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Review

Device-measured physical activity and sedentary time in the Nordic countries: A scoping review of population-based studies

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Abstract

Purpose: The purpose of this scoping review was to summarize and describe the methodology and results from population-based studies of physical activity and sedentary time measured with devices in the Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden) and published in 2000 or later.

Methods: A systematic search was carried out in PubMed and Web of Science in June 2023 using predefined search terms.

Results: Fourteen unique research projects or surveillance studies were identified. Additionally, 2 surveillance studies published by national agencies were included, resulting in a total of 16 studies for inclusion. National surveillance systems exist in Finland and Norway, with regular survey waves in school-aged children/adolescents and adults. In Denmark, recent nationally representative data have been collected in school children only. So far, Sweden has no regular national surveillance system using device-based data collection. No studies were found from Iceland. The first study was conducted in 2001 and the most recent in 2022, with most data collected from 2016 to date. Five studies included children/adolescents 6−18 years, no study included preschoolers. In total 11 studies included adults, of which 8 also covered older adults. No study focused specifically on older adults. The analytical sample size ranged from 205 to 27,890. Detailed methodology is presented, such as information on sampling strategy, device type and placement, wear protocols, and physical activity classification schemes. Levels of physical activity and sedentary time in children/adolescents, adults, and older adults across the Nordic countries are presented.

Conclusion: A growing implementation of device-based population surveillance of physical activity and sedentary behavior in the Nordic countries has been identified. The variety of devices, placement, and data procedures both within and between the Nordic countries highlights the challenges when it comes to comparing study outcomes as well as the need for more standardized data collection.

Keywords: Accelerometer; Light intensity; Moderate-vigorous intensity; Surveillance; Wearable devices

1. Introduction

Based on the extensive benefits of physical activity (PA), the World Health Organization (WHO) provides quantitative guidelines on the amount of aerobic PA that individuals should undertake to see significant health benefits and to mitigate health risks.[1] The guidelines recommend that adults and older adults engage in at least 150−300 min of moderate-intensity PA or 75−150 min of vigorous-intensity activity per week, or an equivalent combination of the two. Children and adolescents 5−17 years are recommended to engage in at least an average of 60 min per day of moderate-to-vigorous PA (MVPA) across the week. The WHO guidelines also recommend that people of all ages limit sedentary time.[1] In addition to the global guidelines, the Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden) all have national guidelines for physical activity similar to the WHO.[2−6]

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Monitoring PA and sedentary time at the population level with reliable and accurate measurement is essential for determining adherence to national PA guidelines, monitoring trends over time, and identifying priority populations to guide public health policies.[7] The Nordic countries have a long tradition of national health surveillance, including self-reported PA and, more recently, time spent being sedentary. However, it is known that self-reports tend to overestimate the amount of time people spend doing PA[8] and underestimate the amount of time spent being sedentary.[9,10] Additionally, questionnaires often focus on structured or leisure-time PA.

Compared to self-reports, wearable technologies such as movement devices (e.g., accelerometers) offer opportunities for large-scale assessment of more precise PA and sedentary time with less measurement error.[11] Contrary to self-reports, wearable devices can capture incidental and light-intensity PA (LPA), which significantly contribute to total daily movement.[12] Wearable devices can also provide the number of daily steps accumulated, a metric that is easily understood by the public.[13] Although novel findings have expanded the evidence on the daily steps needed for health, more research is required to determine the "optimal" number, and there are no step recommendations in current global or national guidelines. Even so, daily steps can be used as a simple measure of total PA level—one that is not dependent on data reduction procedures.

The increased availability, acceptability, and reduced cost of devices such as accelerometers have facilitated the growing use of device-based measurements in both research projects and surveillance studies in the Nordic countries during the past 2 decades.[14,15] Experiences and results from these studies can improve our understanding of movement patterns in the population, and changes therein, as well as contribute to the ongoing development of PA guidelines, which are in transition from evidence based on self-reports to potential development based on device-measured evidence.[11,16] To move forward, there is a need to summarize, compare, and learn from available national device-based PA data. To date, there has been no such comprehensive overview from the Nordic countries.

Thus, the purpose of this scoping review was to summarize and describe the methodology and results from population-based studies of PA and sedentary time measured with devices in Denmark, Finland, Iceland, Norway, and Sweden published in 2000 or later. More specifically our aims were to:

(a) Provide an overview of studies with national or regional representative samples from the Nordic countries that use device-measured data on PA and sedentary time.
(b) Describe sampling and methodologies in these data sources.
(c) Present available data on PA and sedentary time in children/adolescents, adults, and older adults collected in the Nordic countries.
(d) Compare levels of PA and sedentary time in children/adolescents, adults, and older adults across the Nordic countries.

2. Methods

The manuscript was developed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) statement.[17] The completed PRISMA-ScR checklist can be found in Supplementary File 1. We did not register a review protocol.

2.1. Search methods

We searched PubMed and Web of Science on June 13, 2023 using a combination of terms for device-measured PA (e.g., "accelerometer" or "device"), movement behaviors (e.g., "physical activity" or "walking" or "sedentary time"), and 1 or more of the Nordic countries. The full search matrixes are shown in Supplementary File 2. The search was restricted to studies published in 2000 or later [18] and written in English or a Nordic language. Citations were screened using Endnote software (X2; Clarivate, London, UK). Additionally, each author used their national network to identify other relevant data sources, such as reports from national surveillance systems published online. A custom made excel sheet (Version Microsoft 365; Microsoft Corp., Redmond, WA, USA) was used to extract study information.

2.2. Inclusion criteria

Studies were eligible if they were conducted in Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, or Sweden and reported results from device-based measures of PA or sedentary time, and if participants were selected using probability-based sampling from a national or sub-national frame. Studies with sub-national sampling frames were eligible if they represented a full geographical region or if the sampling frame covered parts of 2 or more subnational regions, even if they are not necessarily representative of the entirety of these regions. The latter were considered eligible because they can provide information on within-country differences in PA. Grey literature such as surveillance studies published by governments or national agencies was eligible for inclusion.

2.3. Study selection

Relevant publications were identified using a 2-step process. First, one author (JT) screened titles and abstracts to exclude studies that: (a) had no device-based measurement of a movement behavior, (b) did not measure free-living movement behaviors for at least a full day (e.g., lab-work or measurements during a specific day-segment), (c) were not population-based (e.g., specific occupational groups, athletes, clinical populations), (d) did not provide full study information (e.g., conference abstracts), and (e) were not conducted in a Nordic country. Publications passing the first round were then assessed in duplicate by 3 independent authors (IMD, JSJ, and MH) to identify surveys or research projects with probability-based sampling from nationally or regionally representative sampling frames. Disagreement was solved by consensus.

2.4. Data extraction and analyses

Publications were grouped by study name (i.e., surveillance study/research project). From each study, we extracted data based on the publication with the largest sample size or most detailed description of PA and/or sedentary time. Additional information was sought from other reports or grey literature when relevant. One author (JT) extracted the data that was verified by a second author (JSJ). Disagreement was solved by consensus. We extracted the following information from each study: country, sampling area, year(s) of data collection, target population, exclusion criteria, sampling methodology, seasonality, individuals invited, individuals providing data, analytical sample, weighting for non-response, device and placement, device wear protocol, data reduction protocols, definitions of PA and/or sedentary time, and reported levels of sedentary time, LPA, MVPA, and daily steps. We also categorized the studies, depending on their target population, as preschoolers, children/adolescents, adults, and older adults.

To present data on PA level and sedentary time per age-group, data were collapsed (i.e., men and women or different age-groups), when appropriate, by calculating weighted means. Data on older adults were extracted from adult-focused studies. More detailed information on daily PA levels and sedentary time stratified by age-group and sex is presented in Supplementary Table 1. For comparison across the Nordic countries, we selected studies from each country with the most recent nationally representative samples for each age-group.

Features related to methodological quality, such as selection, study size, sampling approach, and handling of missing data, were extracted and reported.[19]

3. Results

3.1. Study selection

A total of 3698 records were identified in our search. After removal of 224 duplicates, 3474 records were screened based on title and abstract. In the title and abstract stage, 2224 records were excluded as irrelevant. After full-text review of 1250 articles, 111 articles met the inclusion criteria. From these we identified 14 unique research projects or surveillance studies (not counting multiple survey rounds as separate studies and excluding sub-studies or other publications with data from the same cohort). Two additional surveillance studies published by national agencies (grey literature) were included, resulting in 16 studies for final inclusion. We documented the screening process in a PRISMA-ScR study flow diagram (Fig. 1). Four studies were conducted in Denmark (1 dedicated to Greenland),[20−23] 6 studies in Finland,[24−29] 3 studies in Norway,[30−32] and 3 studies in Sweden.[33−35] We found no national or regionally representative studies conducted in Iceland or the Faroe Islands.

3.2. Overview of included studies

Ten studies aimed at national surveillance[21,23−26,28−30,34,35] and 6 studies were multi-regional or regional.[20,22,27,31−33] Seven studies had multiple survey rounds, including a total of 27 survey waves.[21,23,24,27,28,30,32] The first study was conducted in 2001 and the most recent in 2022.[34] The majority of included studies had data collected from 2016 to date. Five studies included children/adolescents,[23,24,30,31,35] ranging from 6 to 18 years; no study included preschoolers. One study included participants aged 16−20 years and was classified as adult-focused.[26] In total, 11 studies included adults,[20−22,25−29,32−34] of which 8 also covered older adults.[20−22,25,28,29,32,34] No study focused specifically on older adults. The analytical sample size had a median of 1587 (interquartile range, 1382), with 11 of the survey waves with an analytical sample size of over 2000. The participation rate had a median of 40% (interquartile range, 23%) of the invited sample. Accelerometers were used in 14 studies, 1 study used a combined monitor (accelerometry and heart rate),[20] 1 study used accelerometers and pedometers,[27] and 1 study used pedometers only.[21] Nine of the included studies also reported adherence to physical activity guidelines.[23,24,26,29,30,32−35] The main characteristics of the included studies are summarized in Table 1 and more detailed information on sampling strategy is presented in Supplementary Table 2.

3.3. Methodology

Device type and placement, wear protocols, and PA classification schemes, including definitions used, are presented in detail in Table 2. The most common accelerometer was ActiGraph (ActiGraph, LLC, Pensacola, FL, USA; in different versions) used in all included studies from Norway and Sweden[30−35] and in 2 of the Finnish studies.[25,27] The ActiGraph was worn on the hip or lower back in all but a single study,[25] in which the device was worn on the wrist. Of the additional 4 Finnish studies, 1 study used Hookie (Hookie AM 20; Traxmeet Ltd., Espoo, Finland),[29] which is worn on the hip, and 3 studies used UKK RM42 (UKK Terveyspalvelut Oy, Tampere, Finland),[24,26,28] which is worn on the hip during waking time and on the wrist during sleep. In the Danish studies, the thigh-worn Ax3 (Axivity, Newcastle-upon-Tyne, UK) was used in 2 studies[22,23] and Actiheart (CamNtech Ltd., Cambridge, UK), a chest-worn monitor recording both heart rate and accelerations, was used in 1 study.[20] Two studies[21,27] used pedometers: Yamax SW-200 (Yamasa Tokeu Keiki Co., Ltd., Japan) and Omron Walking Style One (Omron Healthcare Inc., Hoofddorp, the Netherlands). The most common wear protocol was waking wear time, and the most common valid wear criteria was a minimum of 4 days. Five studies had a 24-h wear protocol.[20,23,25,26,28] Eight studies reported daily steps.[21−24,26−28,32]

3.4. PA and sedentary time by age groups

Studies including children/adolescents reported, on average, 7−10 h of sedentary time and 50−106 min of MVPA per day. The 2 studies that reported step count in children/adolescents showed similar results,[23,24] with 9700 and 9900 steps per day, respectively. Boys were somewhat more active than girls. Studies including an adult population reported, on average, 7−9 h of sedentary time and 33−67 min of MVPA

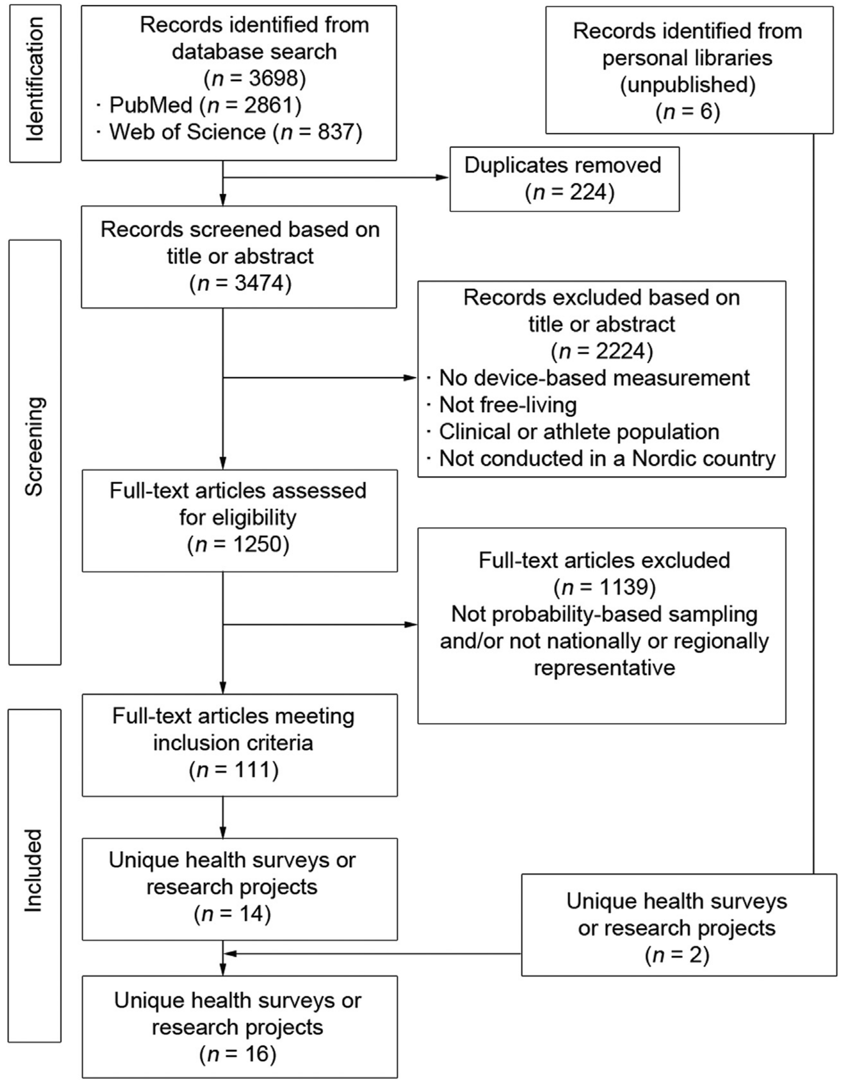

Fig. 1. Flow diagram of the screening process, according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews.

per day. Daily steps were presented in 6 studies with an adult population,[21,22,26–28,32] ranging between 6100 and 8500 steps.

We found no national or regional studies that specifically targeted PA or sedentary time in older adults. However, it was possible to extract data from 5[22,28,29,32,34] of the 9 adult-focused studies that included older adults. Three studies provided data from ≥60 years,[22,28,34] 1 study from ≥65 years,[32] and another from ≥70 years.[29] Reported sedentary time was, on average, 7–10 h per day and MVPA was 26–41 min per day. The studies reporting daily step count for the same age-group showed similar results: 6700 and 6900 steps for persons 60–69 years, and 5200 and 5400 steps for persons ≥70 years.[22,28,29]

3.5. Country comparisons

Levels of device-measured PA and sedentary time in children/adolescents, adults, and older adults across the Nordic countries, when available, are presented in Fig. 2. For the comparison, we chose the most recent study/survey from each country with data from national sampling.[21,23,24,28,30,32,35,36]

3.6. National surveillance in the Nordic countries

3.6.1. Denmark

In Denmark, the first attempt to collect nationally representative PA data was conducted in 2007–2008 as a sub-study for a larger nutritional behavioral study in adults (Danish National Surveys of Diet and Physical Activity).[21] The scope of PA data has since been expanded to include all participants. In a sub-sample of the Health Behaviour in School-aged Children study,[23] 2 waves (2018 and 2022) of PA data have been collected in schoolchildren aged 11, 13, and 15 years.

3.6.2. Finland

Several surveillance systems are in place for device-based monitoring of PA and sedentary time in various age-groups in Finland. Since 2016, nationally sampled data have been collected regularly. This review included studies providing national data from 3 different age-groups: children 7–15 years (Finnish School-age Physical Activity),[24] young adults 16–20 years (Finnish Young Adults Physical

Table 1
Characteristics of included studies.

Study	Sampling	Year	Age (year)	Invited	Analytical sample (% of invited)	Type of device
Denmark						
Inuit Health in Transition study[20]	Regional, Greenland	2005–2010	≥18	4660	1508 (32)	Accelerometer + heartrate monitor
DANSDA[21]	National	2007–2008	18–75	368	205 (56)	Pedometer
		2012–2013	18–75	2925	1419 (49)	
Central Denmark Region [22]	Regional, Central Region	2014–2016	18–80	1569	242 (15)	Accelerometer
HBSC-Denmark[23]	National	2018	11–15	2472	1677 (68)	Accelerometer
		2022	11–15	2179	1268 (58)	
Finland						
Health 2011 Study[29]	National	2011–2012	18–85	4916	1587 (32)	Accelerometer
FinnHealth[25]	National	2017	≥25	2000	915 (46)	Accelerometer
FINFIT[26,28]	National	2017–2019	20–69	13,500	2256 (17)	Accelerometer
		2021–2022	20–69	16,500	2237 (14)	
Finnish School-age Physical Activity[24]	National	2016	9–15	6793	2981 (44)	Accelerometer
		2018	7–15	6565	2650 (40)	
		2022	7–15	5959	1395 (23)	
Finnish Young Adults Physical Activity[26]	National	2020	16–20	14,503	1071 (6)	Accelerometer
Cardiovascular Risk in Young Finns Study[27]	Multi-regional	2007	30–45	3596	1520 (42)	Pedometer
		2011	34–49	3596	1525 (42)	(2007, 2011)
		2020	43–58	3596	1368 (38)	Accelerometer (2020)
Norway						
NNPAS[32,58,59]	Multi-regional	2008–2009	20–85	11,515	3267 (28)	Accelerometer
		2014–2015	20–89	11,147	4756 (36)	
		2020–2022	20–70	7893	2543 (31)	
PANCS[30]	National	2005–2016	9, 15	2818	1823 (65)	Accelerometer
		2011–2012	6, 9, 15	5603	3317 (59)	
		2017–2018	6, 9, 15	5671	3046 (54)	
Active Smarter Kids[31]	Regional	2014	10	1395	1060 (76)	Accelerometer
Sweden						
Riksmaten Adolescents[35]	National	2016–2017	11–18	5145	2419 (47)	Accelerometer
ABC[34]	National	2001	18–75	3300	1114 (34)	Accelerometer
SCAPIS[33]	Multi-regional	2013–2018	50–64	59,909	27,890 (47)	Accelerometer

Abbreviations: ABC = The Attitude, Behaviour and Change study; DANSDA = The Danish National Survey of Diet and Physical Activity; FINFIT = The FinFit Study; HBSC = Health Behaviour School Children; NNPAS = Norwegian National Physical Activity Survey; PANCS = Physical Activity Norwegian Children Study; SCAPIS = Swedish Cardiopulmonary Bioimage Study.

Activity),[26] and working-aged adults 20–69 years (The FinFit Study).[28] These studies have been conducted by the UKK Institute together with several local partners.

3.6.3. Norway

In 2005, Norway established a national surveillance system for device-measured PA and sedentary time in the Norwegian population. Since then, 3 surveillance waves have been conducted among 6-, 9-, and 15-year-olds (Physical Activity among Norwegian Children Study)[30] and 3 surveillance waves have been conducted on the adult and older adult population (National Nutrition and Physical Activity Survey).[32] All studies were funded by the Norwegian Directorate of Health (2005–2016) and later by the Norwegian Public Health Institute.

3.6.4. Sweden

So far, no national surveillance system using device-based monitoring of PA and sedentary time in adults or older adults has been conducted in Sweden. The only national surveillance study using accelerometer-measured PA and sedentary time in Sweden is Riksmaten Adolescents,[35] with participants aged 11–18 years, initiated by the Swedish Food Agency in 2016–2017.

4. Discussion

This is the first scoping review of population-based studies with device-measured PA or sedentary time in the Nordic countries. In our search from the year 2000–2023, we found 16 studies, with most data collected from 2016 to date. This reveals the growing implementation of device-measured PA and sedentary time in population-based studies. National surveillance systems are in place in Finland and Norway, with regular survey waves (i.e., repeated cross-sectional measures of different samples of participants) in school-aged children and adolescents. Finland and Norway also have recent national data on adults from repeated surveillance studies. Multiple waves of data collection using the same devices and data

Table 2
Description of wear protocols and data reduction procedures for the included studies.

Study	Device/placement	Wear protocol and valid wear-criteria	PA classification scheme	Definition of SED	Definition of LPA	Definition of MVPA	Definition of steps	Body posture/activity type classification included
Denmark								
Inuit Health in Transition study[20]	Actiheart Chest	24-h wear-time, 2−4 days ≥48 h of total wear-time	Activity counts and heart rate Manual inspection of intensity time-series Branched-equation for intensity-classification based on population-specific validation	<1.5 METs (includes sleep)	1.5−2.9 METs	≥3.0 METs		
DANSDA[21] 2007−2008 2011−2012	Yamax SW-200 Waist	Remove during sleep, 7 days; ≥4 days ≥600 min/day	Log				Daily steps recorded in log	
Central Denmark Region[22]	Axivity AX3 Thigh	Remove during sleep (night) and naps for >1 h ≥3 days + minimum 24 h total wear-time Daily wear time requirement not reported	Algorithm Manual calibration of all files; vector magnitude and gait cycle frequencies to inform decision-tree algorithm, using 10-s epochs Algorithm developed on orthopedic patients	Algorithm to identify sitting and standing	Algorithm	Algorithm	Algorithm	Standing, walking, cycling, sitting to standing transfers
HBSC-Denmark[23] 2018 2022	Axivity AX3 Thigh	24-h wear-time, 7 days ≥3 days ≥480 min/day	Activity counts and algorithm Intensity-thresholds based on counts, unclear if uni-axial or vector magnitude, in 10-s epoch; activity types from algorithm	Algorithm to identify sitting	100−4970 cpm	≥4971 cpm	Algorithm	Cycling, sitting, lying
Finland								
Health 2011 Study[29]	Hookie AM20 Hip	Remove during sleep, 7 days; ≥4 days ≥600 min/day	MAD MAD of 3-axial signal in 6-s epochs; intensity based on 60-s exponential average MAD-values; sedentary behaviors identified from algorithm	Algorithm to identify sitting and reclining	22.5−91.5 MAD	>91.5 MAD	Algorithm	Sitting/reclining, standing, sitting to standing transfers
FinnHealth[25]	AG GT9X Wrist	24-h wear-time, 7 days ≥4 days ≥600 min/day	Activity counts Vector magnitude in 60-s epoch					
FINFIT[28] 2017−2019 2021−2022	UKK RM42 Hip	24-h wear-time, 7 days	MAD MAD of 3-axial signal in 6-s epochs; intensity based on 60-s exponential average MAD-values	Algorithm to identify sitting and reclining	22.5−91.5 MAD	>91.5 MAD	Algorithm	Sitting/reclining, standing, sitting to standing transfers

(*continued on next page*)

Table 2 (Continued)

Study	Device/placement	Wear protocol and valid wear-criteria	PA classification scheme	Definition of SED	Definition of LPA	Definition of MVPA	Definition of steps	Body posture/activity type classification included
			Sedentary behaviors identified from algorithm					
Finnish School-age Physical Activity[24] 2016 2018 2022	UKK AM30 + RM42 Hip	Remove during sleep, 7 days; ≥4 days, including ≥1 weekend day ≥600 min/day	MAD MAD of 3-axial signal in 6-s epochs; intensity based on 60-s exponential average MAD-values; sedentary behaviors identified from algorithm	Algorithm to identify sitting and reclining	22.5−91.5 MAD	>91.5 MAD	Algorithm	Sitting/reclining, standing, sitting to standing transfers
Finnish Young Adults Physical Activity 2020[26]	UKK RM42 Hip	24-h wear-time, 7 days	MAD MAD of 3-axial signal in 6-s epochs; intensity based on 60-s exponential average MAD-values; sedentary behaviors identified from algorithm	Algorithm to identify sitting and reclining	22.5−91.5 MAD	>91.5 MAD	Algorithm	Sitting/reclining, standing, sitting to standing transfers
Cardiovascular Risk in Young Finns[27] 2007 2011 2020	Omron Walking Style One[a] AG GT3X+ (2020) Waist	≥4 days (2007, 2011) ≥600 min/day (2020)	Log (2007, 2011) Algorithm (2020)				Daily steps recorded in log (2007, 2011) Algorithm (2020)	
Norway								
NNPAS[32,58,59] 2008−2009 2014−2015 2020−2022	AG GT1M AG GT1M + GT3X+ AG GT3X+ Hip	Remove during sleep, 7 days; ≥4 days, ≥600 min/day (2008); ≥1 day, ≥600 min/day (2014) ≥2 days, daily wear time requirement not reported (2020)	Activity counts Vertical axis in 60-s epochs	<100 cpm	100−2019 cpm	≥2020 cpm		
PANCS[15, 30] 2005−2016 2011−2012 2017−2018	AG 7164 AG GT1M + GT3X+ Hip	Remove during sleep, 5 days (2005, 2011) Remove during sleep, 8 days (2017); ≥2 days ≥480 min/day	Activity counts Vertical axis in 10-s epochs	≤100 cpm	101−1999 cpm	≥2000 cpm		
Active Smarter Kids[31]	AG GT3X+ Hip	Remove during sleep, 7 days; ≥4 days ≥480 min/day	Activity counts Vertical axis in 10-s epochs	≤100 cpm	101−2295 cpm	≥2296 cpm		

(*continued on next page*)

Table 2 (Continued)

Study	Device/placement	Wear protocol and valid wear-criteria	PA classification scheme	Definition of SED	Definition of LPA	Definition of MVPA	Definition of steps	Body posture/activity type classification included
Sweden								
Riksmaten Adolescents[35]	AG GT3X+ Hip	Remove during sleep, 7 days; ≥3 days, including ≥1 weekend day ≥500 min/day	Activity count Vertical axis in 5-s epochs	≤100 cpm	101−2295 cpm	≥2296 cpm		
ABC[34]	AG 7164 Back	Remove during sleep, 7 days; ≥4 days, including ≥1 weekend day ≥600 min/day	Activity counts Vertical axis in 60-s epochs	≤100 cpm	101−1951 cpm	≥1952 cpm		
SCAPIS[33]	AG GT3X+ Hip	Remove during sleep, 7 days; ≥4 days ≥600 min/day	Activity counts Vector magnitude in 60-s epoch; low-frequency extension	<200 cpm	200−2689 cpm	≥2690 cpm		

Abbreviations: ABC = The Attitude, Behaviour and Change study; AG = Actigraph; cpm = counts per minute; DANSDA = The Danish National Survey of Diet and Physical Activity; FINFIT = The FinFit Study; HBSC = Health Behaviour School Children; LPA = light-intensity physical activity; MAD = mean amplitude deviation; MVPA = moderate-to-vigorous physical activity; METs = metabolic equivalents; NNPAS = Physical activity among Norwegian children study; PA = physical activity; PANCS = Physical Activity Norwegian Children Study; SCAPIS = Swedish Cardiopulmonary Bioimage Study; SED = sedentary time.

reduction procedures allow for longitudinal analyses to follow temporal trends at the population level. In Denmark, recent nationally representative data have been collected in school children. So far, Sweden has no regular national surveillance system using device-based data collection, even though data are available from single surveys on adolescents and adults. No studies from Iceland met our definition of being nationally representative.

From an international perspective, the use of device-based surveillance of PA is still in its early stages, even though there are some examples of countries with a longer history. For example, Japan has tracked step counts in its population since 1995,[37] Canada has repeated surveys with accelerometers since 2007,[38,39] and the USA used accelerometers for the first time in the 2003−2004 National Health and Nutrition Examination Survey and again from 2011 to 2014.[40] In addition, several research projects with large prospective cohorts have reported device-based PA outcomes.[33] Regular surveillance with devices is one of WHO's strategic objectives to create a society that supports PA as a part of everyday life.[41] The recent development of device-based regular population surveillance of PA and sedentary behavior taking place in the Nordic countries, especially in Finland and Norway, is encouraging, even though there is still need for improvement and development.

We found an important knowledge gap regarding the youngest children: our search found no national surveys or other population-based studies on preschoolers. Given the importance of PA in early childhood and its role in shaping future habits and mitigating health risks related to sedentary behavior, this calls for attention.[1] Our results are consistent with those of a recent systematic review that concluded even though research in this area is rapidly growing, infants' and toddlers' movement behaviors remain understudied in terms of device-based measurement.[42] There are a few well-designed studies conducted in the Nordic countries using device-based assessments in preschoolers in relatively large samples, such as the Early Stockholm Obesity Prevention Project[43] and The Environmental Determinants of Diabetes in the Young[44] in Sweden and Finland, both of which target special populations (i.e., children at risk of obesity or type 1 diabetes), as well as geographically limited regional studies, such as the Preschool Physical Activity Study[45] and Active Learning Norwegian Preschool(er)s from the county of Sogn and Fjordane in Norway.[46] However, these studies were not included in our review because they were not designed to provide regionally or nationally representative data.

Further, we found no national surveillance or other population-based studies specifically targeting older adults. Even though we could extract data from 4 of the included studies, these sub-samples were relatively small. Due to the large health heterogeneity in aging,[47] there is a need for large population-based studies focusing on older adults to allow analyses of different age-groups. Although no study on older adults fulfilled our inclusion criteria, as they collected data from only 1 region, it is worth noticing that there are a few population-based Nordic studies on older adults using accelerometry: the Swedish National study on Aging and Care in Kungsholmen[48] and

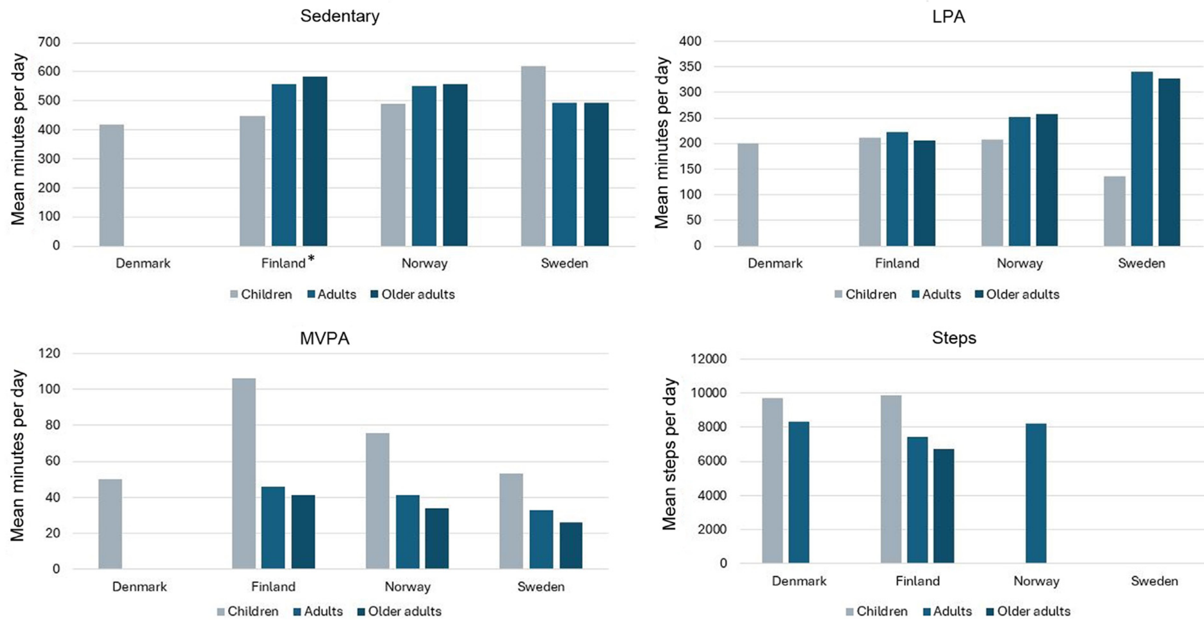

Fig. 2. Best estimates from each country of light-intensity physical activity (LPA), moderate-to-vigorous physical activity (MVPA) and sedentary time (SED) in minutes per day, and steps per day within the age-groups. * Excludes standing. Data on older adults were extracted from adult-focused studies. Definitions of intensity-specific physical activity, sedentary time, and steps/day are not standardized across studies and may limit comparability. Numbers are weekly averages reported in the most recent studies with national samples.[21,23,24,28,30,32,35,36]

Health Age Initiative,[49] the Norwegian Tromsø Study,[50] and the Age, Gene/Environment Susceptibility Reykjavik Study[51] from Iceland. Additionally, in 2019, the data collection started in a national population-based study of Finnish older adults but could not be completed due to the coronavirus disease 2019 pandemic; the next round is scheduled for 2025−2026.

The variety of devices, wear placement, and data procedures, both within and between the Nordic countries, highlight the difficulties of comparing study outcomes; as a result, Fig. 2 must be interpreted with some caution. In Finland, the national surveillance systems have chosen a 24-h wear protocol, with devices placed on the hip during waking hours and on the wrist during time in bed. The physical activity outcomes reported are both intensity- and activity-based (sitting, standing, and steps), and it should be noted that the Finnish studies present a measure of LPA where time spent standing has been removed based on accelerometer orientation. In Denmark, the national surveys have focused on thigh worn devices reporting activity-based outcomes such as sedentary, standing, walking, and cycling, or daily steps. In the studies from Norway and Sweden, the same type of hip-worn device (ActiGraph) has been used with intensity-based outcomes deriving from activity "counts". However, differences in vertical axis cut-points chosen or the use of vector magnitude outcomes make comparisons challenging even between studies using the same device.

Each choice of device, placement, and algorithms for interpretation of the data has advantages and disadvantages, and it is unlikely that there will be a consensus on the best approach. Despite these differences, recent accelerometers collect high-resolution data from 3 axes and can provide raw data, which may allow for future harmonization and improved comparability across studies.

Given the limitations related to different methodologies in the included studies, we chose to report steps per day in addition to the time (min/day) spent sedentary and in PA intensities. Step count is an outcome less hampered by differences in types of devices and data processing and can be reported both from hip-worn and thigh-worn devices. Daily step count is also a measure easy to communicate and a good indicator of total activity, even though it does not give information on intensity. Additionally, there is growing evidence linking steps per day to several health outcomes in a dose−response relationship.[52,53] The available data on steps per day for adults from Denmark, Finland, and Norway show similar estimates between the Nordic countries and slightly higher estimates than worldwide data from smartphone applications.[54]

Concerning the methodological quality of the included studies, several issues need to be discussed. Many of the national samples were relatively small ($n < 1500$) with low participation rates (∼40%), which hampers their representativeness and does not leave much room for subgroup analyses by characteristics, such as levels of education, health-status, or geography. Missing data in device-based surveys seem to be a bigger issue than in ongoing health surveys with self-reported PA.[55] Only a few studies describe handling of the missing data using appropriate methods, such as statistical weighting. The sampling approach can affect the participation rate, and in some studies the participants had to come to a clinic for an examination, which may be less feasible than mailing. On the other hand, it has been suggested that in-person distribution of devices can ensure correct and comfortable attachment, thus improving adherence.[56] In-person distribution may also enable assessment of participants' cardiorespiratory fitness level, which is known to greatly influence relative PA levels compared to absolute levels and, thereby, influence adherence to PA guidelines.[16] Additionally, it must be recognized that there is a risk of selection bias in population-based surveillance that may affect the generalizability of device-based PA data. Individuals who agree to participate in studies and wear activity monitors may be healthier and more active than the general population,[57] and the activity levels in the included studies may, therefore, be a “best case scenario”.

Key strengths of this scoping review are the systematic search strategy according to an *a priori* protocol and the assessment of eligibility of studies done in duplicate by 2 independent authors to reduce the likelihood of bias in study selection. Another strength is the composition of the author team. The authors represent 4 of the 5 Nordic countries, and all authors have experience conducting population-based studies. This enabled the use of national networks and records to identify unpublished relevant data sources, such as reports published in a Nordic language in addition to English-language articles from the database search.

5. Conclusion

A growing implementation of device-based population surveillance of PA and sedentary behavior in the Nordic countries has been identified. The variety of devices, placement, and data procedures both within and between the Nordic countries highlights the challenges with respect to comparing study outcomes. The available data from recent population surveillance in the Nordic countries show similar estimates of steps per day, and the mean level of moderate or higher intensity PA is above the current recommendations for health benefits while the amount of sedentary time is high in all countries. Although it is obvious that countries will maintain their current surveillance systems (accelerometers, place of device, algorithms to analyze acceleration), a more standardized data collection process is needed, including a setup for large pan-European surveillance of PA and sedentary time using device-based measures.

Authors’ contributions

IMD designed the review and drafted the manuscript, screened records, extracted data, and interpreted results; JT helped design the review, conducted the searches, screened records, extracted data, and drafted part of the manuscript; JSJ helped design the review, screened records, extracted data, and revised the manuscript; TV extracted data and revised the manuscript; MH designed the review, screened records, extracted data, drafted part of the manuscript, and interpreted results. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

Supplementary materials

Supplementary materials associated with this article can be found in the online version at doi:10.1016/j.jshs.2024.04.003.

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