Appendix G Accelerometry data collection and processing

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G.1 Accelerometry data collection

G.1.1 Choice of accelerometer

The objective physical activity measure used in the NDNS Rolling Programme (RP) in Years 1 to 4 was the ActiGraph model GT1M (Manufacturing Technology Incorporated, Fort Walton Beach, Florida, USA), a small and lightweight device (smaller than the size of a matchbox) that is worn on the waist using a clip or belt (Figure G1). The ActiGraph is a digital uniaxial[1] accelerometer that records movement on the vertical axis and is also capable of recording pedometer data. ActiGraphs can store up to 1 GB of movement data which is enough for three to four months of activity monitoring on a minute-by-minute basis. However, the battery is limited to a maximum of 14 days of continuous use, after which period it requires re-charging.

Figure G1. The ActiGraph model GT1M

G.1.2 Preparation of the accelerometers

Years 1 to 3

Staff at NatCen initialised and charged the ActiGraphs then posted them to the interviewers.

Year 4

Analysis of data collected in Years 1 and 2 showed that around half of the ActiGraph files contained no recorded data, although the participants had said

they had worn them. This was found to be random: it was not related to the area, nor to individual interviewers or ActiGraphs.

Lengthy investigation eventually revealed that the ActiGraphs did not record if more than two weeks had passed between initialisation and the start of data collection. From the start of Year 4, initialisation continued to be undertaken centrally, due to the difficulties of providing training, equipment and supervision to large numbers of interviewers covering the entire UK, but each individual ActiGraph was marked with the initialisation date. Interviewers were instructed to return the ActiGraph to the office unused if it was more than a fortnight since initialisation and to select a different ActiGraph from their supply. Interviewers also topped up the charge on each ActiGraph that might be used prior to making a visit to a participant. This substantially reduced the proportion of ActiGraphs issued to participants that did not record activity data.

G.1.3 Fieldwork procedures

Eligibility and wearing the ActiGraph

In Year 1, all participating children aged 4 to 10 years were asked to wear an ActiGraph for seven consecutive days during all waking hours, except when it would get wet, such as when having a shower or swimming. Parents were asked to keep a log, noting when the ActiGraph was worn, when it was taken off, and why. They were also asked to note time spent cycling, which is not identified well by the ActiGraph.[1] A token of appreciation of £20 was provided afterwards for those who said they had worn the ActiGraph and who returned it.

In Year 1, participants aged 11 to 15 years had been given a bespoke questionnaire to estimate physical activity. Fieldwork had commenced before the detailed assessment of this new questionnaire against doubly-labelled water (DLW) was complete. The results of the assessment showed that the questionnaire underperformed compared with what had been intended and so it was decided to move to objective assessment in this age group using the ActiGraph from Year 2 onwards. Participants and their parents were no longer asked to keep an activity log from Year 2 onwards. This was both to reduce participant burden and to follow the experience of most researchers in other studies internationally, who have generally ignored the logged data which introduce the subjective errors that objective measures were designed to prevent. The token of appreciation for the ActiGraph component was reduced to £10 to reflect the reduced participant burden.

The ActiGraph was worn on the waist using the elastic belt provided. The belt was adjusted to be snug around the waist, so that the ActiGraph rested on the right side of the body, close to the right hip. Parents and young people were told that the ActiGraph should be worn over a thin layer of clothing, and was best kept fastened on the belt to reduce the risk of it being lost.

Issuing the ActiGraph

Interviewers introduced the ActiGraphs to participants at the first visit. The interviewer explained to the child/young person and their parent/guardian the purpose of wearing the ActiGraphs; provided information materials (see Appendix C); and answered any questions they had. Assenting participants with parental consent were given an ActiGraph to wear during waking hours for seven consecutive days. At the end of this week, interviewers collected the devices from participants' households, completed the relevant despatch forms, and posted them by special delivery to the NDNS RP project team in Brentwood.

The information leaflet given to households by the interviewer provided participants with a list of tips and 'Frequently Asked Questions' about wearing the ActiGraphs correctly. The interviewers also made one or more reminder calls during the measurement week.

Upon receipt the project team downloaded ActiGraph data, labelled and stored the data, recharged the battery, and prepared the ActiGraphs for use in the field again. ActiGraphs were then posted special delivery to the interviewers who repeated the measurement cycle on a new set of participants.

G.2 ActiGraph data processing for the NDNS RP

G.2.1 Data labelling and storage

When the interviewers collected the ActiGraph, they recorded the unique participant serial number on a paper form. The paper form was then dispatched with the ActiGraph to the office-based project team. When the data were downloaded from the ActiGraph, the file name given to the data file was the CAPI case number. The names of the saved data files could then be cross-checked against the CAPI data files to ensure that they had all been received. The data files were stored on a project specific network folder that was backed-up regularly.

G.2.2 Data processing by MRC Epidemiology Unit, Cambridge

ActiGraph files were sent securely by the NDNS RP senior programming manager to the 'Physical Activity Epidemiology Group' at the MRC Epidemiology Unit, Cambridge, for processing. Details of the decisions made for processing and for analysis are given in the Technical Annex at the end of this Appendix, to enable assessment of the data used in this report and to be archived at the UK Data Archive.

Key points

Participants were asked to wear the device only during waking hours. Data beyond seven days from the start of wear were excluded from processing and analysis. The raw accelerometry data were processed using specialist software at the MRC Epidemiology Unit, Cambridge. The main outcome variable was mean daily counts per minute (cpm). Time spent at various levels of activity was provided both in minutes per day and as fractions of the total time the ActiGraph was worn. The thresholds for these levels were less than 100, 200, 500, 1000, 1500, 2000, 2500, and 3000cpm.

Participants were included in this report only if there were at least eight hours of data per day from at least three days during the seven days they had been asked to wear the device. A decision on whether or not the device was being worn was determined from the probability of wear, based on the duration of zero counts.

Validation results

The ActiGraph data were processed as described in the Technical Annex to this Appendix, and energy estimates from ActiGraph wear were tested against those derived from doubly labelled water (DLW) assessment in the Measuring Physical Activity and Energy Expenditure in the NDNS Comparison Study (Tables G1 and G2). Correlation values of 0.70-0.89 are considered to be strong, thus accelerometry data provide a good proxy measure for total energy expenditure (Table G1).

Table G1. Total energy expenditure

	TEE[a] *(kJ/24hr/kg)*		
	Estimate *treadmill equations (Freedson / Trost)*	**Estimate *'lifestyle' equations (Swartz / Puyau)***	**Measured (DLW)**
Adults *(n=90)*	131 (19)[b]	171 (24)	148 (26)
	r=0.72	*r=0.70*	
Children *(n=50)*	215 (50)	237 (40)	238 (56)
	r=0.86	*r=0.85*	

[a] TEE: Total energy expenditure [b] Values are mean (sd).

However, the correlation in adults between accelerometry data and physical activity expenditure as measured by DLW was moderate to low (correlation coefficient r of 0.30-0.49), as it was also for children for an estimate using the Trost treadmill equation. Using Puyau's 'lifestyle' equation, the correlation for children was too low to be meaningful (below 0.16) (Table G2)

Table G2. Physical activity energy expenditure

	PAEE[a] *(kJ/24hr/kg)*		
	Estimate *treadmill equations (Freedson[4] / Trost[5])*	**Estimate *'lifestyle' equations (Swartz[6] / Puyau[7])***	**Measured (DLW) - est. REE[b c]**
Adults *(n=90)*	33 (10)[d]	68 (16)	48 (17)
	r=0.40	*r=0.44*	
Children *(n=50)*	48 (13)	68 (10)	69 (26)
	r=0.30	*r=0.12*	

[a] PAEE: Physical activity energy expenditure
[b] REE: resting energy expenditure
[c] Measured PAEE = 0.9TEE(dlw) – REE (est) , where TEE = total energy expenditure
[d] Values are mean (sd).

References

[1] The ActiGraph was set to measure uniaxial movement of the hip along the axis of the body which is vertical when standing up. Thus physical activity such as cycling or rowing were not recorded very well. Similarly, the ActiGraph measured walking speed accurately but could not detect whether this was on the flat or the extent of any incline.

Technical Annex to Appendix G

Design

An 'awake time only' monitoring protocol was used.

Data processing

Only the first seven days of data in each record (about 10,000 lines) were read. Wear time is an integrated wear probability. It represents the area under the wear probability time-series for each participant and so represents an integral with respect to time. For this report we set the minimum wear time criterion for inclusion in analysis at 24 hours (ie at least eight hours a day (h/d) on at least three days). However, the opportunity for accumulating wear time is somewhat age-dependent, because of decreasing sleep duration with increasing age. Three key variables are:

1. *Wear probability* (Pwear, Black line on second small panel on individual plots) is based on 0-string lengths for ActiGraph counts and its first time derivative. It starts to decay from 1 for strings >90 min and is 0 for strings >120 min.
2. *Include day* criteria (red line on first small panel) is a binary variable, indicating at least 10,000 counts AND a time-integral of Pwear >8 hours in 24 hours (counting in blocks from the start of the file).
3. *Sleep probability* (blue line on third small panel) is used less but is relevant for the imputation and some of the derived estimates. It was also calculated on the basis of the 0-strings; it increases from 0 above 5 hours and starts to decay again above 12 hours.

Analysis decisions

- data in hour-by-hour results include derived variables for all available data (seven days or less if file is shorter)
- it is fully indexed by various time indicators
- *PwearAndSleep* is the sum of Pwear and Psleep. The diurnal acceleration pattern (DiurnalAcc) is the PwearAndSleep-weighted average of all data for included days. The translated accelerometry time-series is the weighted average of PwearAndSleep*RawAcc + (1-PwearAndSleep)*DiurnalAcc
- *average accelerometric intensity* is reported in three variables (raw_meanAcc, censor_meanAcc, worn_obsweighted_meanAcc), reflecting different inclusion criteria with respect to wear/non-wear inference:
    - *raw_meanAcc* does not take non-wear into account

    - *censor_meanAcc* classifies wear as a binary variable. Every segment with >90 minutes of continuous zeros are discarded (as indicatingnon-wear), and an average is calculated of the remaining data
    - *worn_obsweighted_meanAcc* uses a weighted average based on the probability of wear / non-wear, so an observation (always zero) with 50% wear probability counts as 50% of an observation
- these are fairly robust measures of “overall physical activity”, which is fairly proximal to what was truly measured and which has been used in many previous reports using ActiGraph, albeit perhaps with different non-wear detection parameters. In this report, we have used mean daily counts per minute (cpm) as the overall measure of physical activity
- *distribution* variables (time fraction) of *accelerometric intensity* are also included*;* there are seven categories and they are coded as fraction of time spent below the corresponding cutpoints (100-500-1000-1500-2000-2500-3000); by subtracting these fractions from 1, one obtains "above" estimates or subtracting the adjacent category produces time spent in intensity *intervals*
- in the collapsed data set (one line per subject), only data from "Included Days" is used; reviewing the individual plots shows what is currently included and what is not
- variables ending with *"_worn"* (plus PAEE variables not ending with “_ws”) represent the Pwear-weighted averages. Variables ending with "_ws" represent the PwearAndSleep-weighted averages (one approach to get from 'awake only' monitoring to 24 hour estimates). It was recommended that the “_ws” estimates not be used for this report, as the sleep detection algorithm relies heavily on subject compliance with the protocol and may not always have been achieved