversely, very limited evidence substantiated 25.0% increases in MVPA among patients with cardiovascular diseases as measured by a validated questionnaire.[33]

Duration of PA

There was very limited evidence that patients with heart failure displayed an average of 0.8 hours reduction in daily duration of PA as measured by cardiac implantable electronic devices.[5]

Proportion of participants reported change in PA levels

Very limited evidence suggested significant decreases in PA levels among approximately 41% of patients with congestive heart failure 9 or adults with obesity.[23]

Changes in number of participants involving in different PA categories

Very limited evidence showed an increased number of participants classified as no activity in patients with musculoskeletal pain[27] or low PA categories in children with chronic respiratory diseases.[39] Specifically, 1 study showed a 82.5% increase in the number of participants being classified as "no PA,"[27] while another study revealed a 237.5% increase in the number of participants being classified as having less than 1-2 hours of PA per day.[39]

2.1 MET-minute per week

Study	SMD	Standard error	Variance	Lower Limit	Upper limit	Z-value	p-value	Sample Size
Arturo et al. (2020)	-0.492	0.174	0.030	-0.833	-0.151	-2.825	0.005	37
Orlandi et al. (2021)	-0.070	0.021	0.000	-0.112	-0.028	-3.291	0.001	2,218
Weaver et al. (2021)	-0.174	0.053	0.003	-0.278	-0.071	-3.293	0.001	362
Total	-0.164	0.071	0.005	-0.303	-0.025	-2.305	0.021	

Heterogeneity: Tau^2=0.010; df=2 (p=0.013); I^2 = 77%
Test for overall effect: Z=-2.305 (p=0.021)

2.2 Duration of PA

Study	SMD	Standard error	Variance	Lower Limit	Upper limit	Z-value	p-value	Sample Size
Dogas et al. (2020)	-0.060	0.018	0.000	-0.096	-0.024	-3.291	0.001	3,027
Yamada et al. (2021)	-0.082	0.025	0.001	-0.131	-0.033	-3.291	0.001	1,600
Total	-0.068	0.015	0.000	-0.097	-0.039	-4.597	0.000	

Heterogeneity: Tau^2=0.000; df=1 (p=0.466); I^2= 0%
Test for overall effect: Z=-4.597 (p<0.001)

2.3 Step counts (per day or per week)

Study	SMD	Standard error	Variance	Lower Limit	Upper limit	Z-value	p-value	Sample Size
Di Sebastiano et al. (2020)	-7.198	0.083	0.007	-7.361	-7.035	-86.624	0.000	3,533
Pépin et al. (2020)	-0.652	0.001	0.000	-0.654	-0.650	-658.592	0.000	742,200
Wang et al. (2021)	-0.567	0.014	0.000	-0.594	-0.539	-40.422	0.000	3,544
Total	-2.789	0.448	0.200	-3.667	-1.912	-6.229	0.000	

Heterogeneity: Tau2=0.774; df=2 (p<0.001); I^2 = 100%
Test for overall effect: Z=-6.229 (p<0.001)

2.4 Duration of Sedentary time

Study	SMD	Standard error	Variance	Lower Limit	Upper limit	Z-value	p-value	Sample Size
Jia et al. (2020)	0.026	0.010	0.000	0.006	0.045	2.576	0.010	10,082
Weaver et al. (2021)	0.174	0.053	0.003	0.071	0.278	3.293	0.001	362
Zhu et al. (2021)	0.111	0.034	0.001	0.045	0.177	3.291	0.001	889
Total	0.093	0.044	0.002	0.006	0.180	2.088	0.037	

Heterogeneity: Tau^2=0.005; df=2 (p=0.002); I^2 = 84%
Test for overall effect: Z=2.088 (p=0.037)

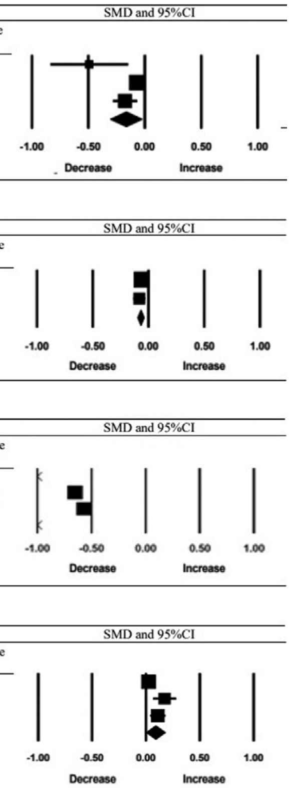

Fig 2 Forest plots of PA in MET-min/wk, duration of PA, step counts, and duration of sedentary time of people without chronic diseases.

Frequency of continuous PA

Very limited evidence supported an increase in the frequency of continuous PA in patients with T2D as recorded by an accelerometer.[29] Rowlands et al revealed that the average frequency of 30- and 60-minute continuous PA in patients with T2D significantly increased from 0.65 d/wk to 1.0 d/wk and from 0.24 d/wk to 0.44 d/wk, respectively.[29]

Sedentary time

Very limited evidence supported a 3.0% increase in sedentary time in patients with T2D as measured by accelerometers[29] and a 14.4% increase in patients with cardiovascular disease documented by a validated questionnaire.[33]

Proportion of participants reporting increases in sedentary time

Very limited evidence suggested that 46% of participants with congestive heart failure[9] and 35% of participants with musculoskeletal pain[27] reported increases in sedentary time.

Discussion

This systematic review and meta-analysis summarized evidence regarding changes in PA among people with and without chronic diseases during the COVID-19 pandemic. Twelve and 8 PA-related variables were used to evaluate changes in PA levels among people with and without chronic diseases, respectively. Moderate evidence from objective measurements (eg, accelerometers) substantiated decreases in step counts in people without chronic diseases during the pandemic. Very limited to limited evidence supported decreases in PA levels and exercise behaviors but increases in sedentary time in both groups, although 2 studies reported increases in continuous PA and MVPA among patients with T2D and cardiovascular diseases, respectively. People living in countries with lockdowns showed significant reductions in PA and increases in sedentary behaviors. The lockdown policy and closure of public facilities refrained people from performing PA.[28] This is attested by the fact that most respondents in a country without lockdown reported no change in their PA and sedentary behaviors.[56]

Effects of physical inactivity on global health

It is well-known that physical inactivity adversely affect physical and mental health, as well as quality of life.[57] Insufficient PA heightens the risk of developing noncommunicable diseases (eg, 24%, 16%, and 42% increase in the risk of having coronary heart disease, cardiovascular accident, and T2D, respectively).[56] Because 23.3% and 27.5% of the global population had insufficient PA in 2010 and 2016, respectively,[57] the WHO implemented an action plan between 2018 and 2030 to counteract physical inactivity[58] and to reduce the global physical inactivity by 10% in 2025 and 15% in 2030.[59] However, the COVID-19 pandemic could adversely affect the attainment of the original WHO 2025 global PA target.

Our meta-analysis and a prior systematic review[45] highlight the negative effect of the COVID-19 pandemic on PA of people with and without chronic diseases globally. Home confinement policies and public facilities closure have heightened the prevalence of global physical inactivity. Lockdown-related physical inactivity may increase the incidence of noncommunicable diseases and related health care burdens.[60] It is well known that regular MVPA boosts immunity against infectious diseases. An average energy expenditure of 500-1000 MET-minutes per week is associated with a lower risk of SARS-CoV-2 infection.[61] PA can also improve an individual's depression and mood by the augmented release of endorphins.[62] Thereby, health authorities should implement new strategies to promote active lifestyle (especially MVPA) during and after lockdowns. Because some people may fear going out even after lockdowns are lifted, governments should run proper campaigns and/or use mobile applications to promote indoor PA and exercises[58] among people who hesitate to exercise outdoor during or after lockdowns.

Effect of physical inactivity on people with chronic diseases

Most of the included studies reported decreases in PA among people with chronic diseases during the pandemic. Physical inactivity may have greater detrimental effects on people with chronic diseases. Increased physical inactivity in patients with chronic heart conditions could heighten their morbidity[63] and mortality rates.[64] A 30-minute reduction of daily PA in any given month during 4 years in patients after implanting cardioverter defibrillators was associated with 48% increased hazard for death compared with active patients in the same month.[65] Similarly, physical inactivity and suspended face-to-face physiotherapy treatments during lockdowns led to increased symptoms in patients with musculoskeletal pain compared with the prepandemic period.[27] Increased frequency and intensity of pain in patients with osteoarthritis[66] or chronic low back pain[67] in turn may result in the adoption of a sedentary lifestyle. If this vicious cycle persists, these patients may experience other pain-related comorbidities (eg, depression). Imperatively, decreased PA levels[8] and the suspension of routine medical care in children with chronic respiratory diseases may lead to weight gain and mental health issues during the pandemic.[39]

While reduced PA during the COVID-19 pandemic is prevalent, some people with chronic diseases reported increased PA during lockdowns. One included study reported no significant change in the duration of MVPA and even increases in the frequency of 30- and 60-minute exercise sessions among people with T2D.[29] These findings might be attributed to the success of the British government in promoting exercise for health maintenance and permitting outdoor exercises during lockdowns. Similarly, increased population interest regarding the effects of PA and screen time on health might inspire some patients with chronic heart diseases to increase their MVPA during the pandemic.[68] Physical activities may increase the levels of adiponectin that can dampen the proinflammatory pathway of T2D[69] and reduce plaque formation in patients with heart diseases.[69] These results underscore the importance of proper public health policies and/or strategies to minimize the negative effect of lockdowns on PA.

Changes in exercise formats

During lockdowns, exercise formats have shifted from outdoors to indoors[70] and from on-field team sports to home-based individual exercises (eg, yoga).[28] Additionally, tele-exercise has gained popularity. Some governments produced online exercise videos by physiotherapists to promote home-based training to the general public.[71] Similarly, nongovernment organizations (eg, National Centre of Health, Physical Activity, and Disability) launched different campaigns (eg, #MoveInMay, online toolkits, workout videos) via social media to engage and educate people to perform PA.[72] While some private companies (eg, ParticipACTION) used websites and/or mobile applications to provide users with exercise demonstration videos and guidelines, interactive team challenges, and rewarding schemes to counteract the lockdown-related physical inactivity,[13] other companies embedded a body positional tracking system in a mirror to provide individualized home exercise training.[73] Although telerehabilitation/telemedicine may facilitate home-based disease management, older people or underprivileged individuals may have difficulty in using telehealth.[27,74] Future studies should investigate the optimal strategies for delivering telerehabilitation/tele-exercise to older people or people in low-income countries.

Validity and reliability of outcome measures

Wearable devices (eg, smart watches) allow objective PA measurements. All included studies[13,26,29,34,35] using wearable devices consistently showed reduced PA in people with and without chronic diseases during the pandemic, except for 1 study investigating patients with diabetes.[29] However, PA levels quantified by wearable devices rely on participants' compliance.[13,75] Studies that used wearable devices to collect PA data might underestimate the negative effects of the pandemic on PA because people using wearable sensors might be more health conscious and intend to monitor their PA levels to stay active.[34]

Most included studies used self-reported questionnaires to estimate PA during the pandemic, which was common in epidemiologic studies to investigate the prevalence of diseases or behaviors.[76] However, self-reported PA levels may be subjected to recall bias. Therefore, PA levels estimated by online questionnaires might not be related to those measured by accelerometers.[77] Further, while 30 included articles used different self-reported questionnaires to estimate PA,[6-12,14-25,27,28,30-33,36-39,56] only 15 studies used self-reported PA questionnaires with reported reliability and validity.[6,7,10,16,18,19,22,24,28,30-33,36,37] The estimated effects of the COVID-19 pandemic on PA might have been more accurate had validated questionnaires been used. Therefore, an international consortium should be formed to determine a core set of PA questionnaires (eg, global physical activity questionnaire)[58] to allow comparisons of PA levels across studies in the future.

Study designs

Given the sudden onset of the pandemic, most of the included studies adopted a cross-sectional design. Twenty-three included studies evaluated the current PA levels. The remaining studies used questionnaires (n=7) or wearable or implanted devices to retrospectively evaluate the changes in PA levels before and after the outbreak. Cross-sectional studies are needed during a pandemic to cost-effectively garner relevant information from large samples[78] to inform policy making and help plan further prospective studies.[79] However, retrospective studies using wearable or implanted devices to quantify changes in PA-related variables following the pandemic are also important because they help reveal causation.[78]

Study limitations

The current review had several limitations. First, the searched keywords might not be comprehensive enough to capture all relevant articles although most key articles have been included. Second, because diverse PA-related variables were used in the included studies, some variables were only used in 1 included study, which prevented the conduction of meta-analysis. Third, the included studies covered a range of chronic diseases, which prevented the conduction of meta-analysis of PA for each disease.

For limitations of the included studies, only 1 article reported PA-related variables in a country without lockdown, which limited its generalizability. Further, people's PA levels may change over time. Their PA levels showed the greatest decline at the beginning of lockdowns, but PA levels increased toward the end of lockdowns.[13, 26] Because some studies did not report the time of data collection, people's PA levels at a given time point might not illustrate changes in PA levels throughout the pandemic. Moreover, many included studies recruited participants by convenience sampling or recruiting from a single center, which might affect the generalizability of results. Finally, although 3 PA-related variables were pooled for meta-analyses, they showed substantial heterogeneity (I^2>60%). The high heterogeneity might be attributed to differences in the sampling methods, delivery mode of questionnaires, durations spent on completing questionnaires, and socioeconomic status.

Conclusions

Moderate evidence from objective PA measurements demonstrated significant decreases in PA during the COVID-19 pandemic, while very limited to limited evidence from self-reported questionnaires revealed reduced PA and increased sedentary behaviors among people with and without chronic diseases during the COVID-19 pandemic globally. Tele-exercise may have the potential to help promote and/or maintain PA levels and exercise habits in people with and without chronic diseases. Future epidemiologic studies are warranted to determine the long-term effects of COVID-19 on the changes of PA and/or exercise habits and the associated health outcomes in people with and without chronic diseases worldwide. An international consortium should be established to determine the core set of PA measurements to allow comparisons of results across studies in the future. It would be prudent to include wearable devices or smartphones to reliably and objectively monitor PA. Collectively, the current review has laid the foundation for relevant stakeholders to develop and implement effective strategies to minimize the negative effects of similar outbreaks on PA and health of people with and without chronic diseases in the future.

Suppliers

a. EndNote X9; Clarivate.
b. Comprehensive Meta-analysis Version 3.3 software; Biostat.

Keywords

COVID-19; Exercise habit; Rehabilitation; SARS-CoV-2; Sedentary behavior

Corresponding author

Arnold Y.L. Wong, PT, MPhil, PhD, Department of Rehabilitation Sciences, Hong Kong Polytechnic University, Hung Hom, Hong Kong SAR, China. *E-mail address:* arnold.wong@polyu.edu.hk.

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Supplemental Digital Content 1. Search strategy

Steps	Keywords
1	COVID* or Cov* or Corona* or Severe acute respiratory syndrome coronavirus 2 or SARS*
2	Physical activit* or activity level or Exercise habit* or Exercise routine* or lifestyle
3	1 and 2

Supplemental Digital Content 2. Determination of overall risk of bias of the included studies and the level of evidence for a given outcome

Risk of bias of a study	
High risk of bias	For a study graded as *high* in at least two domains
Moderate risk of bias	For a study graded as *moderate* in at least one domain, and rated as *low* in other domains
Low risk of bias	For a study graded as *low* in all six domains
Level of evidence of PA-related outcome measures	
Strong evidence	Pooled results from two or more studies, at least two of them have high quality; or consistent narrative findings in multiple studies with high-quality
Moderate evidence	Significant pooled results from multiple statistically heterogeneous studies, at least one of them has high quality; or consistent findings from multiple studies with at least one high quality study
Limited evidence	Findings from a high-quality study, or consistent findings from multiple moderate- or low-quality studies
Very limited evidence	Findings from one moderate- or low-quality study
Conflicting evidence	Inconsistent findings

Appendix 3. Risk of bias of the included cross-sectional studies

Appraisal tool for Cross-Sectional Studies (AXIS)

Study	Objective & study design			Study participation						Handling of non-respondents				Outcome measures			Statistical analysis			Reporting							
Original item number	1	2	S	3	4	5	6	20	S	7	13*	14	S	8	9	S	10	11	S	12	15	16	17	18	19*	S	Overall risk
Ammar et al. (2021)[6]	Y	Y	L	N	N	Y	Y	Y	M	N	N	N	H	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Arturo et al. (2020)[7]	Y	Y	L	N	Y	N	N	Y	M	N	N	N	H	Y	Y	L	Y	Y	L	N	Y	Y	Y	Y	?	M	Moderate
Blom et al. (2021)[55]	Y	Y	L	N	Y	N	Y	Y	M	N	Y	Y	M	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	Y	L	Moderate
Chague et al. (2020)[9]	Y	Y	L	N	Y	Y	Y	Y	M	Y	N	Y	M	Y	Y	L	Y	Y	L	Y	Y	Y	Y	N	Y	M	Moderate
Cooper et al. (2021)[10]	Y	Y	L	N	Y	N	Y	Y	M	Y	?	Y	M	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Deng et al. (2020)[11]	Y	Y	L	N	Y	Y	Y	Y	M	Y	?	N	H	Y	N	M	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Di Renzo et al. (2020)[12]	Y	Y	L	N	Y	Y	Y	Y	M	N	?	N	H	Y	Y	L	Y	N	M	Y	Y	Y	Y	Y	N	M	Moderate
Đogaš et al. (2020)[14]	Y	Y	L	N	Y	Y	Y	Y	M	N	?	N	H	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Duncan et al. (2020)[15]	Y	Y	L	N	Y	Y	Y	Y	M	N	N	N	H	Y	N	M	N	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Galle et al. (2020)[17]	Y	Y	L	Y	Y	Y	Y	Y	L	N	Y	N	H	Y	Y	L	N	Y	M	Y	Y	Y	Y	Y	N	M	Moderate
Hu et al. (2020)[18]	Y	Y	L	N	Y	Y	Y	Y	M	Y	N	N	H	Y	Y	L	N	Y	M	Y	Y	Y	Y	Y	N	M	Moderate
Lehtisalo et al. (2021)[21]	Y	Y	L	N	Y	Y	Y	Y	M	N	N	N	H	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Lesser et al. (2020)[22]	Y	Y	L	N	Y	Y	Y	Y	M	N	?	N	H	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Minsky et al. (2021)[23]	Y	Y	L	N	Y	Y	Y	Y	M	N	Y	N	H	Y	N	M	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Orlandi et al. (2021)[24]	Y	Y	L	N	Y	Y	Y	Y	M	N	?	N	H	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Paltrinieri et al. (2021)[25]	Y	Y	L	N	Y	Y	Y	Y	M	N	N	N	H	Y	N	M	N	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Persiani et al. (2021)[27]	Y	Y	L	N	N	Y	N	Y	H	N	?	N	H	Y	N	M	Y	Y	L	Y	Y	Y	Y	Y	N	M	High
Rodriguez-Nogueira et al. (2021)[28]	Y	Y	L	Y	Y	Y	Y	Y	L	N	N	N	H	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Ruíz-Roso et al. (2020)[30]	Y	Y	L	N	N	N	Y	Y	H	N	N	N	H	Y	N	M	Y	Y	L	Y	Y	Y	Y	Y	N	M	High
Sonza et al. (2021)[31]	Y	Y	L	N	N	Y	Y	Y	H	N	N	N	H	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	M	High
Stanton et al. (2020)[32]	Y	Y	L	N	Y	Y	Y	Y	M	N	N	N	H	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Yamada et al. (2020)[37]	Y	Y	L	N	Y	Y	Y	Y	M	N	N	N	H	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
Zhu et al. (2021)[38]	Y	Y	L	N	Y	Y	Y	Y	M	N	N	N	H	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	M	Moderate
% of studies that reported "yes"/no bias	100	100		9	83	78	87	100		83	13	13		100	74		83	96		96	100	100	100	96	15		

H = High; M = Moderate; L = Low; ? = Uncertain; N = No; Y = Yes; S = Subscore

* For item number 13 and 19 in the AXIS, a point is rewarded when the content is "N".

Appendix 4. Risk of bias of the included retrospective studies

Quality of Prognosis Studies Risk of Bias Assessment Instruments for Prognostic Factor Studies (QUIPS)

Study	Subject participation								Study attrition						Prognostic factor measurement						Outcome measurement				Study confounding								Statistical analysis and reporting					
Original item number	1	2	3	4	5	6	7	S	1	2	3	4	5	S	1	2	3	4	5	S	1	2	3	S	1	2	3	4	5	6	7	S	1	2	3	4	S	Overall risk
Al Fagih et al. (2020)[5]	P	N	Y	Y	P	U	P	H	N	N/A	N/A	N/A	N/A	H	P	P	Y	N	N/A	H	P	U	Y	H	N	N	N	N/A	N/A	N	N	H	Y	Y	Y	U	M	High
Barrea et al. (2020)[8]	P	N	N	Y	P	Y	Y	M	N	N/A	N/A	N/A	N/A	H	P	N	Y	Y	N/A	M	Y	N	Y	M	N	N	N	N/A	N/A	N	N	H	Y	Y	Y	Y	L	Moderate
Di Sebastiano et al. (2020)[13]	Y	N	Y	Y	P	Y	Y	M	Y	N	N/A	N/A	N/A	M	Y	Y	Y	Y	N/A	L	Y	P	P	M	N	N	N	N/A	N/A	N	N	H	Y	Y	Y	Y	L	Moderate
Dunton et al. (2020)[16]	Y	P	Y	Y	P	U	Y	M	Y	P	Y	N	N/A	M	P	N	Y	N/A	N/A	H	Y	N	Y	M	Y	N	N	N/A	N/A	N	N	H	Y	Y	Y	Y	L	Moderate
Jia et al. (2020)[19]	Y	Y	Y	Y	P	Y	Y	L	N/A	N/A	N/A	N/A	N/A	H	P	Y	Y	Y	N/A	M	Y	Y	Y	L	Y	Y	Y	Y	N/A	Y	N	M	Y	Y	Y	Y	L	Moderate
Keel et al. (2020)[20]	Y	P	Y	P	N	U	Y	M	N/A	N/A	N/A	N/A	N/A	H	Y	Y	Y	U	N/A	M	Y	N	Y	M	P	N	P	Y	N/A	P	N	H	Y	Y	Y	U	L	Moderate
Pepin et al. (2020)[26]	Y	N	Y	P	N	U	Y	M	N/A	N/A	N/A	N/A	N/A	H	Y	Y	Y	U	N/A	M	Y	Y	Y	L	P	N	P	U	N/A	P	N	H	P	Y	Y	U	M	Moderate
Rowlands et al. (2021)[29]	Y	Y	Y	Y	Y	Y	Y	L	Y	N/A	N/A	N/A	N/A	H	Y	Y	Y	Y	N/A	L	Y	Y	Y	L	Y	Y	P	Y	N/A	Y	N	M	Y	Y	Y	U	L	Low
Van Bakel et al. (2021)[33]	Y	P	Y	Y	P	Y	Y	M	P	N/A	N/A	N/A	N/A	H	Y	Y	Y	Y	N/A	L	Y	P	Y	M	Y	N	P	Y	N/A	Y	N	M	Y	Y	Y	U	L	Moderate
Vetrovsky et al. (2020)[34]	Y	P	Y	N	N	U	Y	M	N/A	N/A	N/A	N/A	N/A	H	Y	Y	Y	Y	N	M	Y	Y	Y	L	P	Y	P	Y	N/A	P	N	M	Y	Y	Y	Y	L	Moderate
Wang et al. (2020)[35]	Y	Y	Y	Y	P	U	Y	M	N	N/A	N/A	N/A	N/A	H	Y	Y	Y	U	N/A	M	Y	Y	Y	L	Y	Y	P	Y	N/A	Y	N	M	Y	Y	Y	Y	L	Moderate
Weaver et al. (2021)[36]	Y	N	Y	Y	P	Y	Y	M	P	N/A	N/A	N/A	N/A	H	Y	Y	Y	Y	N/A	L	Y	Y	Y	L	P	P	P	Y	N/A	P	N	M	Y	Y	Y	Y	L	Moderate
Zorcec et al. (2020)[39]	Y	N	Y	P	N	U	Y	M	N	N/A	N/A	N/A	N/A	H	Y	Y	Y	Y	N/A	L	Y	N	Y	M	Y	N	Y	Y	N/A	Y	N	M	Y	Y	Y	U	L	Moderate

Y = Yes; N = No; P = Partial; U = Unclear; N/A = Not Applicable; S = Subscore

Appendix 5. Definitions of physical activity according to International Physical Activity Questionnaire (IPAQ) questionnaires[79]

Definition of PA according to IPAQ[79]		
Category 1	Low intensity	This is the lowest level of physical activity. Individuals who do not meet the criteria for the categories 2 or 3 are considered low intensity/inactive.
Category 2	Moderate intensity	Any one of the following 3 criteria: • 3 or more days of vigorous activity for at least 20 minutes per day OR • 5 or more days of moderate-intensity activity or walking for at least 30 minutes per day; OR • 5 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 600 MET-min/week.
Category 3	High intensity	Any one of the following 2 criteria: • Vigorous-intensity activity on at least 3 days and accumulating at least 1,500 MET-min/week OR • 7 or more days of any combination of walking, moderate-intensity or vigorous intensity activities achieving a minimum of at least 3,000 MET-min/week

MET-min = Metabolic equivalent of task-minutes

Appendix 6. Definitions of physical activity according to the Active Australian Survey

Physical activity	Definition
Walking	Continuous in 10-minute intervals of walking
Gardening/yardwork	No description available
Other moderate activities	Activities that make you "*breathe somewhat harder than normal and slightly increase heart rate*"
Other vigorous activities	Activities that make you "*breathe much harder than normal and have a greater effect on heart rate*"

Duration of total activity time = time spent on walking + time spent on moderate activities + (2 x time spent of vigorous activities)

Appendix 7. Interpretation of acceleration in milli-gravitation units

Interpretation of acceleration in milli-gravitation units (mg)[80]	
Time spent:	
100-200 mg	Slow walking
200-350 mg	Brisk walking
350-500 mg	Fast walk / jog
500-1000mg	Slow run
1000-1500mg	Medium run
1500-2000mg	Fast run
>2000mg	Sprint

Conversion from milli-gravitation unit to number of steps based on suggestion of 1.7 mg being equivalent to ~800 steps/day as suggested by Rowlands et al.[29]

Appendix 8. Quality of evidence of PA-related outcome variables in people without chronic diseases

Potential outcomes identified	Number of participants	Number of studies	Number of cohorts	Univariate +	Univariate 0	Univariate -	Phase	GRADE factors: Study limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Moderate/ large effect size	Dose effect	Overall quality
Lockdown															
MET-minute per week	2,617	3	3			3	1	X	✓	✓	✓	X	X	X	+
Duration of PA	6,118	3	3			3	1	X	✓	✓	X	✓	X	X	+
Duration of light PA	2,338	1	1			1	1	X	N/A	X	X	✓	✓	✓	+
Duration of MVPA	12,420	2	2		1	1	1	X	X	X	X	✓	X	X	+
Proportion of participants reported changes in PA levels	16,014	8	8		N/A		1	X	X	X	X	✓	N/A	N/A	-
Changes in number of participants involving in different PA categories	4,392	3	3		N/A		1	X	X	X	X	✓	N/A	N/A	+
IPAQ scores	1,047	1	1			1	1	X	N/A	✓	X	✓	X	X	+
Step counts (per day or per week)	748,971	4	4			4	1	X	✓	✓	X	✓	✓	✓	+++
Proportion of participants reported changes in exercise duration	2,640	2	2		N/A		1	✓	✓	X	X	✓	N/A	N/A	++
Proportion of participants reported doing regular exercise	3,654	2	2	1		1	1	X	X	X	X	✓	N/A	N/A	+/-
Duration of sedentary time	11,333	3	3	3			1	X	✓	✓	X	✓	✓	X	+
Proportion of participants reported changes in sedentary time	6,045	4	4		N/A		1	✓	✓	✓	X	✓	X	X	++
No lockdown															
Proportion of participants reported changes in PA	5,599	1	1		N/A		1	✓	N/A	✓	X	X	X	X	+
Proportion of participants reported changes in exercise duration	5,599	1	1		N/A		1	✓	N/A	✓	X	X	X	X	+
Proportion of participants reported changes in sedentary time	5,599	1	1		N/A		1	✓	N/A	✓	X	X	X	X	+

IPAQ = International Physical Activity Questionnaire; MET-min = metabolic equivalent-minute; MVPA = moderate-to-vigorous physical activity; PA = physical activities
Phase, phase of investigation. For univariate analysis: +, number of significant effects with a positive value; 0, number of non-significant effects; -, number of significant effects with a negative value. For GRADE factors: ✓, no serious limitations; X, serious limitations (or not present for moderate/large effect size, dose effect); ?, unable to rate item based on available information; N/A, not applicable. For overall quality of evidence: -, inconsistent; +, very low; ++, low; +++, moderate; ++++, high
PA = physical activities; MVPA = moderate-to-vigorous physical activity
Phase, phase of investigation. For univariate analysis: +, number of significant effects with a positive value; 0, number of non-significant effects; -, number of significant effects with a negative value. For GRADE factors: ✓, no serious limitations; X, serious limitations (or not present for moderate/large effect size, dose effect); ?, unable to rate item based on available information; N/A, not applicable. For overall quality of evidence: +, very low; ++, low; +++, moderate; ++++, high

Appendix 9. Quality of evidence of PA-related outcome variables for people with chronic diseases

Potential outcomes identified	Number of participants	Number of studies	Number of cohorts	Univariate +	Univariate 0	Univariate -	Phase	GRADE factors: Study limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Moderate/ large effect size	Dose effect	Overall quality
Duration of PA															
Patients with heart failure	82	1	1			1	1	X	N/A	✓	X	✓	✓	N/A	+
Duration of MVPA															
Patients with type 2 diabetes mellitus	165	1	1			1	1	✓	N/A	✓	X	✓	✓	N/A	+
Patients with cardiovascular disease	1,565	1	1	1			1	✓	N/A	✓	X	✓	✓	N/A	+
Proportion of participants reported changes in PA levels															
Patients with congestive heart failure	124	1	1		N/A		1	X	N/A	✓	X	X	N/A	N/A	+
Adults with obesity	279	1	1		N/A		1	✓	N/A	X	X	✓	N/A	N/A	+
Changes in number of participants involving in different PA categories															
Patients with musculoskeletal pain	292	1	1		N/A		1	X	N/A	X	X	✓	N/A	N/A	+
Children with chronic respiratory diseases	72	1	1		N/A		1	✓	N/A	X	X	✓	N/A	N/A	+
Step counts (per day or per week)															
Patients with type 2 diabetes mellitus	165	1	1			1	1	✓	N/A	✓	X	✓	✓	N/A	+
Patients with heart failure	26	1	1			1	1	X	N/A	✓	X	✓	✓	N/A	+
Frequency of continuous PA															
Patients with type 2 diabetes mellitus	165	1	1	1			1	✓	N/A	✓	X	✓	✓	N/A	+
Duration of sedentary time															
Patients with type 2 diabetes mellitus	165	1	1			1	1	✓	N/A	✓	X	✓	✓	N/A	+
Patients with cardiovascular disease	1,565	1	1	1			1	✓	N/A	✓	X	✓	✓	N/A	+
Proportion of participants reported changes in sedentary time															
Patients with congestive heart failure	124	1	1		N/A		1	✓	N/A	✓	X	X	N/A	N/A	+
Patients with musculoskeletal pain	292	1	1		N/A		1	X	N/A	X	X	✓	N/A	N/A	+