












Systematic Review of Physical Activity, Sedentary Behaviour and Sleep Among Adults Living with Chronic Respiratory Disease in Low- and Middle-Income Countries

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Abstract: Physical activity (PA), sedentary behaviour (SB) and sleep are important lifestyle behaviours associated with chronic respiratory disease (CRD) morbidity and mortality. These behaviours need to be understood in low- and middle-income countries (LMIC) to develop appropriate interventions.

Purpose: Where and how have free-living PA, SB and sleep data been collected for adults living with CRD in LMIC? What are the free-living PA, SB and sleep levels of adults living with CRD?

Patients and Methods: The literature on free-living PA, SB and sleep of people living with CRD in LMIC was systematically reviewed in five relevant scientific databases. The review included empirical studies conducted in LMIC, reported in any language. Reviewers screened the articles and extracted data on prevalence, levels and measurement approach of PA, SB and sleep using a standardised form. Quality of reporting was assessed using bespoke criteria.

Results: Of 89 articles, most were conducted in Brazil (n=43). PA was the commonest behaviour measured (n=66). Questionnaires (n=52) were more commonly used to measure physical behaviours than device-based (n=37) methods. International Physical Activity Questionnaire was the commonest for measuring PA/SB (n=11). For sleep, most studies used Pittsburgh Sleep Quality Index (n=18). The most common ways of reporting were steps per day (n=21), energy expenditure (n=21), sedentary time (n=16), standing time (n=13), sitting time (n=11), lying time (n=10) and overall sleep quality (n=32). Studies revealed low PA levels [steps per day (range 2669–7490steps/day)], sedentary lifestyles [sitting time (range 283–418min/day); standing time (range 139–270min/day); lying time (range 76–119min/day)] and poor sleep quality (range 33–100%) among adults with CRD in LMIC.

Conclusion: Data support low PA levels, sedentary lifestyles and poor sleep among people in LMIC living with CRDs. More studies are needed in more diverse populations and would benefit from a harmonised approach to data collection for international comparisons.

Keywords: chronic respiratory disease, low- and middle-income countries, physical activity, sedentary behaviour, sleep

Introduction

Chronic respiratory disease (CRD) (chronic diseases of the airways and the other structures of the lungs) is associated with cigarette smoking, fumes from cooking on open stoves, air pollution,¹ and pulmonary tuberculosis,² and is highly prevalent across low- and middle-income countries (LMIC).³ Physical behaviours include all activities over a 24-h period across the movement spectrum, from no/little movement (sleep, sedentary behaviour) to movement of greater intensities

(light and moderate-to-vigorous physical activity), which are important modifiable risk factors for CRD morbidity and mortality. Physical activity (PA) is defined as any bodily movement produced by skeletal muscles that results in energy expenditure. Optimising the 24-hour behavioural profile of people remains a global challenge.⁴

Physical inactivity is a key risk factor for non-communicable disease, has been estimated to cause 9% of premature deaths worldwide⁵ and global trends are not on track to meet the global physical activity target, which is 10% relative reduction in the prevalence of insufficient physical activity by 2025.^{6,7} People living with CRD are not only less physically active than healthy adults,⁸ but also those living with other chronic diseases.⁹ Symptoms of CRD, including breathlessness, deconditioning and declining lung function, contribute to a physically inactive lifestyle; linked to an increased risk of hospitalisation¹⁰ and premature death.¹¹ Sedentary behaviour (SB) (any waking behaviour characterized by an energy expenditure ≤ 1.5 metabolic equivalents, while in a sitting, reclining or lying posture)¹² comprises the majority of people's waking day. People living with CRD spend more time sedentary¹³ which has been associated with premature mortality.¹⁴ Poor sleep quality,¹⁵ sleep dissatisfaction,¹⁶ and inadequate sleep¹⁷ contributes significantly to societies' health burden.¹⁸ Sleep disturbances are a common feature of CRD, leading to more severe respiratory symptoms and putting people at a greater risk of an acute exacerbation.¹⁹

Whilst distinct behaviours, PA, SB and sleep are intrinsically interrelated components of the 24-hour day, demonstrating the need to examine them in the context of each other rather than in isolation. Recent WHO guidelines for PA and SB²⁰ and Canadian 24-hour movement guidelines²¹ have started to reflect this notion, but research is almost exclusively from high-income countries (HIC).²² Not least, PA in LMIC is mainly accumulated through transportation and occupation-related activities, contrasting HIC where most PA is undertaken recreationally.²³ Economical, societal and cultural diversities in LMIC must be considered in the evaluation and monitoring of physical behaviours.²⁴ A range of measurement options are available to quantify free-living PA, SB and sleep.

By compiling the current evidence on free-living PA, SB and sleep of adults living with CRD in LMIC, this review seeks to highlight research priorities, enabling researchers and clinicians to address important lifestyle health challenges in a more time- and cost-effective manner. Our scoping exercise identified no similar published reviews in LMIC. Similar reviews have been conducted in HIC^{25,26} which have aided comparisons between our findings from LMIC with findings from HIC. This systematic review addressed the following questions: Where have free-living PA, SB and sleep data been collected for adults living with CRD in LMIC? How have the data been collected? What are the free-living PA, SB and sleep levels of adults living with CRD?

Materials and Methods

This systematic review is reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement.²⁷ The protocol was prospectively registered on the International Prospective Register of Systematic Reviews (PROSPERO; CRD42020176196).

The search strategy was developed by an experienced clinical librarian [PD] using appropriate subject headings for each database. Search terms included chronic respiratory disease, "physical* activ*", "sedent*" and sleep* alongside filters on LMIC (a full search strategy is provided in [Appendix A](#)). The strategy was adapted for each database.

Relevant articles were identified through systematic searches in five databases (Ovid-MEDLINE, Cochrane library, Ovid-EMBASE, Ovid-EMCARE and CINAHL). Searches for articles published in peer-reviewed journals were from the inception of each database until 30th January 2020. Global Index Medicus was searched, which included African Index Medicus, Index Medicus for Eastern Mediterranean Region, Index Medicus for South-East Asia Region, Latin Am. and Carib. Center on Health Sci Info, and Western Pacific Region Index Medicus. Reference lists of included articles were searched by hand for additional eligible articles. Studies on adults living with CRD in LMIC (population) which related to PA, SB and sleep (intervention), irrespective of the presence or absence of comparator (control group) which report what, where and how PA, SB and sleep data have been collected (outcome) were included in the review. Eligible studies included cross-sectional, longitudinal and case-control studies. Intervention studies were included if baseline data were presented. No restrictions were placed on sample size or language. The full text of the conference abstracts were

requested from the corresponding author and if the authors did not respond, conference abstracts were also considered due to the paucity of the empirical evidence in LMICs.

Search results were screened using Rayyan software.²⁸ Two reviewers independently screened for eligibility by title and abstract [MO, AVJ]. Interrater agreement was 99.6%. Discrepancies between the two reviewers were resolved through discussion and with final decision provided by ZY. The full texts of these potentially eligible articles were then retrieved and independently assessed by two reviewers [MO, ZY]. Discrepancies between the two reviewers were resolved through discussion and final decision provided by SS in the event of no consensus. Interrater agreement was 88.1%. Study authors were asked for full text copies if these could not be retrieved.

Data from included studies were extracted using a bespoke Microsoft Excel spreadsheet which included details on study location,²⁹ study design, participant characteristics, free-living 24-hour physical behaviour measurements and methods, income classification,³⁰ climate classification,³¹ air quality³² (see [Appendix B](#) for full data extraction form/table). Authors of included studies were not contacted in the event of missing data. Data extraction was performed by five authors [AA, ARJ, BG, MO, WK], with double-data extraction for each study. Any conflicts in data extraction were resolved through discussion with final decision provided by MO/SS.

The main summary measures were objectively measured overall free-living PA, SB and sleep. Given the nature of the review, no formal risk of bias assessment was conducted. Instead, indicators of quality of reporting and questionnaire/device deployment were examined. Reporting quality of the included studies was conducted by considering whether key information was provided. The presence or absence of information relating to each of the above items was used to describe the quality of reporting. Reporting quality of the included studies was presented through narrative and table summaries. In accordance with our PROSPERO registration, a meta-analysis was not planned due to anticipated heterogeneity in measurement approaches ([Table 1](#)).

Extracted data and summary measures were stratified into subgroups: Region²⁹ (African, Region of the Americas, South-East Asia, European, Eastern Mediterranean, Western Pacific); income classification (Countries with low-income economies (Gross national income per capita \$1045 or less in 2020); lower middle-income economies (GNI per capita between \$1046 and \$4095) and upper middle-income economies (GNI per capita between \$4096 and \$12,695) constitute low-and middle-income countries (LMIC)),³³ Köppen-Geiger climate classification (Equatorial, Arid, Warm temperature, Snow, Polar),³¹ air quality levels (PM10: above or below 20µg/m³ annual mean and PM2.5: above or below 10µg/m³ annual mean),³⁴ and measurement approach.

Results

Study Selection and Characteristics

[Figure 1](#) shows the selection process according to the PRISMA statement.²⁷ The initial search retrieved 18,121 records, 153 full texts were screened for eligibility and 89 articles (0.6%) met the criteria for inclusion ([Appendix C](#)). Of the 89 articles identified, 78 were articles and 11 were conference abstracts. The full text of the selected conference abstracts were requested from the corresponding authors but none responded. Most studies recruited exclusively COPD (65 studies [73%]) and asthma patients (13 studies [15%]). Four studies (4%) recruited a combined sample of COPD and asthma and two studies (2%) recruited bronchiectasis patients. Excluding studies covering all regions, sample sizes totalled 8986 participants. Most studies were cross-sectional in design (65 studies [73%]), comprised male majority samples (55 studies [62%]) and included data collected in warm temperature climates (45 studies [51%]) ([Table 2](#)). Fifteen studies reported having a control group and eight studies compare the patients with healthy control ([Appendix D](#)).

Income Classification

Of the 89 articles identified, none were conducted in low-income countries, 12 (13%) were conducted in lower-middle-income countries, 71 (80%) were conducted in upper-middle-income countries (UMIC) and six (7%) spanned income classifications.

Table I Summary of the Variables Used to Describe Physical Activity, Sedentary Behaviour and Sleep

Physical Behaviour Category of Variables	Frequency
Physical activity (PA)	
Steps per day	21
Energy expenditure (e.g. kcal/day, EE during activity)	21
Active/inactive binary groups (e.g. ≥ 80 min MVPA, ≥ 30 min above 3METs)	19
Time spent walking	16
A physical activity score or index (e.g. IPAQ score, YPAS summary index)	16
Time in moderate-to-vigorous PA (MVPA) (e.g. time in >3 METs, time in ≥ 3 METs)	11
Movement intensity (e.g. movement intensity during walking)	9
Physical inactivity (e.g. severe inactivity <4580 steps)	8
Active/inactive 3+ groups (e.g. Inactive/Moderately inactive/Moderately active/Active)	7
Time in PA (e.g. total active time)	6
Leisure activities	4
Metabolic equivalents (MET)-min/week (e.g. MET-min/week walking)	4
Sport activities	4
Time in vigorous PA	4
Time in moderate PA	3
Household PA	3
Standing and walking time	2
Time in light PA	2
Distance walked	1
Impaired daily functioning	1
Ratio between time in moderate PA & walking	1
Time in other behaviours	1
Sedentary behaviour	
Sedentary time (e.g. time in <1.5 METs, time in <2 METs)	16
Standing time	13

(Continued)

Table 1 (Continued).

Physical Behaviour Category of Variables	Frequency
Sitting time	11
Lying time	10
Sedentary (yes/no) (e.g. ≥ 8 hr/day, ≥ 8.5 hr/day)	4
Sitting index	1
Standing index	1
Time television watching/video games	1
Sleep	
Overall sleep quality (e.g. Global PSQI score, poor sleep quality [yes/no])	32
Sleep duration (e.g. total sleep time, short/medium/long sleep)	14
Use of sleep medication	11
Sleep disturbances (e.g. wake up several times per night)	11
Sleep efficiency	9
Sleep latency (e.g. time to fall asleep, trouble falling asleep)	8
Daytime sleep dysfunction	7
Appropriate sleep	1
Sleep alterations	1
Fixed sleep schedule	1

WHO Regions

The most prevalent region for included studies was the Region of the Americas (45 studies [51%]; 43 in Brazil) followed by European (11 studies [12%], eight in Turkey) and South-East Asian (10 studies [11%], six in India). Three studies were conducted solely in Africa (all in Nigeria).

The Methods of Physical Behaviour Data Collection

PA (66 studies) was the most commonly measured behaviour; measured solely in 47 studies, in combination with SB in 16 studies, with sleep in one study and with SB and sleep in two studies. Sleep (24 studies) was measured exclusively in 21 studies and SB (20 studies) was measured solely in two studies.

Majority of studies assessed physical behaviours using questionnaires only (52 studies [58%]). Fourteen different questionnaires were used across included studies, with an additional 12 studies reporting specific questions. For sleep, the Pittsburgh Sleep Quality Index (PSQI) was the most common questionnaire (18 studies). For PA/SB, the International Physical Activity Questionnaire (IPAQ) was most common (11 studies). Questions or questionnaires were not provided in four studies. Most studies (58%) did not report the recall period of the questionnaires used and only one study (2%) reported how missing data were handled ([Appendix E](#)).

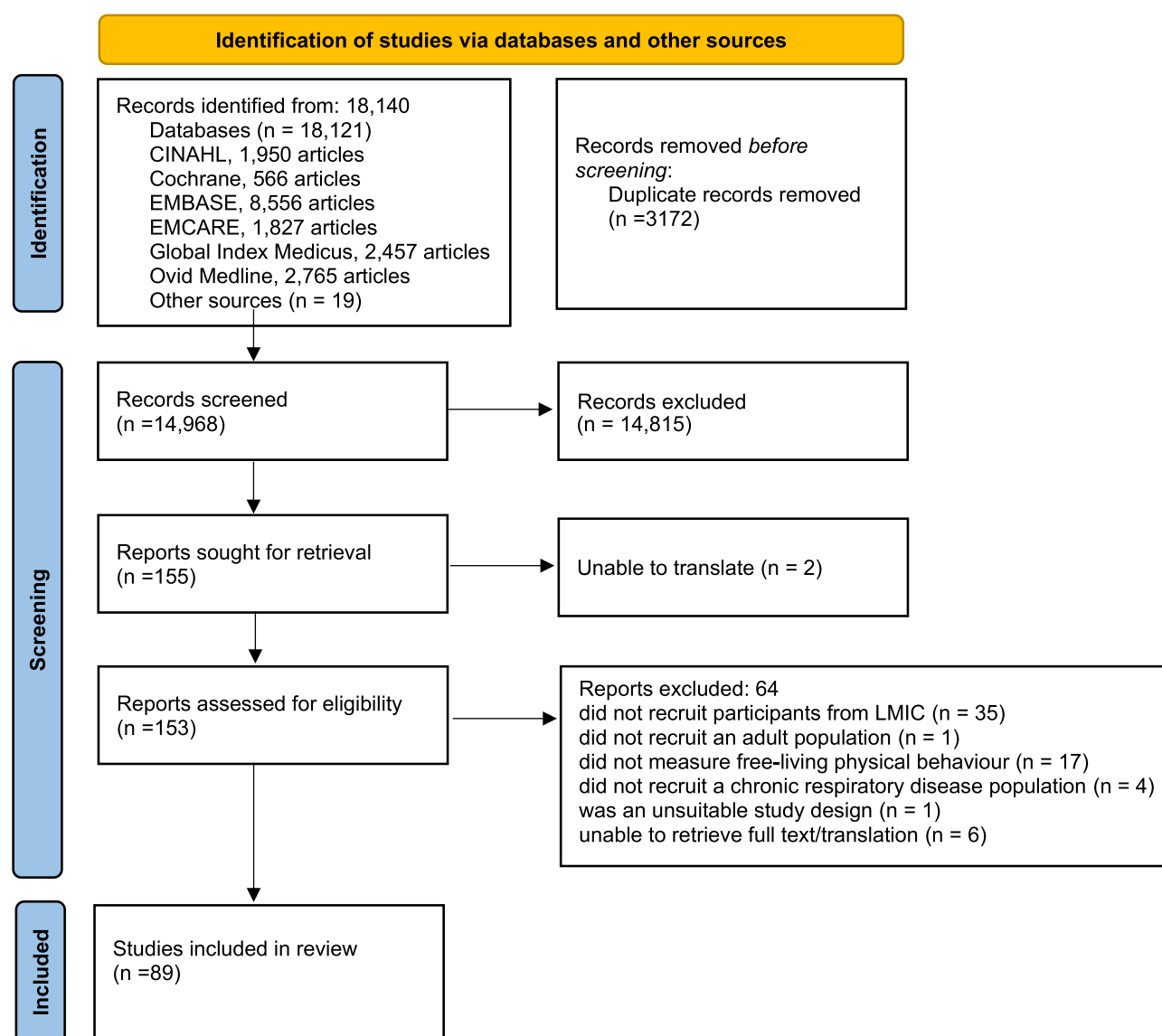


Figure I PRISMA flow diagram of study selection.

Of the 36 studies using device-based measurement of physical behaviours, twenty-six studies (72%) used accelerometers and 10 studies (28%) used pedometers. Dynaport activity monitors were used in 15 studies (58% of accelerometer studies) and the SenseWear Armband in seven studies. Five studies (19%) deployed a Dynaport and SenseWear simultaneously. Four studies (15%) did not provide the model of activity monitor used. Most studies (32, 89%) did not report whether participants had access to feedback on their behaviour during the measurement period. Four studies (11%) did not report the number of days participants were asked to wear the device. Most studies (18, 50%) monitored behaviours for two days and six studies (17%) had a seven-day wear protocol. Fifteen studies (42%) did not report how long each day participants were asked to wear a device. Of the 21 studies reporting this information, the majority (18 studies, 86%) asked for 12 hours of wear and during a fixed time period (19 studies, 90%) to be included in analysis, 14 studies (39%) did not report the minimum number of hours each day and minimum number of days the device needed to be worn. Most studies (35, 97%) did not report average wear-time and 34 studies (94%) did not report if or how periods of non-wear were calculated ([Appendix F](#)).

Table 2 Characteristics of Individual Studies Included in the Review

Reference	Study Location: Country	Income Classification	Climate Classification	Air Quality PM2.5	Air Quality PM10	Study Design	CRD Population	Sample Size	Age (Years)	Gender Mix (Majority %)	Behaviour Measured
African region											
Adetiloye (2018) ⁴²	Nigeria (Ile-Ife)	Lower-Middle	Equatorial	Not available	Not available	Cross-sectional	COPD	60	70 (8)	53% male	Sleep
Adewolea (2017) ⁴³	Nigeria (Ile-Ife)	Lower-Middle	Equatorial	Not available	Not available	Cross-sectional	Chronic pulmonary parenchyma	410	48.5 (16.5)	69.3% female	Sleep
Desalu (2019) ⁴⁴	Nigeria (Northwest, Southeast, Northcentral geopolitical zones)	Lower-Middle	Not available	Not available	Not available	Cross-sectional	Asthma	172	37 (15)	67.4% female	Sleep
Eastern Mediterranean Region											
Ali Zohal (2013) ⁴⁵	Iran (Qazvin city)	Upper-Middle	Warm temperate	Above	Below	Case-control	COPD	120	66.4 (10.8)	66% male	Sleep
Borji (2018) ⁴⁶	Iran (Ilam)	Upper-Middle	Arid	Above	Above	RCT	Asthma	120	Not stated	Not stated	Sleep
Chegeni (2018) ⁴⁷	Iran (Khorramabad)	Upper-Middle	Arid	Above	Above	RCT	COPD	91	57.14 (11.8)	59% male	Sleep
Eslaminejad (2017) ⁴⁸	Iran (Tehran)	Upper-Middle	Arid	Above	Above	Cross-sectional	COPD	850	53.88 (16.5)	53.6% female	Sleep
Mahmood (2019) ⁴⁹	Iraq (Basra, Baghdad)	Upper-Middle	Arid	Above	Above	Cross-sectional	Asthma	56	40–49years: 50%; 50–59years: 12.4%; 60+ years: 28.6%	62.5% female	Physical activity
Moussa (2014) ⁵⁰	Tunisia (Sousse)	Lower-Middle	Arid	Above	Above	Case-control	COPD	16	48.99 (5.33)	100% male	Physical activity
Moussa (2016) ⁵¹	Tunisia (Sousse)	Lower-Middle	Arid	Above	Above	Case-control	COPD	16	48.99 (5.33)	100% male	Physical activity

(Continued)

Table 2 (Continued).

Reference	Study Location: Country	Income Classification	Climate Classification	Air Quality PM _{2.5}	Air Quality PM ₁₀	Study Design	CRD Population	Sample Size	Age (Years)	Gender Mix (Majority %)	Behaviour Measured
European Region											
Mihaltan (2019) ⁵²	Bulgaria, Serbia (Unknown)	Upper-Middle	Not available	Not available	Not available	Cross-sectional	COPD	Not stated	Not stated	Not stated	Physical activity
Mihaltan (2019) ⁵³	Bulgaria; Serbia (Unknown)	Upper-Middle	Not available	Not available	Not available	Cross-sectional	COPD	Bulgaria: 210; Serbia: 250	B: 66.7; S: 68.0	Not stated	Physical activity
Vukoja (2018) ⁵⁴	Serbia (Sremska Kamenica)	Upper-Middle	Snow	Not available	Not available	Cross-sectional	Asthma, COPD	Asthma: 117, COPD: 100	Asthma: 39 (14); COPD: 63 (10)	Asthma 48% male; COPD 61% male	Sleep
Akinci (2013) ⁵⁵	Turkey (Kirkilareli)	Upper-Middle	Warm temperate	Above	Above	Cross-sectional	COPD	102	66.8 (10.0)	86.1% male	Sleep
Genc (2012) ⁵⁶	Turkey (Afyonkarahisar)	Upper-Middle	Warm temperate	Above	Above	Pre-post trial	COPD	30	57.9 (10.2)	100% male	Physical activity
Genc (2014) ⁵⁷	Turkey (Afyonkarahisar)	Upper-Middle	Warm temperate	Above	Above	Cross-sectional	COPD	30	54.1 (8.1)	100% male	Physical activity
Pehlivan (2019) ⁵⁸	Turkey (Istanbul)	Upper-Middle	Warm temperate	Above	Below	Single-arm intervention study	Non-cystic fibrosis bronchiectasis	19	Median [IQR] 48.36 [34–73]	63% female	Physical activity
Sahin (2015) ⁵⁹	Turkey (Kafkas)	Upper-Middle	Snow	Not available	Not available	Single-group pretest/posttestpretrial model	COPD	45	58.36 (10.12)	50.3% male	Sleep
Sagliam (2013) ⁶⁰	Turkey (Ankara)	Upper-Middle	Arid	Above	Below	Cross-sectional	COPD	28	NW: 63.07 (6.32); OW/OB: 63.79 (6.87)	100% male	Physical activity

Turan (2016) ⁶⁰	Turkey (Afyonkarahisar)	Upper-Middle	Warm temperate	Above	Above	Cross-sectional	COPD	93	61.4 (9.8)	100% male	Physical activity
Yilmaz (2016) ⁶²	Turkey (Sivas)	Upper-Middle	Snow	Above	Above	Experimental design	COPD	50	Median [IQR] NW: 61[56–65]; OW: 65[62–69]; OB: 66[61–69]	90% male	Physical activity
Region of the Americas											
Lopez Jove (2013) ⁶³	Argentina (Buenos Aires)	Upper-Middle	Warm temperate	Above	Below	Observational prospective study	COPD	113	63.1 (8.3)	71.1% male	Physical activity
Molinas (2007) ⁶⁴	Argentina (Córdoba)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	Asthma	151	24.24 (8.86)	81.5% female	Physical activity
Amorim (2014) ⁶⁵	Brazil (São Paulo)	Upper-Middle	Warm temperate	Above	Below	Cross-sectional	COPD	40	64.4 (7.7)	55% male	Physical activity
Athayde (2014) ⁶⁶	Brazil (Belo Horizonte)	Upper-Middle	Equatorial	Above	Below	Cross-sectional	COPD	72	65.86 (9.25)	65.3% male	Physical activity
Borges (2012) ⁶⁷	Brazil (São Paulo)	Upper-Middle	Warm temperate	Above	Below	Longitudinal	COPD	20	68.6 (10.7)	70% male	Physical activity; Sedentary behaviour
Campos (2017) ⁶⁸	Brazil (Fortaleza)	Upper-Middle	Equatorial	Not available	Not available	Cross-sectional	Asthma	123	50.8 (12.2)	100% female	Sleep
Cani (2019) ⁶⁹	Brazil (Florianópolis, São José)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	59	DOT: 68.3 (7.72); CG: 67.5 (7.61)	DOT: 72% male; CG: Not stated	Physical activity; Sedentary behaviour
Cavalcante (2012) ⁷⁰	Brazil (Fortaleza)	Upper-Middle	Equatorial	Not available	Not available	Cross-sectional	COPD	104	69.1 (8.0)	Not stated	Sleep
Cetlin (2012) ⁷¹	Brazil (Ribeirão Preto)	Upper-Middle	Warm temperate	Above	Below	Cross-sectional	Asthma	200	Not stated	67% female	Physical activity

(Continued)

Table 2 (Continued).

Reference	Study Location: Country	Income Classification	Climate Classification	Air Quality PM2.5	Air Quality PM10	Study Design	CRD Population	Sample Size	Age (Years)	Gender Mix (Majority %)	Behaviour Measured
Coelho (2018) ⁷²	Brazil (Minas Gerais)	Upper-Middle	Equatorial	Not available	Not available	Cross-sectional	Asthma	36	45.8 (12.3)	100% female	Physical activity
Coelho (2018) ⁷³	Brazil (Minas Gerais)	Upper-Middle	Equatorial	Not available	Not available	Randomized parallel-group controlled trial	Asthma	37	Median [IQR] Ped: 45.0 [19.0]; Con: 47.0 [14.0]	86% female	Physical activity
da Costa (2012) ⁷⁴	Brazil (Vale Dos Sinos)	Upper-Middle	Warm temperate	Not available	Not available	Prospective comparative study	COPD	7	64 (8.12)	100% female	Physical activity
Cukier (2020) ⁷⁵	Brazil (Blumenau, Botucatu, Campinas, Porto Alegre, Rio de Janeiro, Sao Bernardo do Campo, São Paulo)	Upper-Middle	Warm temperate, Equatorial	Above	Below	Cross-sectional	COPD	593	67.7 (9.0)	52.1% male	Physical activity
Felcar (2018) ⁷⁶	Brazil (Londrina)	Upper-Middle	Warm temperate	Not available	Not available	Randomised trial	COPD	36	LG: 68 (8); WG: 69 (9)	64% male	Physical activity
Filippin (2011) ⁷⁷	Brazil (Cascavel)	Upper-Middle	Warm temperate	Not available	Not available	Cohort retrospective cross-sectional study	COPD	55	Physically active: 67.12 (5.72); physically inactive: 71 (6.18)	Not stated	Physical activity
Fonesca (2016) ⁷⁸	Brazil (Florianópolis)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	17	67 (8)	82% male	Physical activity; Sedentary behaviour

Freitas (2018) ⁷⁹	Brazil (São Paulo)	Upper-Middle	Warm temperate	Above	Below	Randomised trial	Asthma	51	WL+S: 48.5 (9.8); WL+E: 45.9 (7.7)	98% female	Physical activity; Sedentary behaviour; Sleep
Furlanetto (2016) ⁸⁰	Brazil (Londrina)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	104	66 (8)	63% male	Physical activity
Furlanetto (2017) ¹⁴	Brazil (Londrina)	Upper-Middle	Warm temperate	Not available	Not available	Cohort retrospective cross-sectional study	COPD	101	Median [IQR] 66 [60–72]	57% male	Physical activity; Sedentary behaviour
Furlanetto (2017) ⁸¹	Brazil (Londrina)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	19	69 (7)	53% male	Physical activity
Gulart (2019) ⁸²	Brazil (Florianópolis)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	61	65.5 (8.76)	77% male	Physical activity; Sedentary behaviour
Hernandes (2009) ⁸³	Brazil (Northern Paraná)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	40	66 (8)	55% female	Physical activity; Sedentary behaviour
Jardim (2011) ⁸⁴	Brazil (São Paulo)	Upper-Middle	Warm temperate	Above	Above	Cross-sectional	COPD	49	68.9 (8.5)	59% male	Physical activity
Karloh (2016) ⁸⁵	Brazil (Florianópolis)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	38	Median [IQR] 65 [63–68]	58% male	Physical activity; Sedentary behaviour
Landal (2014) ⁸⁶	Brazil (Northern Paraná)	Upper-Middle	Warm temperate	Not available	Not available	Longitudinal	COPD	30	66 (7)	51% female	Physical activity; Sedentary behaviour

(Continued)

Table 2 (Continued).

Reference	Study Location: Country	Income Classification	Climate Classification	Air Quality PM2.5	Air Quality PM10	Study Design	CRD Population	Sample Size	Age (Years)	Gender Mix (Majority %)	Behaviour Measured
Lanza (2018) ⁸⁷	Brazil (São Paulo)	Upper-Middle	Warm temperate	Above	Below	Cross-sectional	Bronchiectasis	100	48 (14)	59% female	Physical activity
Lopes (2019) ⁸⁸	Brazil (São Paulo)	Upper-Middle	Warm temperate	Above	Below	Cross-sectional	COPD	150	68 (8.3)	67% male	Physical activity
Mantoani (2011) ⁸⁹	Brazil (Londrina)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	67	Median [IQR] 66 [61–72]	54% male	Physical activity; Sedentary behaviour
Monteiro (2012) ⁹⁰	Brazil (Londrina)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	74	65 (9)	61% male	Physical activity
Morita (2018) ⁹¹	Brazil (Londrina)	Upper-Middle	Warm temperate	Not available	Not available	Retrospective cross-sectional	COPD	145	Median [IQR] 65 [60–73]	54% male	Physical activity; Sedentary behaviour
Munari (2018) ⁹²	Brazil (Florianópolis)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	110	66 (8)	68.2% male	Physical activity; Sedentary behaviour
Nobeschi (2020) ⁹³	Brazil (Santo André)	Upper-Middle	Warm temperate	Above	Below	Single-arm intervention study	COPD	30	68.17 (6.11)	56.7% male	Sleep
Nunes (2008) ⁹⁴	Brazil (Ceará)	Upper-Middle	Equatorial	Not available	Not available	Randomized, double-blind, parallel-group, placebo-controlled study	COPD	25	Melatonin: 64.17 (9.9); Placebo: 67.38 (8.1)	56% male	Sleep
Nyssen (2013) ⁹⁵	Brazil (São Carlos)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	30	68 (10)	77% male	Physical activity

Pitta (2009) ⁹⁶	Brazil (Londrina)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	40	66 (8)	55% female	Physical activity; Sedentary behaviour
Probst (2011) ⁹⁷	Brazil (Londrina)	Upper-Middle	Warm temperate	Not available	Not available	Prospective randomized trial	COPD	40	Calisthenics and Breathing Exercises Group: 65 (10); Endurance and Strength Training Group: 67 (7)	53% male	Physical activity; Sedentary behaviour
Reboredo (2017) ⁹⁸	Brazil (São Pedro)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	166	64.94 (9.9)	59% male	Physical activity
Rocha (2017) ⁹⁹	Brazil (Florianópolis)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	25	67.56 (9.21)	56% male	Physical activity; Sedentary behaviour
Rodrigues (2014) ¹⁰⁰	Brazil (Gurupi)	Upper-Middle	Equatorial	Not available	Not available	Cross-sectional	Lung diseases	Not stated	Not stated	Not stated	Physical activity
Schneider (2018) ¹⁰¹	Brazil (Londrina)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	45	66 (8)	56% male	Physical activity; Sedentary behaviour
Silva (2011) ¹⁰²	Brazil (Porto Alegre)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	95	67.3 (8.1)	65% male	Physical activity
Simon (2009) ¹⁰³	Brazil (Curitiba)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	38	Physically active: 67 (6); Physically inactive: 65 (9)	71% male	Physical activity
Tavares (2017) ¹⁰⁴	Brazil (Recife)	Upper-Middle	Equatorial	Not available	Not available	Cross-sectional	COPD	54	≥60 years: 68.5%	68.5% male	Physical activity

(Continued)

Table 2 (Continued).

Reference	Study Location: Country	Income Classification	Climate Classification	Air Quality PM2.5	Air Quality PM10	Study Design	CRD Population	Sample Size	Age (Years)	Gender Mix (Majority %)	Behaviour Measured
Vitorasso (2012) ¹⁰⁵	Brazil (Londrina)	Upper-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	73	65 (9)	63% male	Physical activity; Sedentary behaviour
Xavier (2016) ¹⁰⁶	Brazil (Unknown)	Upper-Middle	Not available	Not available	Not available	Cross-sectional	COPD	153	68 (8)	68% male	Physical activity
South-East Asian Region											
Yunus (2018) ¹⁰⁷	Bangladesh (Dhaka)	Lower-Middle	Equatorial	Above	Above	Cross-sectional	COPD	116	Not stated	Not stated	Sleep
Bhuker (2012) ¹⁰⁸	India (New Delhi)	Lower-Middle	Arid	Above	Above	Cross-sectional	Asthma	50	Range: 18–50 years	Not stated	Physical activity
De (2012) ¹⁰⁹	India (Maharashtra)	Lower-Middle	Arid	Not available	Not available	Cross-sectional	COPD	40	62.2 (9.2)	Not stated	Sleep
Gupta (2018) ¹¹⁰	India (Doiwala, Chakrata, Joshimath)	Lower-Middle	Warm temperate	Not available	Not available	Cross-sectional	COPD	130	Not stated	Not stated	Sleep, physical activity
Panigrahi (2018) ¹¹¹	India (Bhubneshwar)	Lower-Middle	Equatorial	Above	Above	Cross-sectional	Asthma	101	38 (16.2)	44% male	Sleep
Poongadan (2016) ¹¹²	India (New Delhi)	Lower-Middle	Arid	Above	Above	Cross-sectional	Asthma	125	Not stated	56% male	Physical activity; Sedentary behaviour; Sleep
Sharma (2019) ¹¹³	India (Nalhar)	Lower-Middle	Arid	Not available	Not available	Cross-sectional	COPD	120	Dep: 58.1 (6.43); No Dep: 57.72 (7.95)	59% male	Physical activity
Ulfathinah (2019) ¹¹⁴	Indonesia (DKI Jakarta Province)	Upper-Middle	Equatorial	Above	Above	Cross-sectional	COPD	200	61.76 (10.089)	67.5% male	Sleep

Widyastuti (2017) ¹¹⁵	Indonesia (Central Java)	Upper-Middle	Equatorial	Not available	Not available	RCT	COPD	36	Not stated	Not stated	Physical activity
Chanthitvech (2017) ¹¹⁶	Thailand (Bangkok)	Upper-Middle	Equatorial	Above	Above	Cross-sectional	COPD	26	67.73 (7.56)	88.5% male	Physical activity
Western Pacific Region											
Chunrong (2014) ¹¹⁷	China (Guangzhou)	Upper-Middle	Warm temperate	Above	Above	Cross-sectional	COPD	71	65.17 (6.80)	76% male	Physical activity
Ding (2017) ¹¹⁸	China (Beijing, Chengdu, Guangzhou, Jinan, Nanjing, Shanghai, Shenyang, Wuhan, Xi'an)	Upper-Middle	Snow climate, Warm temperate	Above	Above	Cross-sectional	COPD and Asthma-COPD Overlap	675	62.0 (11.4)	60.7% male	Sleep
Tao (2016) ¹¹⁹	China (Tianjin)	Upper-Middle	Snow	Above	Above	Cross-sectional	COPD	35 b	69.1 (6.9)	64.1% male	Physical activity
Wang (2016) ¹²⁰	China (Tianjin)	Upper-Middle	Snow	Above	Above	Cross-sectional	COPD	154	72.8 (9.6)	59.7% male	Physical activity
Wang (2016) ¹²¹	China (Tianjin)	Upper-Middle	Snow	Above	Above	Cross-sectional	COPD	100	71.23 (9.58)	71% male	Physical activity
Wang (2017) ¹²²	China (Jilin)	Upper-Middle	Snow	Above	Above	Cross-sectional	COPD	334	Not stated	Not stated	Sleep
Zheng (2019) ¹²³	China (Qingdao city, Shandong province)	Upper-Middle	Snow	Not available	Not available	Cohort retrospective study	COPD	72	66.00 (5.59)	76% male	Sleep
All Regions											
Vancampfort (2017) ¹²⁴	See footnote c	All	Not available	Not available	Not available	Cross-sectional	Asthma	11,857	Not stated	Not stated	Physical activity
Koyanagi (2017) ¹²⁵	China, Ghana, India, Mexico, Russia, South Africa	Lower-Middle; Upper-Middle	Not available	Not available	Not available	Cross-sectional	Asthma, COPD	Asthma: 2696; COPD: 5392 d	Not stated	Not stated	Physical activity

(Continued)

Table 2 (Continued).

Reference	Study Location: Country	Income Classification	Climate Classification	Air Quality PM _{2.5}	Air Quality PM ₁₀	Study Design	CRD Population	Sample Size	Age (Years)	Gender Mix (Majority %)	Behaviour Measured
Vancampfort (2017) ¹²⁶	China, Ghana, India, Mexico, Russia, South Africa	Lower-Middle; Upper-Middle	Not available	Not available	Not available	Cross-sectional	Chronic lung disease	4477	Not stated	Not stated	Sedentary behaviour
Vancampfort (2018) ¹²⁷	China, Ghana, India, Mexico, Russia, South Africa	Lower-Middle; Upper-Middle	Not available	Not available	Not available	Cross-sectional	Asthma; Chronic lung disease	Not stated	Not stated	Not stated	Physical activity
Vancampfort (2017) ¹²⁸	China, Ghana, India, Mexico, Russia, South Africa	Lower-Middle; Upper-Middle	Not available	Not available	Not available	Cross-sectional	Asthma, COPD	Not stated	Not stated	Not stated	Physical activity
Vancampfort (2018) ¹²⁹	China, Ghana, India, Mexico, Russia, South Africa	Lower-Middle; Upper-Middle	Not available	Not available	Not available	Cross-sectional	Asthma, COPD	Not stated	Not stated	Not stated	Sedentary behaviour

Variables to Assess 24-Hour Physical Behaviours

A summary of the variables used to describe physical behaviours is given in [Table 1](#) (full extraction of the variables in [Appendix B](#)). The most common PA categories of variables used were steps per day ($n=21$), energy expenditure ($n=21$), binary classification of active/inactive ($n=19$), time spent walking ($n=16$) and classification of active/inactive using at least three groups ($n=16$). For SB, the common categories of variables used were sedentary time ($n=16$), standing time ($n=13$), sitting time ($n=11$) and lying time ($n=10$). Overall sleep quality ($n=32$), sleep duration ($n=14$), use of sleep medication ($n=11$) and sleep disturbances ($n=11$) were the most commonly used categories of sleep variables.

Levels of Free-Living PA, SB and Sleep

Time spent walking (12 studies; range 36–91min/day) and movement intensity (eight studies; range 0.18–1.9m/s²) measured by Dynaport activity monitor were most common, followed by the number of steps per day measured by Dynaport (six studies; range 2669–6557steps/day) and Yamax (five studies; range 4227–7490 steps/day) and MVPA measured by SenseWear Armband (five studies; range 29–89min/day). Three SB variables, all measured using Dynaport, were directly comparable between studies; comprising sitting time (12 studies; range 283–418min/day); standing time (12 studies; range 139–270min/day); lying time (11 studies; range 76–119min/day). For sleep, PSQI score was provided in 12 studies (range 4–11) and PSQI classification of poor sleep quality in 11 studies (range 33–100%) ([Table 3](#)).

Sub-Group Analysis of 24-Hour Physical Behaviours

Four studies measuring PA and two studies measuring SB spanned all regions. The Region of the Americas accounted for the majority of studies measuring PA (45 studies [68%]) ([Figure 2A](#)) and SB (19 studies [95%]) ([Figure 2B](#)). Studies measuring sleep were distributed across regions in small numbers with South-East Asia as the most common (six studies [25%]) ([Figure 2C](#)). One study measuring PA included data from all low- and middle- income classifications. No studies solely took place in low-income countries. Most took place in upper-middle income countries (60 [91%] measured PA, 19 [95%] measured SB and 16 [67%] measured sleep). We were unable to classify climate for seven studies measuring PA, two studies measuring SB and one study measuring sleep. Most studies were conducted in warm temperature climates (41 studies [69%] of PA, 17 studies [94%] of SB and six studies of sleep [26%]). There were 52 studies where we were unable to classify air quality (61% measuring PA, 85% measuring SB and 46% measuring sleep). All other studies exceeded the annual 10µg/m³ PM_{2.5} threshold. Using the annual 20µg/m³ PM₁₀ threshold, 15 studies (58%) measured PA, one study (33%) measured SB and ten studies (77%) measured sleep in areas exceeding the threshold ([Table 4](#)).

Discussion

This systematic review provided a comprehensive assessment of the prevalence, levels and measurement approaches of studies assessing 24-hour physical behaviours in people living with CRD in LMIC. The majority of studies examining PA and SB in CRD in LMIC are limited to Brazil (UMIC), whilst studies measuring sleep were more evenly distributed across regions. Questionnaires were more commonly used to measure physical behaviours than device-based methods, with data supporting low physical activity levels, sedentary lifestyles and poor sleep quality for people in LMIC living with CRDs.

Most studies were conducted in upper-middle-income countries with Brazil accounting for almost half. In other regions, Turkey (European), India (South-East Asian) and Nigeria (Africa) had the monopoly of identified articles within their respective regions. No studies were conducted exclusively in low-income countries. Therefore, more studies are needed to compare physical behaviours within and between regions and income classifications. For large cohort studies of general adult populations, such as those included in The Lancet physical inactivity series,⁵ data were from predominantly HIC in Europe and North America; with data from Africa and Central Asia particularly scarce.³⁵

Table 3 Summary of the Studies with Comparable Measurement of Physical Activity, Sedentary Behaviour and Sleep

Reference	Value for Physical Behaviour	Study Location(s): Country	Study Location(s): Region	Income Classification(s)	Climate Classification(s)	PM2.5 Air Quality (Year Taken)	PM10 Air Quality (Year Taken)
Step count (Dynaport, steps/day)							
Borges (2012) ⁶⁷	3575±2799	Brazil	Region of the Americas	Upper-Middle	Warm temperate	35 (2012)	18 (2012)
Cani (2019) ⁶⁹	DOT: 2669±1883; CG: 4599 ±2308	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Gulart (2019) ⁸²	5273±2726	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Karloh (2016) ⁸⁵	6557[5496–7619]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Munari (2018) ⁹²	5292±3200	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Rocha (2017) ⁹⁹	6388.12 ± 3671.66	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Walking time (Dynaport, min/day)							
Borges (2012) ⁶⁷	6.1±4.4%	Brazil	Region of the Americas	Upper-Middle	Warm temperate	35 (2012)	18 (2012)
Cani (2019) ⁶⁹	DOT: 36.1±23.7; CG: 90.7 ±39.6	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Fonesca (2016) ⁷⁸	68.0[57.5–87.0]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Gulart (2019) ⁸²	68.5±38.2	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Hernandes (2009) ⁸³	55 ± 33	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Karloh (2016) ⁸⁵	81.1[68.1–94.0]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available

Mantoani (2011) ⁸⁹	51[34–73]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Morita (2018) ⁹¹	55[37–81]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Munari (2018) ⁹²	67.4±31.5	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Pitta (2009) ⁹⁶	56±32	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Probst (2011) ⁹⁷	CBEG 54±28; ESTG 57±32	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Vitorasso (2012) ¹⁰⁵	53[36–80]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Movement Intensity (Dynaport, m/s²)							
Canis (2019) ⁶⁹	DOT: 1.53±0.22; CG: 1.88 ±1.01	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Fonesca (2016) ⁷⁸	1.81±0.30	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Hernandes (2009) ⁸³	1.9 ± 0.4	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Karloh (2016) ⁸⁵	1.78[1.70–1.97]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Mantoani (2011) ⁸⁹	1.9[1.6–2.1]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Munari (2018) ⁹²	1.72±0.27	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Pitta (2009) ⁹⁶	1.9±0.4	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Rocha (2017) ⁹⁹	0.18 ± 0.03	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available

(Continued)

Table 3 (Continued).

Reference	Value for Physical Behaviour	Study Location(s): Country	Study Location(s): Region	Income Classification(s)	Climate Classification(s)	PM2.5 Air Quality (Year Taken)	PM10 Air Quality (Year Taken)
MVPA time (SenseWear, min/day)							
Furlanetto (2017) ¹⁴	0.48 [0.14–1.24] hours/day	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Furlanetto (2017) ⁸¹	89±15 vs 84±15 during summer and winter	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Mantoani (2011) ⁸⁹	29 [10–86]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Probst (2011) ⁹⁷	CBEG 4533±5968; ESTG 4539±5314	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Schneider (2018) ¹⁰¹	49.3 [25.7–100]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Step count (Yamax, steps/day)							
Amorim (2014) ⁶⁵	6251.0 ± 2422.8	Brazil	Region of the Americas	Upper-Middle	Warm temperate	35 (2014)	19 (2014)
Coelho (2018) ⁷²	7490.3±3330.2	Brazil	Region of the Americas	Upper-Middle	Equatorial	Not available	Not available
Coelho (2018) ⁷³	PED: 7295±3241; CON: 6998 ±3490	Brazil	Region of the Americas	Upper-Middle	Equatorial	Not available	Not available
Felcar (2018) ⁷⁶	LG: 5891±3054; WG: 6101 ±3591	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Nyssen (2013) ⁹⁵	4227±2075	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Sitting time (Dynaport, min/day)							
Borges (2012) ⁶⁷	38.9±17.6%	Brazil	Region of the Americas	Upper-Middle	Warm temperate	35 (2012)	18 (2012)

Canis (2019) ⁶⁹	DOT: 418±104; CG: 390 ±111	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Fonesca (2016) ⁷⁸	394.9±93.6	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Furlanetto (2017) ¹⁴	5.28 [3.95–6.52] hr/day	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Gulart (2019) ⁸²	383±104	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Hernandes (2009) ⁸³	294 ± 114/41%	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Karloh (2016) ⁸⁵	381[351–412]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Morita (2018) ⁹¹	317[248–386]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Munari (2018) ⁹²	378±105	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Pitta (2009) ⁹⁶	296±109	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Probst (2011) ⁹⁷	CBEG 283±121; ESTG 296 ±91	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Vitorasso (2012) ¹⁰⁵	307[228–376]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Standing time (DynaPort, min/day)							
Borges (2012) ⁶⁷	22.7±14.0%	Brazil	Region of the Americas	Upper-Middle	Warm temperate	35 (2012)	18 (2012)
Canis (2019) ⁶⁹	DOT:139±64.3; CG:149±60.9	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Fonesca (2016) ⁷⁸	130.0[112.0–163.5]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available

(Continued)

Table 3 (Continued).

Reference	Value for Physical Behaviour	Study Location(s): Country	Study Location(s): Region	Income Classification(s)	Climate Classification(s)	PM2.5 Air Quality (Year Taken)	PM10 Air Quality (Year Taken)
Gulart (2019) ⁸²	140±54.9	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Hernandes (2009) ⁸³	36%	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Karloh (2016) ⁸⁵	155[140–171]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Mantoani (2011) ⁸⁹	237[161–345]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Morita (2018) ⁹¹	209[147–276]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Munari (2018) ⁹²	149±62.4	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Pitta (2009) ⁹⁶	246±122	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Probst (2011) ⁹⁷	CBEG 270±139; ESTG 248 ±95	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Vitorasso (2012) ¹⁰⁵	196[137–289]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Lying time (Dynaport, min/day)							
Borges (2012) ⁶⁷	30.7±20.2%	Brazil	Region of the Americas	Upper-Middle	Warm temperate	35 (2012)	18 (2012)
Canli (2019) ⁶⁹	DOT: 114±81.6; CG: 103 ±85.4	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Fonesca (2016) ⁷⁸	76[0–143.5]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Furlanetto (2017) ¹⁴	1.72 [0.56–2.97] hr/day	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available

Gulart (2019) ⁸²	105±105	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Hernandes (2009) ⁸³	15%	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Karloh (2016) ⁸⁵	77.1[53.3–101]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Morita (2018) ⁹¹	107[25–183]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Munari (2018) ⁹²	101±87.2	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Pitta (2009) ⁹⁶	119±110	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Probst (2011) ⁹⁷	CBEG 108±100; ESTG 113±101	Brazil	Region of the Americas	Upper-Middle	Warm temperate	Not available	Not available
Sleep quality (PSQI Score)							
Adetiloye (2018) ⁴²	9.93±4.19	Nigeria	African Region	Lower-Middle	Equatorial	Not available	Not available
Akinci (2013) ⁵⁵	7.1±3.9	Turkey	European Region	Upper-Middle	Warm temperate	70 (2016)	47 (2016, converted)
Ali Zohal (2013) ⁴⁵	8.03±3.66	Iran	Eastern Mediterranean Region	Upper-Middle	Warm temperate	44 (2013)	18 (2013, converted)
Campos (2017) ⁶⁸	9.9±4.6	Brazil	Region of the Americas	Upper-Middle	Equatorial	Not available	Not available
Chegeni (2018) ⁴⁷	TG: 6.33±3.41, CG: 6.41±3.12	Iran	Eastern Mediterranean Region	Upper-Middle	Arid	75 (2016, converted)	33 (2016)
De (2012) ¹⁰⁹	Median 11	India	South-East Asian Region	Lower-Middle	Arid	Not available	Not available
Nobeschi (2020) ⁹³	6.5[4.75–8.75]	Brazil	Region of the Americas	Upper-Middle	Warm temperate	27 (2016)	12 (2016, converted)

(Continued)

Table 3 (Continued).

Reference	Value for Physical Behaviour	Study Location(s): Country	Study Location(s): Region	Income Classification(s)	Climate Classification(s)	PM2.5 Air Quality (Year Taken)	PM10 Air Quality (Year Taken)
Panigrahi (2018) ¹¹¹	4 [3–7]	India	South-East Asian Region	Lower-Middle	Equatorial	81 (2012)	43 (2012, converted)
Sahin (2015) ⁵⁹	9.52±0.22	Turkey	European Region	Upper-Middle	Snow	Not available	Not available
Ulfathinah (2019) ¹¹⁴	Median 6	Indonesia	South-East Asian Region	Upper-Middle	Equatorial	82 (2016, converted)	45 (2016)
Vukoja (2018) ⁵⁴	Asthma 4.9±3.9; COPD 5.8 ±4.3	Serbia	European Region	Upper-Middle	Snow	Not available	Not available
Zheng (2019) ¹²³	Intervention 9.50±2.87; Control 9.31±2.98	China	Western Pacific Region	Upper-Middle	Snow	Not available	Not available
Poor sleep quality (PSQI, %)							
Adetiloye (2018) ⁴²	81.7%	Nigeria	African Region	Lower-Middle	Equatorial	Not available	Not available
Adewolea (2017) ⁴³	37.8%	Nigeria	African Region	Lower-Middle	Equatorial	Not available	Not available
Ali Zohal (2013) ⁴⁵	67.9%	Iran	Eastern Mediterranean Region	Upper-Middle	Warm temperate	44 (2013)	18 (2013, converted)
Campos (2017) ⁶⁸	80.4%	Brazil	Region of the Americas	Upper-Middle	Equatorial	Not available	Not available
Cavalcante (2012) ⁷⁰	59.6%	Brazil	Region of the Americas	Upper-Middle	Equatorial	Not available	Not available
De (2012) ¹⁰⁹	100%	India	South-East Asian Region	Lower-Middle	Arid	Not available	Not available
Gupta (2018) ¹¹⁰	33.3%	India	South-East Asian Region	Lower-Middle	Warm temperate	Not available	Not available
Nobeschi (2020) ⁹³	73%	Brazil	Region of the Americas	Upper-Middle	Warm temperate	27 (2016)	12 (2016, converted)

Panigrahi (2018) ¹¹¹	48.5%	India	South-East Asian Region	Lower-Middle	Equatorial	81 (2012)	43 (2012, converted)
Ulfathinah (2019) ¹¹⁴	66%	Indonesia	South-East Asian Region	Upper-Middle	Equatorial	82 (2016, converted)	45 (2016)
Vukoja (2018) ⁵⁴	Asthma 40.4%; COPD 38%	Serbia	European Region	Upper-Middle	Snow	Not available	Not available

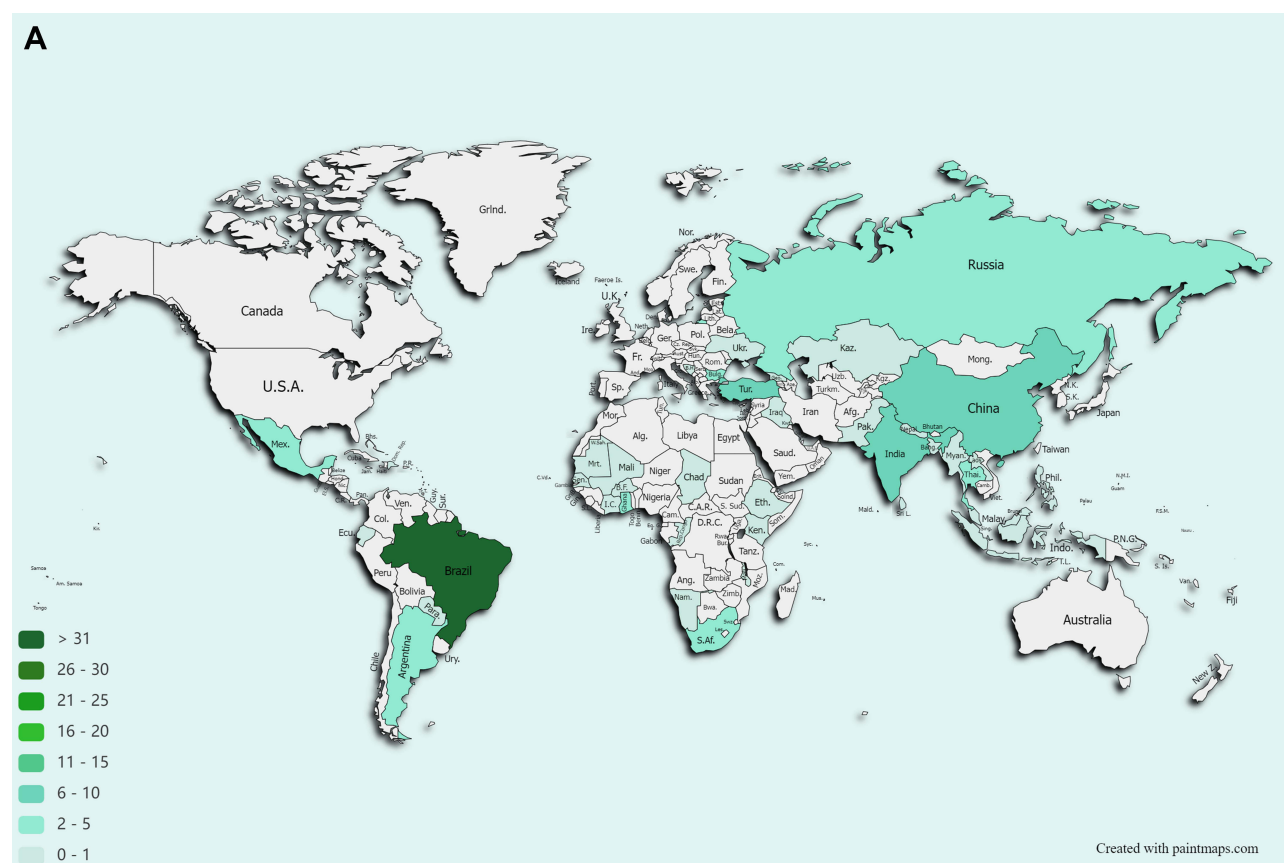


Figure 2 (A) Location of studies measuring physical activity. **(B)** Location of studies measuring sedentary behaviour. **(C)** Locations of studies measuring sleep.

Efforts to increase the available data on PA, SB and sleep in other LMIC are needed before any reliable prevalence estimates and worthwhile comparisons can be made.

PA was most commonly investigated. There was a relatively equal split of device- and questionnaire-based assessment of PA, with almost exclusively device-based assessment of SB and questionnaire-based assessment of sleep. Compared with a previous systematic review of 76 studies measuring free-living PA in COPD (almost exclusively studies in HIC), the Dynaport activity monitor was more commonly used (42% versus 14%). The disproportionate use of the Dynaport in the included studies from Brazil explains this disparity, whereas the previous review contained a large proportion of studies from HIC. For questionnaire-based PA and SB, we found the IPAQ to be most commonly used; consistent with the evidence base for large epidemiological studies of healthy adult populations.⁵ IPAQ is commonly used in LMIC for population surveillance, with more than 50 countries adopting it as of 2016,⁷ but it was developed for individuals aged 15–69 years of age which may not be appropriate for many CRD populations.³⁶ The PSQI was the most common questionnaire in our review with relatively consistent use of the overall PSQI score and classification of poor sleep quality. The PSQI was also more consistently used across regions and currently offers the greatest opportunity for pooled analysis and standardisation. The popularity of the PSQI is supported by a previous review of sleep disorders in COPD.²⁶ Although it is also possible to assess free-living sleep in CRD populations using devices,^{37,38} the PSQI offers a simple tool to examine sleep quality and duration in LMIC.

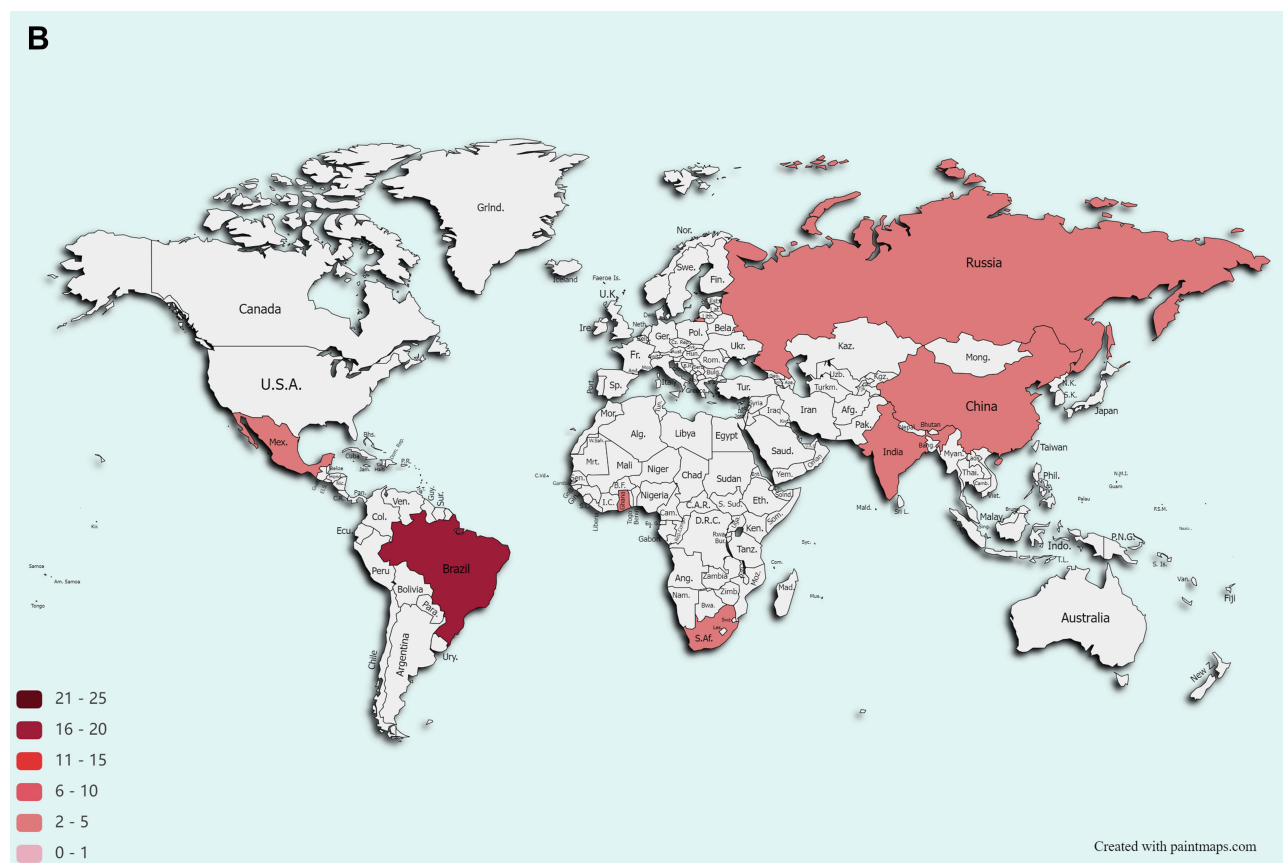


Figure 2 Continued.

Articles included in our review relied predominantly on summary variables of physical behaviours, such as steps per day, sedentary time and overall sleep quality. The high prevalence of summary variables supports previous work exploring device-based PA, which found 70% of studies used a marker for total activity, with half using step count. Postural assessments such as sitting, standing or lying down were more commonly reported in the included studies using more device-based assessments than previously found (44% versus 20%); due to the exclusive measurement of postures in Brazilian studies.

The commonly reported variables of PA were mostly related to walking (time spent walking and step count) which is easily interpretable and at the heart of clinical practice guidelines for COPD.³⁹ It is estimated that 7000–10,000 steps per day is approximately equivalent to taking part in 30 minutes of daily MVPA⁹ and data from the included articles support people living with CRD in LMIC to be physically inactive. Indicating a global nature of the problem, prevalence of physical inactivity was found more than twice as high in high-income countries compared to low-income countries.⁶ However, the considerable variation between studies and locations, such as their measurement and data processing protocols, make it difficult to generalise.

Only the range of PA, SB and sleep levels were presented in the study. The reported study variables were not consistent across the included articles which caused considerable heterogeneity, and it may lead to false conclusions. Pooling the data on various study designs increase the methodological heterogeneity. Studies included in our review suggest people living with CRD in LMIC have worse sleep quality than healthy counterparts across income classifications. We found PSQI classification of poor sleep quality ranged 33–100%; higher than the

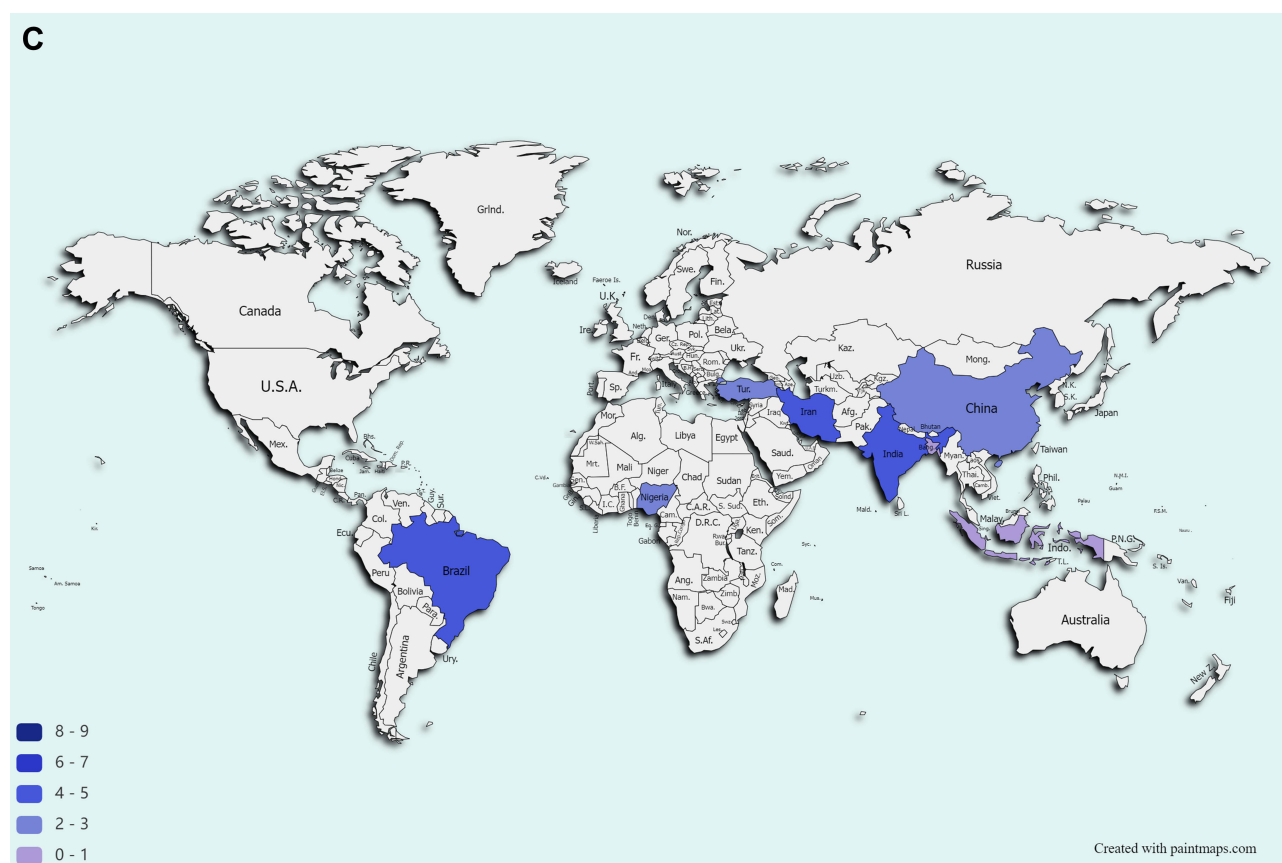


Figure 2 Continued

estimated prevalence of 32.8% (95% confidence interval: 25.9–39.7%) based on a meta-analysis of 19 studies of working-age adults in LMIC⁴⁰ and from adults residing in high-income European countries.⁴¹

The strengths of our systematic review include a pre-defined rigorous search methodology, registered on PROSPERO before study screening, bias assessment, including the use of validated search terms, the comprehensive array of databases searched, the absence of language restrictions and screening included reference lists to reduce selection bias. The data extraction phase was also duplicated to minimise assessor bias and error. However, there may be databases unknown to the authors where additional studies may be published in this area. We were unable to translate two non-English publications (Persian). The climate and air quality classifications were not always possible to identify from information reported in the included studies, limiting subgroup analyses.

Conclusion

Based on 89 articles included in our systematic review of the PA, SB and sleep of people living with CRD in LMIC, we showed considerable inequity between behaviours, geographical locations and income classifications. The majority of studies examining PA and SB in CRD in LMIC were limited to Brazil, whilst studies measuring sleep were more limited and spread across regions. Questionnaires were more commonly used to measure physical behaviours than device-based methods, with summary data supporting low physical activity levels, sedentary lifestyles and poor sleep quality for people in LMIC living with CRDs. There was large variation in measurement approaches and poor quality methodological reporting for all physical behaviours which limited direct comparisons. The lack of standardisation and poor reporting reduces the strength of evidence needed to strengthen the scientific integrity of data and resulting clinical and policy implications to support patients to lead healthier lifestyles. More studies of PA, SB and sleep are needed in a broader range of LMICs. Future work would benefit from a harmonised approach to data collection to ensure international comparisons.

Table 4 Summary of the Number of Studies Measuring Each Physical Behaviour, Stratified by Region, Income Classification, Measurement Approach, Climate Classification and Air Quality

Sub-Grouping	Physical Activity	Sedentary Behaviour	Sleep
Region			
African Region	4	2	3
European Region	12	2	3
Eastern Mediterranean Region	7	2	4
Region of the Americas	45	19	5
South-East Asia Region	10	3	6
Western Pacific Region	8	2	3
Income classification			
Low	1	0	0
Lower-middle	10	3	8
Upper-middle	60	19	16
Measurement			
Device	36	17	1
Questionnaire	32	3	23
Not provided	1	0	0
Köppen-Geiger climate classification			
Arid	7	1	5
Equatorial	8	0	8
Polar	0	0	0
Snow	4	0	5
Warm temperature	41	17	6
Unable to classify	7	2	1
Air quality classification			
Above 10 μ g/m ³ PM2.5	26	3	13
Below 10 μ g/m ³ PM2.5	0	0	0
Above 20 μ g/m ³ PM10	15	1	10
Below 20 μ g/m ³ PM10	11	2	3
Unable to classify	40	17	11

Abbreviations

CRD, Chronic respiratory disease; HIC, High-income countries; LMIC, Low- and middle-income; countries; PA, Physical activity; PRISMA, Preferred reporting items for systematic review and meta-analysis; PROSPERO, International prospective register of systematic reviews; SB, Sedentary behaviour; UMIC, Upper-middle-income countries; WHO, World health organisation.

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Disclosure

The authors report no conflicts of interest in this work.

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