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Utilization and Harmonization of Adult Accelerometry Data: Review and Expert Consensus

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Short title: Utilization & Harmonization of Monitor Data

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CONFLICTS OF INTEREST

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ABSTRACT

Purpose: To describe the scope of accelerometry data collected internationally in adults; and, to obtain a consensus from measurement experts regarding the optimal strategies to harmonize international accelerometry data. **Methods:** In March 2014 a comprehensive review was undertaken to identify studies that collected accelerometry data in adults (sample size N ≥400). Additionally, twenty physical activity experts were invited to participate in a two-phase Delphi process to obtain consensus on: unique research opportunities available with such data; additional data required to address these opportunities; strategies for enabling comparisons between studies/countries; requirements for implementing/progressing such strategies; and, value of a global repository of accelerometry data. **Results:** The review identified accelerometry data from >275,000 adults from 76 studies across 36 countries. Consensus was achieved after two rounds of the Delphi process; 18 experts participated in one or both rounds. Key opportunities highlighted were the ability for cross-country/cross-population comparisons, and the analytic options available with the larger heterogeneity and greater statistical power. Basic socio-demographic and anthropometric data were considered a pre-requisite for this. Disclosure of monitor specifications, and protocols for data collection and processing were deemed essential to enable comparison and data harmonization. There was strong consensus that standardization of data collection, processing and analytical procedures was needed. To implement these strategies, communication and consensus among researchers, development of an online infrastructure, and methodological comparison work were required. There was consensus that a global accelerometry data repository would be beneficial and worthwhile. **Conclusion:** This foundational resource can lead to implementation of key priority areas and identifying future directions in physical activity epidemiology, population monitoring and burden of disease estimates. **Key words:** accelerometry, adult, global, physical activity, sedentary, pooling, sensor

INTRODUCTION

Regular participation in moderate- to vigorous-intensity physical activity has well established benefits for both physical and mental health (49). More recently, the detrimental health impacts of sedentary time (too much sitting) (68), and the potential benefits of light intensity activities have been identified (43, 51). These advances in understanding activity across a broadened and more differentiated spectrum have, in large part, been due to advances in activity monitor technology (48), which address several of the limitations associated with self-report measures (21). Wearable, accelerometer-based activity monitors that collect date and time stamped posture and/or activity information are becoming increasingly available and affordable. Correspondingly, they are becoming more widely used in observational (including surveillance) and intervention studies as a measure of physical activity and sedentary time *levels* (i.e. total volumes). Furthermore, the time resolution of data collected from such devices has also provided important insights into the accumulation *patterns* of physical activity and sedentary time across the day.

Most of these insights have so far been gained from individual studies. Analysis of pooled international accelerometry data (plus other relevant variables) may, however, facilitate more in-depth understanding of (a) the levels and patterns of activity across the intensity spectrum; (b) the impact of physical activity, physical inactivity and sedentary time on physiological, psychological, and health outcomes; (c) the correlates and determinants of these behaviors; and, (d) how these levels and patterns, health associations, and correlates and determinants, as described above, may vary between sub-groups and populations. For brevity, from here onwards the terminology "physical activity" and "activity" will be used as umbrella terms to cover the whole spectrum of physical activity variables (including the whole intensity spectrum from sedentary, through to light-, moderate- and vigorous-intensity activity).

In 2008 the International Children's Acceleromtery Database (ICAD) project (http://www.mrc-epid.cam.ac.uk/research/studies/icad/) was launched which, for the first time, pooled Actigraph (Actigraph LLC, Pensacola, FL) accelerometry data (epoch-level) and harmonised accompanying data on children 5-18 years (63). The database, which holds information on ~26,000 children from 20 studies worldwide, has allowed new analyses to generate a clearer understanding of predictors of activity, activity-disease associations and the types and levels of activity that should be promoted to maximize health benefit (e.g. (22, 47)). The ICAD project shows that international groups are prepared to collaborate and share data in a pooled archive, with data access procedures in place following submission of analysis proposal, open to all researchers in the world. This project has also provided insights into some of the benefits (e.g. large sample sizes and increased heterogeneity in activity and accompanying data) and challenges (e.g. varying protocols and measures for the activity or accompanying data) associated with such pooling efforts. Researchers have now expressed an interest to extend pooling to include adults, different accelerometer models/versions and a broader range of accompanying data (including data relating to correlates, determinants and health outcomes, as well as to the accelerometer technology and study design).

However, differences between monitor types, models, calibration methods, attachment procedures and wear locations, deployment strategies, monitor setup, and data processing procedures of existing studies, together with further developments in measurement methodology, pose evolving challenges in this research field (48). To better understand and to begin to address these challenges, this article reports on:

A. a comprehensive review describing the scope of accelerometry data collected internationally in adults; and,

B. an expert consensus, via a two-phase Delphi process, regarding optimal strategies to harmonize international accelerometry data.

It is intended that the data reported in this article will provide a foundational resource for implementing key priority areas and identifying future directions for pooling and harmonizing accelerometry data, which could substantially progress the field of physical activity epidemiology.

PART A: Comprehensive Review

The first part of this manuscript provides the results of a comprehensive review, reporting on the amount of accelerometry data collected internationally in adults, the types of monitors used, the wear location, the study designs, the sampling frames and other study-specific information.

METHODS

Search strategy: Three different search strategies were employed. A PubMed electronic literature database search was undertaken on the 7th March 2014, using the search syntax "acceleromet* AND adult* AND physical activity". Second, authors' own literature databases were screened for publications which matched the inclusion criteria but were not identified from the PubMed database search, as was authors' knowledge of unpublished studies with completed or on-going data collection.

Inclusion and exclusion criteria: Studies that used an accelerometer-based activity monitor that measured activity across the movement intensity spectrum with a sample size of N ≥400 adults (18+ years) were eligible to be included. We excluded: non-human studies; studies with a mean age <18 years; non time-stamped pedometer (steps-only) studies; heart-rate monitoring only studies; studies which purposely recruited a specific population (i.e. populations with functional or cognitive limitations, pregnant women, military and athlete groups, students, and patients [studies involving overweight/obese adults and those at high risk for diabetes were included]); methodological studies (i.e. reliability, validity and feasibility studies); laboratory studies; sleep only studies; and, studies not relating to physical activity.

Data extraction: Data were extracted using a standardized form which included study name, country, monitor type/model, anatomical site worn, N, age, gender, study design, sampling frame/strategy and timing of data collection. For multi-phase studies, only data of the first phase providing accelerometry data were extracted. In cohorts with an age range covering childhood/adolescence and adulthood the total age range was provided, but N was derived for adults only, given the focus of this review. When needed, more than one information source was used per study, to enable complete data extraction. For studies sourced from published documents, any information not provided in the corresponding document was determined by contacting the corresponding author. Data extraction from published manuscripts were performed by one author (K.Wi.) and double-checked by a second author (G.N.H.). Included studies were stratified into national population-based studies and other (which includes non-national population-based studies, birth or twin studies, intervention studies, and case-control studies).

RESULTS

Supplemental Digital Content Table 1 provides an overview of all 76 included studies providing accelerometry data in adults. [See Table, Supplemental Digital Content 1, Overview of all identified studies with accelerometry data in adults, http://links.lww.com/MSS/A531.] Sixty one published studies were identified, with 39 of these identified via the PubMed literature database search, and 22 sourced from authors' literature databases (some of them published after the 7th March 2014). Fifteen additional studies were identified through authors' knowledge of studies in progress.

The 76 included studies represented studies in 36 different countries, across 6 different continents (Africa (5), Asia (4), Europe (21), North America (3), Oceania (2) and South America (1)). This is illustrated in Figure 1. Here, countries with national population-based cohorts are represented in dark grey, whereas countries with any other study types (non-national population-based, birth and twin cohorts and other) are represented in light grey. Globally, accelerometry data are/will be collected in >275,000 adults. Sixteen percent of this total participant number is available from national population-based cohorts (Canada, Greenland, Hong Kong, Norway, Portugal, the UK, the US and Sweden). [See Table, Supplemental Digital Content 1, Overview of all identified studies with accelerometry data in adults, http://links.lww.com/MSS/A531.]

As shown in Figure 2a, over one third (38%) of the global pool of 277,370 adults with accelerometry data was collected using the Axivity accelerometer (Axivity Ltd, UK), with nearly one third (30%) using different versions of the Actigraph accelerometer, followed by smaller contributions from the Actiheart (CamNtech Ltd, UK), Actical (Philips Respironics, USA), activPAL (PAL Technologies Ltd, UK), and GENEActiv (Activinsights Ltd, UK) monitors. When considered by studies using the monitors (Figure 2b), more than half (51%) of studies have used an Actigraph activity monitor, with 16% using the Actiheart montor and 12% using the Actical monitor. Other monitors, including the Axivity accelerometer, were used in a minority of studies. A range of different anatomical positions have been used, including variations within monitor type (e.g. the Actigraph monitor which was worn on the hip, waist, lower back, and wrist). [See Table, Supplemental Digital Content 1, Overview of all identified studies with accelerometry data in adults, http://links.lww.com/MSS/A531.]

SUMMARY

In summary, this comprehensive review highlights the enormous scope and potential of accelerometry data available, with data from >275,000 participants across 76 studies (with ≥400 participants) and 36 countries. North-America, Europe and Oceania are well represented in terms of available accelerometry data. Most other regions are less well represented and investment in data collection in these regions will be important to understand variations between populations. Other important opportunities for future accelerometry data collection include an expansion in terms of nationally representative cohorts, which are currently only available for North-American, some European countries and Hong Kong, as well as follow-up of these national cohorts, which is currently lacking.

The analytical opportunities available with these data (both historic and in future data collections) along with the short- and long-term priorities, steps to take advantage of these opportunities, and ways to harmonize this diversity of data are discussed in Part B: an expert consensus on the harmonization of accelerometry data.

PART B: DELPHI SURVEY. Consensus from an international expert panel on the harmonization of international physical activity data derived from accelerometer-based activity monitors.

In October 2012, an invitation-only meeting was held at the 4th International Congress on Physical Activity and Health (ICPAPH; Sydney, Australia) to discuss the potential opportunities to utilize the increasing amount of accelerometry data being collected internationally. As a result of that meeting (13 attendees from five countries), it was decided to run a Delphi process with the aim to achieve expert consensus on the harmonization of internationally-available accelerometry data.

METHODS

Participants: Twenty researchers (see Table, Supplemental Digital Content 2, Alphabetical list of the twenty individuals with recognized expertise in physical activity monitoring, epidemiological studies, surveillance, advocacy, and/or measurement expertise, who were invited to participate in the Delphi survey, http://links.lww.com/MSS/A532.) with recognized expertise in physical activity monitoring, epidemiological studies, surveillance, advocacy, and/or measurement expertise were invited to participate in the survey.

Process: The Delphi expert consensus process consisted of two rounds. Both rounds were administered via an online questionnaire (Limeservice: https://www.limeservice.com/en/). Consistent with Delphi principles (16, 38), responses were anonymous.

Round 1: In Round one, experts were given a brief overview of the aims of the study (as presented in the introduction) and were then asked to provide responses to the following five open-ended questions. They were also given the opportunity to provide any additional comments or observations in regard to the survey.

1. *What do you consider to be the unique research opportunities for utilizing the large amount of internationally available activity monitor data?*
2. *Which additional data (i.e. other than activity monitor data) would this require?*
3. *What strategies do you think will be effective in enabling comparisons of activity monitor data between studies/countries, both for historical and future data collection?*
4. *What may be required to implement or progress such strategies?*
5. *Do you think that the development of an International Activity Monitor Database (IAMD), i.e., a global repository of objectively measured activity monitor data, would be a worthwhile/valuable investment? If no, please clarify. If yes, what would be the additional value of the IAMD?*

Answers from the first round were then collated and summarized (K.Wi., S.S., G.N.H.), and used to form the second online survey (Round 2).

Round 2: In Round two, experts were asked to comment on the summary of the responses from Round 1, and, as appropriate, rank the responses provided in order of priority. Based on the responses provided, it was considered that no further rounds were required.

Ethics

The Delphi study was approved by The University of Queensland School of Population Health Ethics Committee (Australia). Participants were provided with information about the study and consent was required prior to commencing the survey. All experts who participated in the process were invited as co-authors.

RESULTS

Characteristics of the expert panel

An overview of the characteristics of the expert panel is provided in Table 1. In Round one, 14 experts participated, in Round two, 16 experts participated, with 12 experts providing data for both rounds, and 18 experts participating in either round.

Findings from the Delphi Process

1. Unique research opportunities for utilising the large amount of internationally available activity monitor data

The two key themes highlighted by the expert panel were the ability for cross-country/cross-population comparisons, and the analytic opportunities available with the larger heterogeneity and the greater statistical power. More specifically, the unique research opportunities for utilising the large amount of internationally available accelerometry data, as agreed by absolute consensus (100% of experts), were identified as:

- The estimation and comparison of the prevalence of physical activity (levels and patterns), as well as trends over time (surveillance), around the world and in different contexts, including in populations that are typically under-represented.
- More statistically powerful etiological analyses on dose-response associations with health outcomes, including: detection of more subtle associations; consistency of associations across populations; and, gene-environment interactions.
- More comprehensive and powerful analyses of the correlates/determinants of physical activity and identification of target groups for future intervention.

2. Collection of data in addition to the accelerometry data

In the first round of the Delphi survey, the participant responses regarding the additional data that should be collected in addition to the accelerometry data fell into nine different categories.

During the second round, participants were asked to indicate which of these categories they considered essential to be included in data pooling. For any categories deemed non-essential, participants indicated the level of scientific priority and feasibility of harmonization. Table 2 provides an overview of all nine categories, with categories presented in order of priority (i.e. most essential listed first).

In summary, there was strong agreement on the necessity of basic socio-demographic and anthropometric data, and the majority of participants also rated health status and occupational classification data as essential to pool. Half or less than half of participants deemed data on death registration, cardio-metabolic profile, function (physical, cognitive, fitness), the environment, and biological tissue sample data as essential. However, while these items were deemed non-essential, participants rated their scientific priority as relatively high (median ≥3 for each category), indicating that adding these data would be of significant value. The dependence between data necessity and research aims was raised, with surveillance applications generally requiring less information to be pooled. Most items rated as highly essential were perceived to be relatively feasible to harmonize between studies. In contrast, participants indicated that less essential items may be less feasible to harmonize and pool. Notably, the questions relating to scientific priority and feasibility of harmonization (for data which was considered non-essential) were not compulsory, and therefore not all experts provided responses for these (Table 2). For categories such as death registry information, differences in data quality between countries/studies were acknowledged as a consideration. Other categories, such as environmental data, were rated as non-feasible given the high volume of work required to process and harmonize such data. Cost and potential deterrence of studies participating in a pooling effort were other salient characteristics raised, especially for categories such as biological tissue sample data.

3. *Effective strategies enabling comparisons of activity monitor data between studies/countries*

In general, there was a strong consensus that standardization of monitor calibration, data collection, data processing and data analytical procedures are needed. Disclosure of monitor information, and protocols for data collection and processing were deemed essential to enable comparison, with access to raw (i.e. unprocessed waveform) data preferred.

3a. Historically collected data

Following responses from the first round of the survey, two different approaches were broadly proposed for historically collected data, specifically:

1. Centralized re-processing of the highest resolution of data with uniform methodology based on a developed consensus.
2. De-centralized re-processing by the original researchers on their own data with uniform methodology, relative to the different research questions of interest and meta-analysis of results.

Participants were asked which approach was preferable and why. As shown in Table 3, the vast majority of experts preferred centralized re-processing of data, followed by a preference for a mixed approach (i.e. providing either option for the researcher), then for de-centralized data reprocessing. Table 3 also summarizes the perceived benefits, caveats and facilitating utilities needed for each of the proposed approaches, as indicated by the experts.

Four additional strategies were identified as important for enabling comparisons of the historically collected data. In order of priority, these were:

1. the availability of raw signal data instead of proprietary data processing and outputs (e.g. “counts”), where possible (and transparency where not);
2. development of criteria to determine which types of monitor data can be pooled;
3. disclosure of data collection protocols; and,
4. standardization of cut-points within each monitor type/model.

3b. Future data collection

The panel (n=16) identified five main strategies to enable comparison of monitor data collected in the future. The two main priorities identified were:

- the development, public availability and ensured implementation of standardized protocols, tools and analytical methods; and,
- the use of raw signal data (rather than outputs resulting from proprietary data processing).

Secondary priorities identified were:

- obtaining better wear compliance;
- ensuring data collection in representative samples; and,
- convergence in terms of monitor types used.

4. Requirements for implementation of these strategies

In general, three key requirements for the implementation of these strategies were highlighted:

- communication and consensus among researchers;
- the development of an online infrastructure; and,
- methodological comparison work.

For the *online infrastructure*, user-friendliness and high-speed access; capacity to host a database (with adequate data storage space) and data sharing agreements; and, capacity for centralized data processing and analysis, were identified as potentially important characteristics. Modifying or adapting existing accelerometry data processing systems (e.g. MOVE-e-Cloud [Newcastle University, UK], DataSHaPER [http://www.datashaper.org], MeterPlus [Santech Inc, USA], KineSoft [KineSoft, Loughburough, UK: http://www.kinesoft.org]), which are already available or in development was generally preferred, as this was deemed more efficient, robust and financially viable.

For *methodological comparison work*, standardization and harmonization of methods and procedures for data collection, processing and analysis were deemed important. The following two components were highlighted as key requirements:

- Convergent validity studies (particularly free-living) to establish models to equate outputs from different monitors, anatomical sites, decision rules, etc. A global web-based dashboard is needed to map what has been done and what needs doing, as this is work in progress.

- An international consensus process, potentially in the form of an International Taskforce, to define, publish and publicize internationally agreed standards for collection and processing of data.

Strong support was identified for the organization of an international consensus to set standards as mentioned above, acknowledging that this would be a worthwhile but challenging process. Considerations raised included the necessity of scrutinising agreed standards before implementation to ensure they result in valid activity parameters, to allow for multiple standards for different purposes, to involve a sufficiently wide range of experts, to avoid overly strict standards imposing on researchers' creativity and to ensure that standards are updated to keep pace with changing technology.

Participants indicated that convergent validation research would benefit from a well-structured approach, potentially in the form of a separately funded programme of coherent and coordinated studies. A global web-based dashboard would need to clearly characterize the knowledge already gathered; including quantification of uncertainty, as well as what is still unknown. Some participants anticipated that the potential increase in the use of wrist-worn monitors collecting raw acceleration signals may diminish the need for convergent validity studies in the future.

5. ***Value of an International Activity Monitor Database (IAMD), i.e. a global repository of objectively measured activity monitor data***

There was full (100%) consensus that an International Activity Monitor Database (IAMD) would be beneficial and worthwhile, but that the success of this would be dependent on several factors, including:

- the development/existence of strong international standards for data collection, management, and analysis which are published and easily accessible;
- sufficient quality control, and good governance;
- perception from data contributors that their contribution is worthwhile; and,
- perception that the benefits for researchers in general are greater than the resources required to develop an IAMD.

5a. Priorities and aims of an IAMD

Three key *short-term priorities* were proposed:

1. The development of goals and strong international standards and protocols for data collection, management, analysis and quality assurance. This could be facilitated through a working group holding consultations at various international conferences.
2. Securing funding to start with a demonstration project involving a limited number (e.g. 10) of studies/countries involved, which has a relatively simple objective as a proof of principle, before increasing complexity. Such a demonstration project could, for example, only include a few accelerometry brands and primarily focus on mapping between those.
3. Commence examination of the equivalence between monitors, anatomical sites, etc., as well as harmonization of variable naming conventions.

Four key *long-term priorities* were proposed:

1. Securing the funding to support an IAMD and to ensure its long-term sustainability.
2. Creating a widespread appreciation among researchers of the importance of following the international standards and protocols for data collection, management, analysis and quality assurance, as developed in the short term, and of providing their data to an IAMD. This could be facilitated by ensuring easy data access for investigator-driven research use, such as in the NHANES dataset (http://www.cdc.gov/nchs/nhanes.htm).
3. Building international capacities and recruiting multiple countries, following examples such as the International Physical Activity and the Environment Network (IPEN) project (44).
4. Keeping a strong emphasis on quality control throughout this process.

Several potential mechanisms were suggested to enable high quality control and wider scrutiny of the whole process. These included utilities to ensure easy accessibility to the internationally established standards and protocols; the development of minimum criteria for information sharing at each level of the process (e.g. logs of routine calibration checks for raw data); sharing information and protocols (e.g. syntaxes) in the public domain; and setting up a data monitoring council. Methodologically, moving on to more generalized inference on body movement including all accelerometry data was considered a long-term priority. Other types of bio-signals (such as temperature, heart rate, breathing etc.) could be included in the inference of generalized body movement information in the long run, to keep up with new measurement approaches.

5b. *Potential funding sources for an IAMD*

Short-term funding

A variety of potential sources were identified by participants as options for short term funding. These included national funding bodies, some of which provide specific international network/collaboration grants, such as the Wellcome Trust (UK), Bupa Foundation (Australia), US National Institutes of Health, the Leverhulme Trust (UK), Economic and Social Research Council (ESRC, UK) and large philanthropic groups. Funding from individual countries as well as international funding sources, such as European project funding and the World Health Organization, were also proposed. The possibility of partial cost absorption by local departments in the initial stages was suggested as well. Finally, as many funders typically do not like to fund international studies, the idea to focus the IAMD database to a certain health outcome to increase attractiveness to specific funders was also brought forward.

Long-term funding

In general, suggestions for *long-term funding* predominantly involved international funding bodies, some of which focus on advancing global health, such as the World Health Organization, the NIH Fogarty International Center, the United Nations, the European Union, large philanthropic groups, as well as international consortia of research councils, with industry funding being another proposed candidate.

5c. *Governance of an IAMD*

Other large international projects, including multi-country self-report data collection initiatives, were recommended as important models to follow when organising an IAMD (e.g. International

Physical Activity Questionnaire (IPAQ, https://sites.google.com/site/theipaq/); WHO STEPS chronic disease risk factor surveillance and the Global Physical Activity Questionnaire (GPAQ, http://www.who.int/chp/steps/en/index.html)). An important common element in each of these projects is that they involve substantial manpower and require a dedicated team of full time staff. Securing funding for a Coordinating Centre which provides sufficient resources and support staff was therefore suggested. In addition, installation of an Advisory Board, consisting of a strong group of high-level, well-connected experts, to oversee the development of the IAMD was proposed. In general, the governance structure would need representation of researchers from multiple countries involved. Capacity building resources enabling face-to-face meetings were recommended as they may provide a lot of momentum to the project.

DISCUSSION

This article reported on the findings from a comprehensive review describing the scope of accelerometry data collected internationally in adults, as well as conclusions from an expert consensus regarding the most optimal strategies to harmonize international accelerometry data.

The review – which included data from both published and ongoing studies – highlighted the now considerable amount of accelerometry data available internationally, with data collected from >275,000 participants across 36 countries. As such, it provides an important resource for identifying not only opportunities with the existing data, but also evidence gaps which could direct future data collection priority areas/countries. The review also highlighted the multitude of accelerometer-based activity monitors, models, and attachment procedures used across studies.

Of note is that although comprehensive, it was not a systematic review and it is possible that relevant studies may have been missed.

The expert consensus provided strategies and short- and long-term priorities, as well as potential funding sources for addressing the current challenges in comparing the data across studies and populations. A key strength of the consensus was the inclusion of experts (median of 18 years of expertise in physical activity) across a diverse range of physical activity interest areas. However, it should be noted that not all experts in the field were contacted for inclusion in the Delphi process, which may have resulted in some key considerations, strategies, priorities, and/or funding sources being misrepresented in terms of priorities or even remaining unidentified. For example, one consideration not made explicit during the Delphi process is the wide variety of calibration procedures that have been used for different monitor types (e.g. locomotion calibration, multiple activity type calibration) – the majority of which are laboratory-based studies, with some studies using free-living protocols. Harmonization of existing data without re-processing will require the use of scoring approaches that were derived from the same type of calibration studies.

Notably, some of the strategies identified through the consensus are already occurring. This includes data pooling (such as in the International Children's Accelerometry Database: ICAD (63) and the DEDIPAC European knowledge hub: https://www.dedipac.eu/); and, standardization (such as through the Sensor Methods Collaboratory (70), the Sittonomy (9)), and the Database of Genotypes and Phenotypes (dbGaP: http://www.ncbi.nlm.nih.gov/gap). Given the rapid evolution of both monitor technology and methodology, regular revision (e.g., every three years) of the key priorities and most optimal strategies to harmonize international accelerometry data is recommended.

In summary, the accelerometry data collected across the globe provides a key opportunity to further understand the distribution, determinants, health impacts and burden of disease for physical activity across the intensity spectrum, as well as how these may vary between sub-groups and populations. By identifying the scope of the data available, and obtaining an expert consensus on the strategies, priorities, and potential funding sources, this article provides a foundational resource to maximize this opportunity.

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CONFLICTS OF INTEREST

The results of the present study do not constitute endorsement by the American College of Sports Medicine. Dale Esliger is Founder and CEO, KineSoft, accelerometry analytics software; Steven N. Blair is supported by unrestricted research grants to the University of South Carolina from The Coca-Cola Company, Body Media, and Technogym; Malcolm Granat is Director of PAL Technologies Ltd, Glasgow, UK; Soren Brage is an advisor for UK Biobank.

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FIGURE LEGENDS:

Figure 1. Global overview of countries with accelerometry data (N ≥400) in adults. Countries with national population-based cohorts are represented in dark grey (all with N >1000), whereas countries with any other study types (i.e. non-national population based, birth and twin cohorts and other) are represented in light grey.

Figure 2: Contribution by sample size (A) or by study (B) of the different monitor types to the global pool of accelerometry data.

Supplemental Digital Content Table 1. Overview of all identified studies with accelerometry data in adults.

Supplemental Digital Content 2: Alphabetical list of the twenty individuals with recognized expertise in physical activity monitoring, epidemiological studies, surveillance, advocacy, and/or measurement expertise, who were invited to participate in the Delphi survey.

Figure 1

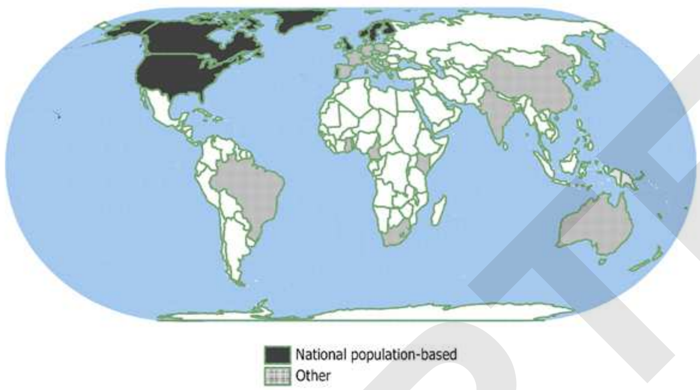

Figure 2

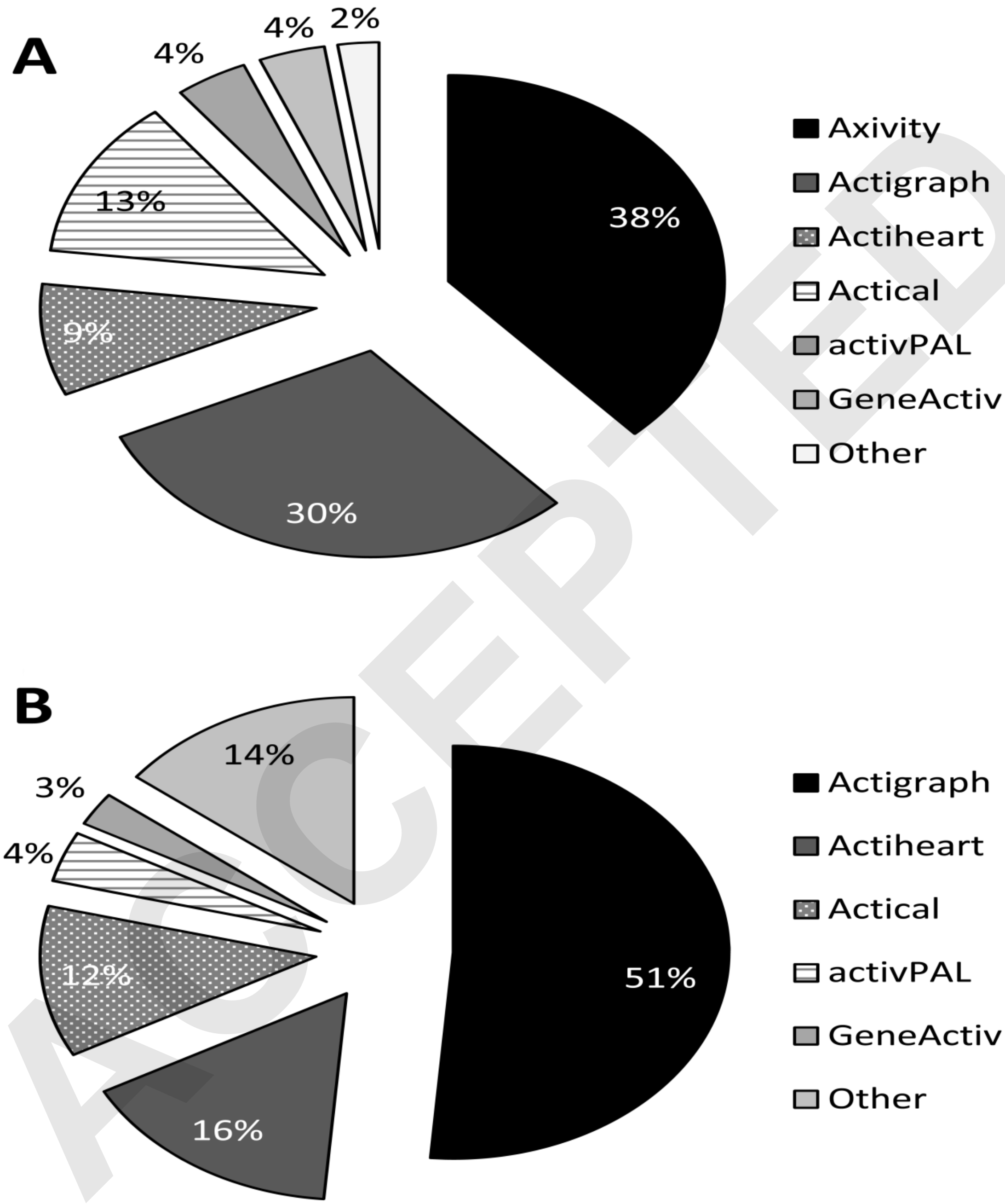
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Table 1: Characteristics of the 18 experts who contributed to either Round 1 or Round 2 of the Delphi Process

Characteristic	**%, or median (range)**
Women, %	14.3%
Institutional location, %	
United Kingdom	35.7%
United States	28.6%
Australia	21.4%
Other	7.1%
Research Field (multiple choices allowed)*, %	
• Measurement	80%
• Epidemiology	73%
• Interventions	73%
• Policy	26%
• Other	53%
Years as physical activity researcher, median (range)*	18 (5 to 40)

*data only available for 15 participants

Table 2: Additional data, other than accelerometry data, required (most essential listed first)

Additional data	Proportion of participants who deemed this information essential (%; n=16)	When not deemed essential [a]	
		Scientific priority (median; 1=low; 5=high)	Feasibility of harmonization (median; 1=low; 5=high)
Basic socio-demographic data such as age, sex, race/ethnicity, country, and socio-economic status (i.e. income, education, employment status)	94%	/	/
Anthropometric data (i.e. weight, height, waist circumference)	88%	4 (n=1)	4 (n=1)
Health status data (i.e. diabetes, cardiovascular disease, cancer)	75%	4 (n=1)	4 (n=1)
Occupational classification data (i.e. type of occupation)	63%	3.5 (n=2)	4 (n=1)
Death registry information/cause of death data	50%	3.5 (n=2)	2 (n=2)
Cardio-metabolic biomarker data (i.e. blood biomarkers, blood pressure)	44%	4 (n=5)	3.5 (n=4)
Data on function (i.e. physical, cognitive, fitness)	31%	4 (n=4)	2.5 (n=4)
Built environment / Geographic Information Systems (GIS) data	19%	4 (n=7)	2 (n=7)
Biological tissue sample data (other than blood samples)	6%	3 (n=8)	2 (n=7)

[a] Questions on scientific priority and feasibility of harmonization were only asked if the information was deemed non-essential. These latter two questions were not compulsory: the lower n's for some responses indicate the degree of missing data.

Table 3: Preferred approach, and perceived benefits and caveats of the approach, as well as utilities needed to enable comparisons of historically collected accelerometry data (N=16)

	Centralized	**De-centralized**	**Mixed approach**	**No opinion**
Percentage	63%	13%	19%	6%
Perceived benefits	• Uniformity and standardization of methodology • Higher feasibility • More robust quality control • More time-efficient • Flexibility in terms of re-processing (i.e. no additional burden on participating studies)	• Flexibility in terms of additional/novel variable output • More realistic	• Tailoring to data sharing preference of data owners - i.e. enabling inclusion of studies experiencing issues with sharing of raw data • Tailoring to data complexity – e.g. “counts” only data (with lower data volume transfer) would enable centralized approach	/
Perceived caveats	• Detail in methodology not taken into account • Methodological standard not evolving with improvements in monitor methodology • Too great of a constraint on research process (e.g. if output measures are specific to certain research questions, or novel ways of data	• Lower quality control • No funding for processing, so big burden of voluntary work • Lack of transparency in processing decisions	• Only feasible if processing approach can be implemented consistently between studies using the centralized and non-centralized approach	/

	analysis develop which were not anticipated in initial centralized processing) • Substantial man-power needed			
Facilitating utilities needed	• Cloud-computing to enable large dataset transfer	• Provision of processing protocols and codes/tools for uniform de-centralized processing (e.g. via internet or supplementary information in papers)	• Provision of processing protocols and codes/tools for uniform de-centralized processing (e.g. via internet or supplementary information in papers)	/

Supplemental Digital Content Table 1. Overview of all identified studies with accelerometry data in adults

Study name & source	Country	Monitor type	Anatomical site worn	N [a]	Age	Gender	Study design	Sampling frame/strategy	Year collected
National population-based studies									
Experience of the Reasons for Geographic and Racial Differences in Stroke (REGARDS) Study Source: Howard et al. (37), Lee et al. (48)	US	Actical	right hip	9422	≥56	both	cohort	subsample of original national, population-based REGARDS cohort (2003-2007), which consisted of 30239 Blacks and Whites, aged >45, from communities across all 48 of the lower US, including residents of 1855 of the 3033 US counties	2009-2013
National Health and Nutrition Examination Survey (NHANES) 2011-2012 Source: http://www.cdc.gov/nchs/nhanes.htm	US	Actigraph GT3X+	wrist	~5300	≥18	Both	cohort	Non-institutionalized civilian population; multistage stratified probability design.	2011-2012
National Health and Nutrition Examination Survey (NHANES) 2013-2014 Source: http://www.cdc.gov/nchs/nhanes.htm	US	Actigraph GT3X+	wrist	~5300	≥18	Both	cohort	Non-institutionalized civilian population; multistage stratified probability design.	2013-2014
National Health and Nutrition Examination Survey (NHANES) 2005-2006 Source: Tudor-Locke et al. (71)	US	Actigraph 7164	hip	3744	≥6	both	cohort	US civilian, non-institutionalized population, complex multistage probability design	2005-2006
/ Source: Hansen et al. (32)	Norway	Actigraph GT1M	hip	3267	20-85	both	cohort	Norwegian population registry	2008-2009
NHANES 2003-2004 Source: Troiano et al. (69)	US	Actigraph 7164	hip	3088	≥6	both	cohort	US civilian, non-institutionalized population, complex multistage probability design	2003-2004
Canadian Health Measures Survey (CHMS) Source: Colley et al. (12)	Canada	Actical	hip	2832	6-79	both	cohort	household based (15 sites across Canada)	2007-2009

Health Survey for England 2008 (HSE 2008): Source: Aresu et al. (1)	UK	Actigraph GT1M	waist	2339	≥4	both	cohort	English population living in private households, multi-stage stratified probability design: accelerometry in random subsample of HSE 2008	2008
/ Source: Baptista et al. (5)	Portugal	Actigraph GT1M	hip	1982	≥10	both	cohort	Portuguese non-institutionalized population, stratified random sampling	2006-2008
Health 2011 Survey Source: Husu et al. (39)	Finland	Hookie AM 20 (Traxmeet, Ltd)	waist	1863 (1589 with 4+ days)	18-85	both	cohort	Physical activity subsample of Health 2011 Survey	2011
Hong Kong Jockey Club FAMILY Project Cohort Source: Lee et al. (50)	Hong Kong	Actigraph GT1M	waist	1740	≥15	both	cohort	household based, random selection of residential addresses provided by Hong Kong Census and Statistics Department	2009-2011
Inuit Health in Transition Study Source: Dahl-Petersen (15)	Greenland	Actiheart	chest	1545	≥18	both	cohort	stratified random sample of Greenland adults aged ≥18	2005-2010
Attitude Behaviour and Change Study (ABC Study) Source: Hagstromer et al. (30)	Sweden	Actigraph 7164	lower back	1114	18-69	both	cohort	Swedish population registry	2001
n = 43536 (15.7% of total N)									
Other study types									
Biobank UK Source: Biobank UK: http://www.ukbiobank.ac.uk/ (accessed 27th October, 2014)	UK	Axivity	wrist	~100000	40-69	both	cohort	Subsample of Biobank cohort, a sample of around 500,000 UK adults aged 40-69, living within a convenient distance (10 miles) from one of the 35 assesment centres located throughout the UK; assessment centres were located in areas with a sufficient population aged 40-69 (about 150,000 eligible people within target area), avoiding overlapping of target areas. Monitors were	2013-ongoing

								mailed to participants providing consent over email.	
Women`s Health Study Source: Lee et al. (48)	US	Actigraph GT3X+	hip	18000	≥62	women	observational follow up in subsample of intervention study sample	subsample of original trial (1992-2004) in 39876 health women, ≥45 years, living throughout US	2011-on-going (foreseen to finish in 2014)
Hispanic Community Health Study Evenson et al. (23)	US	Actical	right hip	12750	18-74	both	cohort	US Hispanic/Latino adults enrolled in the Hispanic Community Health Study/Study of Latinos	2008-2011
Fenland Study Source: Burgoine et al. (8)	UK	Actiheart and GeneActiv	chest (Actiheart); wrist (GeneActiv)	Actiheart: 12000; GeneActiv: 2000	30-55	both	cohort	residents recruited from GP lists in and around Cambridgeshire (Cambridge, Ely and Wisbech), born between 1950-1975	2004-on-going (foreseen to finish end 2014)
Maastricht Study Source: Schram et al. (61)	Netherlands	activPAL	thigh	10000	40-75	both	cohort	all individuals aged between 40 and 75 years and living in the southern part of the Netherlands (municipalities Maastricht, Margraten-Eijsden, Meersen, Valkenburg); study population will be enriched with T2DM participants	2010-ongoing
INTERVAL Study Source: Moore et al. (53)	UK	Axivity	dominant wrist	6000	18-77	both	intervention	subsample of trial with a total sample of around 50,000 UK adult blood donors from all 25 static donor centres of NHSBT throughout England	2014-on-going (foreseen to finish in 2016)
EVIDENT Study Source: Garcia-Ortiz et al. (26)	Spain	Actigraph GT3X	right waist	5451	20-80	both	cohort	subjects selected from the PEPAF (Multicenter Assessment of Experimental Program Promoting	to be collected

								Physical Activity) project	
European Prospective Investigation into Cancer and Nutrition Study – Norfolk, 3rd Health Check (EPIC-Norfolk 3HC) Source: Hayat et al. (34)	UK	Actigraph GT1M	right hip	4134	49-92	both	cohort	participants in 3HC of EPIC Norfolk study, originally recruited (1HC: 1993-1997) as residents of the Norfolk region, via participating GP lists	2006-2011
Pelotas 1982 Birth Cohort Source: da Silva (14)	Brazil	GeneActiv	wrist	3900	30	both	cohort	Birth cohort: all individuals born in 1982 in urban area of Pelotas	2012
Pelotas 1993 Birth Cohort Source: da Silva (14)	Brazil	GeneActiv	wrist	3816	18	both	cohort	Birth cohort: all individuals born in 1993 in urban area of Pelotas	2011-2012
Avon Longitudinal Study of Parents and Children (ALSPAC): ALSPAC Mothers Cohort Source: Fraser et al. (24)	UK	Actigraph 7164	waist	2800	52 ± 5	women	cohort	subsample of original cohort of women resident in defined geographical area in the South West of England with expected date of delivery between 1st April 1991 and Dec 1992	2011-on-going
Framingham Heart Study (FHS) 3rd Generation cohort Source: Glazer et al. (27)	US	Actical	waist	2616	47 ± 9	both	cohort	Children of offspring cohort and grandchildren of original FHS cohort	2008-2010
Modeling the Epidemiologic Transition Study (METS) Source: Luke et al. (52)	Ghana, South Africa, Seychelles, Jamaica and US	Actical	waist just behind left hip	2500	25-45	both	cohort	representative sample of specific region in each of 5 countries	2010-2011
Swedish Neighborhood and Physical Activity (SNAP) (< IPEN) Source: Sundquist et al. (66)	Sweden	Actigraph GT1M	hip	2269	20-66	both	cohort	32 neighbourhoods in Stockholm	2008-2009
Neighborhood Quality of Life Study (NQLS) (< IPEN) Source: Coleman et al. (11)	US	Actigraph 71256	waist	2199	20-65	both	cohort	32 neighbourhoods in 2 US cities	2002-2005
Understanding the Relationship between Activity and Neighbourhoods (URBAN) (< IPEN) Source: Witten et al. (74)	New Zealand	Actical	hip	2033	20-65	both	cohort	48 neighbourhoods in 4 cities in New Zealand	2008-2010
InterAct Source: Peters et al. (59)	Denmark, France, Germany,	Actiheart	chest	1941	18-92	both	cohort	sample of approximately 2000 healthy individuals, age and sex representative of original EPIC-	2007-2009

	Greece, Italy, Netherlands, Norway, Spain, Sweden, UK							Europe cohort (12 centres in 10 countries)	
Framingham Heart Study (FHS) 2nd Generation cohort Source: Author network	US	Actical	waist	~1850		both	cohort	Offspring of original FHS cohort	
National Survey for Health and Development - 1946 Birth Cohort (NSHD) Source: Golubic et al. (28)	UK	Actiheart	chest	1787	60-64	both	cohort	Birth cohort: nationally representative sample of all single legitimate births in 1 week in March 1946 in England, Scotland and Wales	2006-2010
Twins UK Source: den Hoed et al. (19)	UK	Actiheart	chest	1661	17-82	both	cohort	twin pairs recruited from St Thomas' UK adult twin registry (Twins UK)	2008-2010
British Regional Heart Study Source: Jefferis et al. (41)	UK	Actigraph GT3X	right hip	1593	70-93	men	cohort	survivors from British Regional Heart Study, originally recruited in 1978-1980, from primary care centres in 24 British towns, aged 40-59	2010-2012
PROPELS Source: Author network	UK	Actigraph GT3X+ and activPAL	Actigraph GT3X+: right hip; activPAL: thigh	Actigraph GT3X+: 1308; activPAL: no target (optional)	40-74	both	intervention	adults within the age range eligible for the NHS Health Check Programme (40-70 years old or 25-74 years old if South Asian) and confirmed to have impaired glucose regulation, recruited from existing population-based studies, risk score searches in GP practices in Cambridge and Leicester (UK) and NHS Health Checks	2014-ongoing
Belgian Environmental Physical Activity Study (BEPAS) (< IPEN) Source: Van Dyck et al. (72)	Belgium	Actigraph 7164	right hip	1166	20-65	both	cohort	24 neighbourhoods in Ghent	2007-2008
NCI Polish Breast Cancer Case-	Poland	Actigraph 7164	waist	1164	25-74	wome	populat	women aged 20-74, residing in	2000-2003

Control Study Source: Dallal et al. (17)						n	ion-based case-control (1164 controls, 996 incident breast cancer cases (the latter not included in sum for total N)	Warsaw; controls selected from Polish Electronic System, matching cases who were identified from Warsaw cancer registry	
Kenya Diabetes Study Source: Christensen et al. (10)	Kenya	Actiheart	chest	1099	17-68	both	cohort	rural adults from Luo, Kamba and Maasai ethnicity living a traditional lifestyle	2005
ICMR-MRC Diabetes Prevention Project Source: Author network	India	Actigraph GT3X+	right hip	Target 1050	35-55	both	intervention	Individuals with HbA1c measures in 6-6.4% range identified through the Indian Diabetes Risk Score	2012-ongoing
	UK	Actigraph GT3X+	right hip	Target 1134	40-74	both	intervention	Individuals with HbA1c measures in 6-6.4% range identified through primary care screening or NHS health check	2013-ongoing
Activity and Function in the Elderly in Ulm (ActiFE Ulm) Source: Denkinger et al. (20)	Germany	activPAL	right thigh (continuous wear)	1059	65-90	both	cohort	Ulm and adjacent regions in Southern Germany	2009-2010
Cameroon II Source: Author network	Cameroon	Actiheart and GeneActiv	Actiheart: chest; GeneA	Actiheart: 1000; GeneA	18-65	both	cohort	two urban and two rural areas in Cameroon (new cohort)	2012-2014

			ctiv: non-dominant wrist	ctiv: 1000					
Pedometer and consultation evaluation - UP (PACE-UP) Source: Harris et al. (33)	UK	Actigraph GT3X+	hip	993	45-75	both	intervention	adults aged 45-75 registered at GP practice, able to walk outside without contra-indications to increase moderate PA, recruited via consenting GP practice in South-West London with list >9,000 and practice nurse and room for recruitment	2013-on-going
The Netherlands Epidemiology of Obesity (NEO) study Source: de Mutsert (18)	The Netherlands	Actiheart	chest	955	45-65	both	cohort	men and women aged between 45-65 years with a self-reported BMI of ≥27 kg/m2, living in the greater area of Leiden (in the West of the Netherlands), as well as all inhabitants aged between 45-65 years from Leiderdorp (one municipality), irrespective of their BMI	2008-2012
Coronary Artery Risk Development in Young Adults (CARDIA) Source: Gordon-Larsen et al. (29)	US	Actigraph 7164	waist	951	38-50	both	cohort	residents from Birmingham, Chicago, Minneapolis, Oakland, balanced by race, sex, education and age	2005-2006
Western Australian Pregnancy Cohort (Raine), Source: Author network	Australia	Actigraph GT3X+	hip	~900	23	both	cohort	Birth cohort: Offspring of mothers recruited at 18 weeks gestation from hospitals and privates practices in Perth, Western Australia (198-1992). Cohort representative of Western Australian population at 17 years.	2012-2014
Senior Neighborhood Quality of Life Study (SNQLS) Source: Buman et al. (7)	US	Actigraph 71256 or 7164	right hip	862	≥66	both	cohort	2 major US metropolitan regions (Seattle King County and Baltimore)	2005-2007
British Women`s Heart Health Study Source: Jefferis et al. (41)	UK	Actigraph GT3X	right hip	857	69-90	women	cohort	survivors from British Women's Heart Health Study, originally recruited in 1999-2001, from	2010-2012

								primary care centres in 24 British towns, aged 40-59	
/ Source: Yoshioka et al. (75)	Japan	Lifecorder, Suzuken Co	waist	788	18-84	both	cohort	Japanese volunteers who underwent a regional medical examination in Fukuoka, Saga and Niigata regions of Japan and from university students in Fukuoka region	1999-2000
/ Source: Sigmund et al. (64)	Czech Republic	Caltrac	right waist	787	18-24	both	cohort	young adults, predominantly recruited from lists of university students of Palacky University in Olomouc and Ostrava University, and their friends	2000-2005
/ Source: Inoue et al. (40)	Japan	Lifecoder EX, 4-second version, Suzken Company, Nagoya, Japan	waist	786	20-69	both	cohort	subsample of neighbourhood environment and PA study, random sample of residents from 4 cities in Japan	2007-2008
The Australian Diabetes, Obesity and Lifestyle Study Source: Tanamas et al. (67)	Australia	ActivPAL3 and Actigraph GT3X+	activPAL3: thigh; Actigraph GT3X+: waist	activPAL3: 740; Actigraph GT3X+: 745	≥36	both	cohort	random sub-sample of AusDiab participants: Australian adults general population	2011-2012
ACTION! Worksite Wellness Program Source: Webber et al. (73)	US	Actigraph 7164	right hip	729	20-70	women	intervention	elementary school personnel of 22 schools in large suburban school district in greater New Orleans area (White and Black females only in this manuscript)	2006
Walking Away from Type 2 Diabetes Study (WA) Source: Henson et al. (35)	UK	Actigraph GT3X	right hip	725	63.7 ± 7.8	both	intervention	middle-aged and older adults at high risk of impaired glucose regulation, impaired fasting glycaemia or type 2 diabetes, recruited via their GP practice in Leicestershire region	2010-2011
Twin Cities Walking Study Source: Oakes et al. (55)	US	Actigraph MTI	?hip/waist (belt	716	≥25	both	cohort	36 neighbourhoods in northern sector of Minneapolis-St Paul	unknown

			provided)					metropolitan area (stratified cluster design)	
Travel Assessment and Community Project Source: Kang et al. (42)	US	Actigraph GT1M	hip	706	50.9 ± 13.3	both	cohort	adults recruited from greater Seattle area, i.e. a spatial sampling frame covering 773 census block groups with uniform range of household income, race, home values, net residential density, and levels of bus ridership	2008-2009
Southampton Women`s Survey Source: Hesketh et al. (36)	UK	Actiheart	chest	650	25-47	women	cohort	subsample of mothers of 4- and 6-year olds, originally recruited into the Southampton Women's Survey through general practices based in Southampton (UK) (interviewed between 1998-2002 when they were aged between 20-34 years and invited to take part in the study when they became pregnant after the interview; subsequent live births (n = 3159) were followed up)	2005-2012
Alaska Yup'ik Study Source: Author network	US	Actiheart	chest	637 >=18 years (712 total)	14-95	both	cohort	Study of adult Yup'ik Eskimo people living a subsistence lifestyle in southwestern Alaska	2008-2011
Relationship between Insulin Sensitivity and Cardiovascular risk (RISC) Source: Kozakova et al. (46)	14 European countries (Italy, UK, France, The Netherlands, Denmark, Ireland, Switzerlan	Actigraph 7164	small of the back	614	30-60	both	cohort	apparently healthy Caucasians recruited in 19 centres in 14 European countries	2002-2004

	d, Germany, Sweden, Austria, Spain, Greece, Serbia and Montenegro, Finland)								
Research of physical activity, lifestyle, obesity and the environment (<IPEN) Source: Kerr et al. (39)	Czech Republic	Actigraph GT1M and GT3X	hip	600	20-65	both	cohort	62 neighbourhoods in Olomouc, Hradec and Kralove area	2009-2011
Age, Gene/Environment Susceptibility-Reykjavik Study Source: Arnardottir et al. (2)	Iceland	Actigraph GT3X	right hip	579	73-98	both	cohort	subsample of AGESII-Reykjavik study, which is follow up of random sample of Reykjavik Study, which consists of a random sample of men and women born in 1907-1935 living in Reykjavik in 1967	2009-2010
Shanghai Physical Activity Study Source: Peters et al. (60)	China	Actigraph MTI	left hip	576	40-74	both	cohort	randomly selected subset of participants from the Shanghai Women`s Health Study (SWHS) and the Shanghai Men`s Health Study (SMHS)	2005-2008
Cameroon I Source: Assah et al. (3)	Cameroon	Actiheart	chest	552	25-55	both	cohort	two urban (Yaoundé and Bamenda) and two rural areas (Mbankomo and Bafut) in Cameroon; sampling frame established following enumeration of eligible adults (25-55 year of age) in houses in delimited areas of study sites; exclusion of those with diagnosed diabetes or cardiovascular disease	2006-2007
/ Source: Gando et al. (25)	Japan	Actimarker EW4800,	left waist	538	23-74	both	intervention	subsample of participants in the Nutrition and Exercise Intervention Study (NEXIS), a trial aiming to determine the	2007-2009

								effects of physical activity on incidence and risk factors of cardiovascular diseases in healthy people	
/ Source: Paul et al. (58)	US	Actigraph 7164	waist	524	30-70	both	cohort	adults from the Baltimore, MD/Washington, DC area	2002-2003
/ Source: Ayabe et al. (4)	Japan	Lifecorder, Suzuken Co	left waist	507	19-69	both	cohort	Japanese volunteers underwent a regional medical examination in Fukuoka and Saga prefectures	1999-2000
Steps to Health Study Source: Ostbye et al. (56)	US	Actical	right hip	492	45 ± 10	both	interve ntion	obese employees at Duke University and Medical Center, benefit-eligible and enrolled in a health insurance program offered through Duke, 20+h per week	2011-2012
Commuting and Health in Cambridge Study Source: Panter et al. (57)	UK	Actigraph GT1M	right hip	486	≥16	both	cohort	adults ≥16 working in Cambridge and living within 30km radius of Cambridge city centre, workplace-based recruitment strategy	2009
/ Source: Kim et al. (45)	Japan	HJA-350IT, Active style Pro, Omron Healthcare Co.	right hip	483	30-64	both	cohort	health middle-aged Japanese adults recruited from local community newspapers in Tsukuba, Ibaraki	2008-2010
Nakanojo Study Source: Shephard et al. (62)	Japan	Lifecorder, Suzuken Co	waist	468	65-84	both	cohort	community-living Japanese volunteers aged ≥65, residents from Nakanojo, excluding those who were severely demented or bedridden	2002-2007
Get Moving Study Source: Author network	UK	Actiheart	chest	455	18-65	both	interve ntion	individuals working or studying on the Cambridge Biomedical Campus (including Addenbrooke`s Hospital), Cambridge	2012-2013
Whitehall II Source: Hamer (31)	UK	Actigraph GT3X	waist	446	54.0 ± 5.4	both	cohort	subsample of Whitehall II cohort (adults recruited from British Civil Service in 1985, stratified by grade of employment (SES))	2009-2010
/	Portugal	Actigraph	hip	435	≥20	both	cohort	Healthy adults aged ≥20, resident	2008-2010

Source: Bento et al. (6)		GT1M						in Municipality of Vila Real (North Portugal), recruited by word of mouth	
Positive Action for Today`s Health (PATH) trial Source: Coulon et al. (13)	US	Actical	right hip	434	≥18	both	interve ntion	African-American adults residing in three low-income communities located in the Southeastern US	2008
/ Source: Murakami et al. (54)	Japan	Actimarker EW4800	lower back	434	23-85	both	cohort	?	?
Jackson Heart Study (JHS) Source: Smitherman et al. (65)	US	Actigraph 7164	waist	404	35-84	both	cohort	subset of JHS: population-based sample of non-institutionalized African-American adults from Jakcson metropolitan statistical area	2000-2004
n = 233834 (84.3% of total N)									

[a] Extracted N depended on the individual studies' inclusion criteria in terms of wear time (e.g. Tudor-Locke et al. (71): ≥1 valid day (consisting of ≥10 hours valid wear time); Baptista et al. (5): ≥3 valid days, including ≥1 valid weekend day (consisting of ≥10 hours valid wear time); Evenson et al. (23): ≥3 valid days, (consisting of ≥10 hours valid wear time)). In cohorts with an age range covering childhood/adolescence and adulthood, N was derived for adults only, with the age cut-off depending on the information provided (Baptista et al. (5): ≥18; Colley et al. (12): 20-79; Aresu et al. (1): ≥16; Lee et al. (50): ≥15; Troiano et al. (69): ≥20; Tudor-Locke et al. (71): ≥20 year of age). For studies with on-going or future data collection, the target N was provided.

Supplemental digital content 2: Alphabetical list of the twenty individuals with recognized expertise in physical activity monitoring, epidemiological studies, surveillance, advocacy, and/or measurement expertise, who were invited to participate in the Delphi survey:

Adrian Bauman
Steven N. Blair
Søren Brage
Fiona Bull
Sebastien FM. Chastin
David W. Dunstan
Ulf Ekelund
Dale W. Esliger
Patty S. Freedson
Malcolm H. Granat
Charles E. Matthews
James J. McClain
Neville Owen
Alex V. Rowlands
James F. Sallis
Lauren B. Sherar
Mark S. Tremblay
Richard P. Troiano
Stewart G. Trost
Nicholas J. Wareham