Feasibility of incorporating objective measures of physical activity in the STEPS program. A pilot study in Malawi.

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Location: Malawi (Lilongwe and Dowa districts)

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1.1 LIST OF ABBREVIATIONS

AX3	AX3 model of tri-axial accelerometer (Axivity, UK)
EA	Enumeration Area (geographical region)
ENMO	Euclidian Norm Minus One (activity-related acceleration metric)
GPAQ	Global Physical Activity Questionnaire
HPFVM	High-Pass Filtered Vector Magnitude (alternative activity-related acceleration metric)
IT	Information technology
LPA	Light intensity physical activity
MRC	Medical Research Council
MVPA	Moderate to vigorous intensity physical activity
ODK	Open Data Kit, used by the Android application for data collection on tablets
PA	Physical activity
PA_ID	Physical activity identification number (alternative ID number)
QC	Quality control checks
STEPS	Stepwise approach to non-communicable disease (NCD) risk factor surveillance
SFTP	Secure file transfer protocol (allowing data to be send securely over the internet)
WHO	World Health Organization

1.2 ACKNOWLEDGEMENTS

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1 EXECUTIVE SUMMARY

Background

Physical activity is an important determinant of human health but it is inherently difficult to measure. Global surveillance systems for physical activity have so far only included self-report measures, which capture only a small subset of daily activity and are limited due to issues of recall bias. Wrist-worn accelerometry offers a reasonably cost-effective objective method of measuring physical activity during free-living with proven feasibility in large-scale population studies.

The key objective of this project was to pilot wrist-worn accelerometry within a surveillance setting in order to inform the implementation of this methodology into the global WHO STEPS programme.

Method development and implementation

Accelerometry protocols were developed and deployed within an existing STEPS survey in two regions of Malawi (Dowa and Lilongwe). This also included developing training for local staff. Survey information was collected on tablets. Accelerometers could only be set up on PCs, so the protocol was adapted to do this in advance of recruiting participants. For this, an alternative Participant ID linkage system was developed to enable linking accelerometer files to the rest of the survey data.

On the whole, the implementation was successful. During the process evaluation, some issues were identified. For example, black wrist straps were culturally associated with the Devil by some participants. A total of 499 participants were recruited for Step 1 and 2, of whom 446 returned for Step 3 measurements which included accelerometry.

The accelerometry data collection was well accepted by both fieldwork team members and study participants, with only four participants (<1% of those eligible) declining to wear the device. There were no major technical issues with devices, although a small number of wrist straps were damaged and 13 monitors were lost (3% of deployed). Of 456 accelerometer files retrieved, 410 files (90%) could be linked to survey participants.

All but two accelerometer files could be processed with standard techniques to produce participant-level summary results. Sufficient valid data (defined as at least 48 hours of monitor wear time with reasonable diurnal representation) were available for 386 survey participants (87% of eligible).

Results

Objective levels of physical activity in Malawi from this pilot study were about 50% higher than levels observed in the UK using similar methodology. Rural dwellers were more active than urban dwellers, particularly in the morning hours of the day. Men had higher activity levels compared to women, and there were decreasing trends with advancing age.

Conclusion and recommendations

This pilot demonstrated that it is feasible to implement wrist-worn accelerometry within the STEPS program in settings such as Malawi. Detailed description of objectively measured physical activity patterns could be produced from nearly all accelerometer files retrieved, including behavioural indicators known to be important for human health.

In future surveys, culturally specific issues that could impact data collection should be identified early in the fieldwork planning stage and changes to the protocol made. Experiences from this pilot have led to development of software platforms that allow accelerometers to be set up from Android tablets at the point of issuing the device to the participant, which would simplify future fieldwork training and reduce risk of data linkage error.

2 BACKGROUND

Insufficient physical activity is the fourth leading cause of mortality globally and is a key risk factor for many non-communicable diseases (World Health Organization, 2010). Higher levels of physical activity can reduce the risks of obesity, diabetes, hypertension and cardiovascular disease, as well as some cancers. It is also important for maintaining general fitness, muscle strength and bone health and provides benefits for mental health (2018 Physical Activity Guidelines Advisory Committee, 2018). Current estimated global levels of physical inactivity (Guthold, Stevens, Riley, & Bull, 2018) are responsible for significant health-care costs and productivity losses, placing a considerable economic burden on societies (Ding et al., 2016).

Physical activity information has traditionally been captured via self-reported measures, such as the Global Physical Activity Questionnaire (GPAQ (Bull, Maslin, & Armstrong, 2009)). Whilst they provide insight into the domains and types of activity (e.g. occupational, transport-related, leisure-time, walking), an individual's recall can only broadly capture the timing, frequency, duration and intensity of a specific activity. Many of the principle activities of daily life are difficult to quantify in this way, such as household tasks or childcare. Objective measures, especially those that can capture intensity over several days, provide much more detailed and accurate information and are the only feasible and valid way to capture the more incidental, habitual activities of daily life.

Wrist-worn accelerometers have gained in popularity because they have higher feasibility for long-term wear than accelerometers worn at the hip or other body parts (van Hees et al., 2011). Advances in waterproofing have also reduced the need to remove the accelerometer, simplifying study protocols. Together, these two factors increase wear compliance and reduce bias associated with non-wear (Da silva et al., 2014; Doherty et al., 2017; Troiano, McClain, Brychta, & Chen, 2014). Wrist-worn accelerometers have proven to be feasible even in very large population studies, such as the UK Biobank study which measured >100 000 adults in the United Kingdom (Doherty et al., 2017). Furthermore, more recent accelerometers have the capacity to capture raw (i.e. high resolution) acceleration in three planes of movement over a week, which not only allows generic (non-brand specific) quantification of human movement in natural units of acceleration which allows a fuller description of the biomechanics of movement (Perez-Pozuelo et al., 2019) and also has the potential to be used for pattern recognition to identify behaviour types (Willetts, Hollowell, Aslett, Holmes, & Doherty, 2018).

The World Health Organization's (WHO) recommended physical activity self-report instrument is the GPAQ, which is currently included as part of the WHO STEPwise approach to non-communicable disease (NCD) risk factor surveillance (STEPS). The STEPS approach is a flexible protocol for the surveillance of multiple NCD risk factors.

In 2016, preliminary protocols were developed to integrate objective physical activity data using wrist-worn raw accelerometry into the program. Malawi was selected to host the pilot study after expressing an interest to participate.

3 OBJECTIVES

The overall aim of this pilot study was to assess the feasibility of integrating wrist-worn raw accelerometry into the national STEPS survey in Malawi. The study also aimed to inform the feasibility of future implementation of this methodology into the global WHO STEPS programme.

The AX3 accelerometer (Axivity, UK) was the instrument of choice, as this accelerometer provides raw measurement of acceleration in natural units (not arbitrary counts) and it had successfully been used in a large-scale population-based study (UK Biobank). Wrist-worn accelerometry fieldwork and training methodology developed previously for the UK Biobank was adapted to suit the specific requirements of this pilot. A key consideration in the protocol adaptations was to avoid compromising the existing STEPS methodology, response rate, and data collection.

Study Aims:

1. Adapt the accelerometry data collection protocol for Malawi
2. Develop generic STEPS accelerometry documents and adapt for Malawi
3. Deliver a training module on accelerometry data collection and provide practical experience of data collection (to fit within the existing data collection training programme)
4. Monitor pilot data collection
5. Assess feasibility including:
    a. Acceptance by field workers
    b. Acceptance by participants
    c. Adherence to protocol
    d. Reliability of the AX3 accelerometers
    e. Information technology (IT) including hardware such as tablet devices and services (e.g. electronic file transfer)
6. Process the pilot data and produce relevant indicators of physical activity
7. Provide recommendations for the future objective measurement of physical activity within the STEPS Program in Malawi and to inform the wider use of accelerometry within the STEPS Program globally.

4 PROTOCOL DEVELOPMENT

4.1 LOCATION

Malawi is located in Southern-Central Africa, bordering Tanzania in the North and Mozambique in the South, with Zambia to the west and Lake Malawi to the East (Figure 1). It has a population of just over 18 million (2016), with the majority (85%) being from rural areas. The largest city is Lilongwe, which is also the capital of Malawi. The country is divided into a total of 28 districts, two of which (Dowa and Lilongwe) were chosen by the chief co-ordinator for this pilot. This choice was based on their close proximity to the survey headquarters in Lilongwe and the mixture of rural and urban areas in both districts.

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Figure 1: Malawi geographical regions

4.2 INITIAL PROTOCOL DEVELOPMENT

Objective monitoring of physical activity requires a different logistical setup than what is otherwise used in surveys, not least because of the typically weeklong monitoring period where study participants are wearing devices which need to be deployed, collected, downloaded, and recharged before redeployment.

The MRC Epidemiology Unit (University of Cambridge, UK) has extensive experience of objective physical activity measurement in a wide range of global settings; including Kenya, Cameroon, Brazil, Jamaica, India, Greenland, as well as large-scale epidemiological studies within the UK. This includes the design of the UK Biobank accelerometry sub-study with over 100,000 participants, the enhancement protocol for which is publicly available (UK Biobank, 2007). To date UK Biobank is the largest study to use raw wrist-worn accelerometers. This study demonstrated excellent compliance with the 7-day 24-hour protocol, with >93% of participants providing useable data (Doherty et al, 2017). Therefore, the Biobank protocol was used as the basis for this pilot study, except for the placement of the monitor on the non-dominant wrist (Biobank used dominant wrist) as most studies use this position and it is also slightly better correlated with whole-body physical activity (White et al., 2019; White, Westgate, Wareham, & Brage, 2016). The proposal for the accelerometry element of the STEPS survey protocol was initially drafted by Kelly and Richards (University of Edinburgh/Sport New Zealand/University of Sydney) in April 2016 after a series of tele-conferences with the MRC Epidemiology Unit. This draft protocol was then later adapted for use in the context of Malawi (in 2017), following discussions between the MRC Epidemiology Unit and WHO teams in Geneva and Malawi.

4.3 ADAPTION OF ACCELEROMETRY PROTOCOL INTO EXISTING STEPS PROTOCOL

A key consideration was how best to integrate accelerometry into the existing STEPS protocol. The three “steps” are: (1) questionnaires, (2) physical measurements, and (3) biochemical measurements with participants usually assessed in their homes for Steps 1 and 2, and then travelling to attend an assessment centre for the biochemical measures in Step 3 within the next day or two.

Historically the self-reported physical activity measures have been collected alongside other physical measurements within Step 2 of the STEPS protocol, so logically it was initially considered that the accelerometry measures would also be added to Step 2. This would maximise the number of potential participants with accelerometry data, since participation rates tend to be lower for Step 3. This is due to the additional time and travel commitments needed to attend an assessment centre, as well as potential participant concerns about blood sampling. However, it was important to take into account that if added to Step 2, the 7-day monitoring period for the accelerometry would then include the time and travel involved in attending the assessment centre for those taking part in Step 3. This would not necessarily reflect the participants ‘usual’ activity patterns. Therefore, it was decided to fit the accelerometer at the end of Step 3 to avoid the accelerometry wear period being influenced by the study protocol.

An overview of the accelerometer-handling processes is shown in Figure 2. This included accelerometer initialisation, deployment, collection and data download, followed by quality control (QC). A particular logistical challenge for the pilot involved devising a simple deployment and linkage system that would minimise burden on the fieldwork team, yet allow the matching of participant ID numbers to the accelerometer used and ultimately the correct accelerometry file.

In the generic, standard data collection protocol, accelerometers are programmed at set-up to include a participant ID number. This ensures that each accelerometry file includes the participant ID number and avoids errors in matching accelerometer files to participants. This stage would ideally be carried out by the data collectors with the participant present.

However, at the time of the pilot in October 2017, the AX3 accelerometer required direct attachment via USB to a laptop or desk based personal computer to initialise the accelerometer for set-up. However, Android tablets are used within the field, for the existing survey components, primarily because these do not require a constant mains electricity supply.

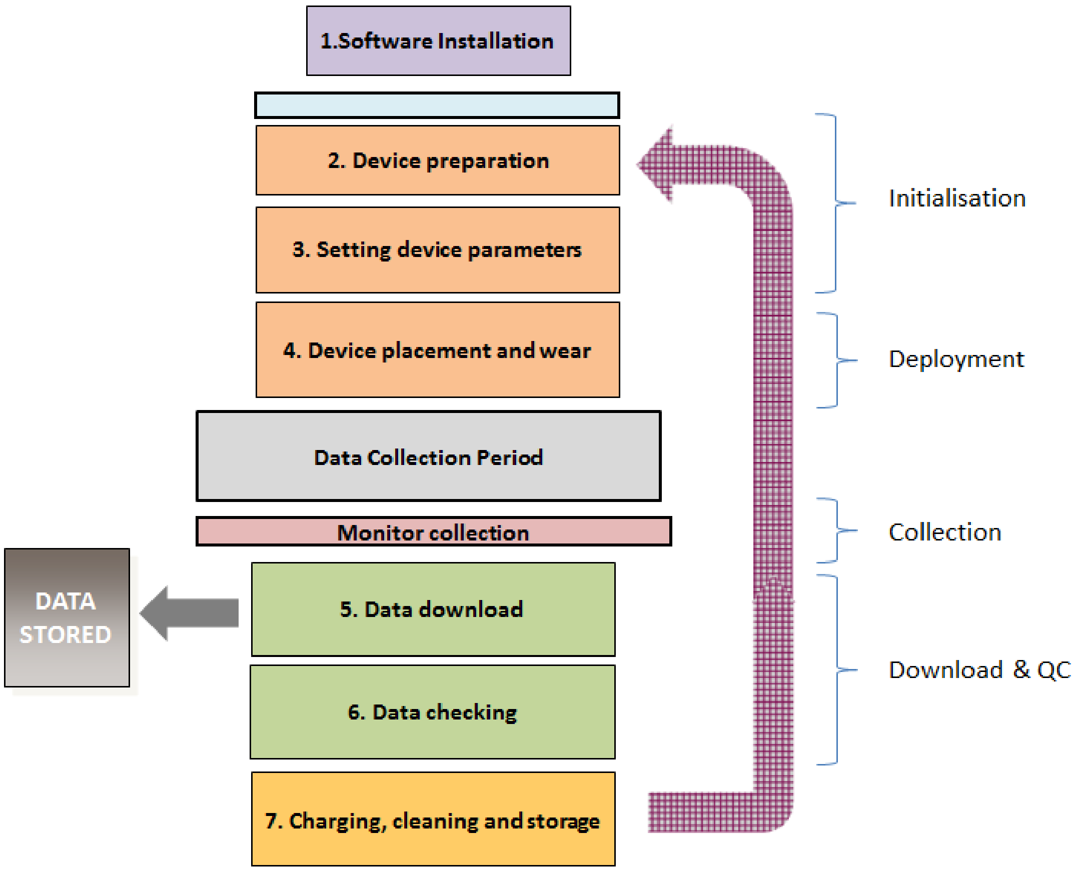


Figure 2: Summary of accelerometry data collection: Initialisation, deployment, collection, download and quality control (technical check to allow re-deployment of accelerometer & compliance check)

To accommodate the requirement for laptops or PCs with a USB connection, the accelerometers were initialised in bulk (by the 'Accelerometry Champions' – see below) in advance of Step 3 testing. However, as this was prior to participant consent, it was not known in advance which individuals would take part. Therefore, the accelerometers could not be initialised with the participant ID numbers. This created two challenges, 1) how to link participant information to the accelerometry file, and 2) estimating the additional time required for fieldwork team members to get the accelerometers initialised in advance, to allow this additional time to be factored into team members' working practices.

To minimise the potential for error, a secondary ID number system was developed that comprised the Enumeration Area (EA) code and the accelerometer serial number. The accelerometer serial number was then recorded in the Android tablet under the Participant ID record (which also had EA number) at the time of issue, which enabled linking to participant ID at a later date for analysis. As there is scope for error here, and to provide a check of whether two study participants might have got their accelerometers mixed up, the intention was that this information would be recorded again when the accelerometers were collected, as a further check on the accelerometer serial number provided to the participant. However, in practice the acquisition of this additional linkage information was limited, as participants often removed their accelerometer at the end of the measurement period and left the accelerometer at the village for later collection by the study team rather than having to wait in person. Field work staff could arrive to find several accelerometers left behind for collection, so were unable to record which accelerometer was received from which participant. Screenshots of the relevant forms on the Android tablet is available in Appendix 5, and Table 1 below provides an overview of the information collected.

Table 1: Summary of information collected by the Open Data Kit (ODK) forms in the STEPS Android application

Stage	Name of ODK form	Information collected on tablet forms
Accelerometer deployment	Within the “Step 3” form (which already has linkage to Step 1 & 2 data).	EA Accelerometer serial number Time of start of wear Dominance (right or left handed)
Accelerometer collection	“PA”	EA Accelerometer serial number Time of end of wear Feedback from participant Accelerometer loss (if relevant)
Accelerometer download & quality control	“Download”	Accelerometer serial number Accelerometer download success Technical faults Compliance

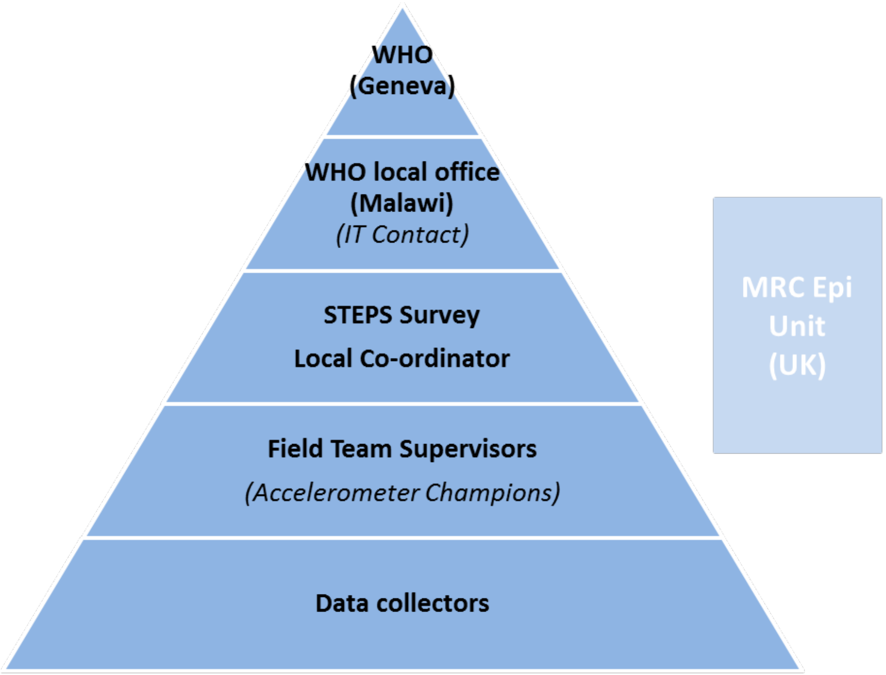
4.4 ADAPTION OF FIELDWORK DOCUMENTATION

Training and participant information documents were adapted to include culturally specific images to suit the local context. A ‘Frequently Asked Questions’ document was produced for both participants and fieldwork staff (See Appendix 3). These were based on the MRC Epidemiology Unit’s experience from data collection in other countries (Cameroon, Kenya, Jamaica, Brazil, India, and the UK). These documents may need further adaptation when used in new contexts.

It can be very helpful to consult fieldworkers early to identify additional cultural or region-specific considerations which had not previously been anticipated. For example, the accelerometer was housed within a watch-strap type band, which is usually black. The fieldworkers identified that this may cause issues in Malawi because of superstitions surrounding the colour black. Although the band is also available in blue from the manufacturer, it was not possible to source an alternative colour at such short notice for the pilot study. For future considerations, this highlights the importance of having preliminary discussions with the people at local sites at the fieldwork planning stage to identify any issues that may require changes to the protocol.

4.5 FIELDWORK TEAM CONFIGURATION

The local coordinator appointed fieldwork team supervisors to manage smaller teams of data collectors as in the standard protocol. Specifically, for this pilot, the coordinator also identified 'Accelerometry Champions' within each team of data collectors who were to be trained to deliver all fieldwork aspects of the accelerometry module (Figure 3). A list of responsibilities for these 'Accelerometry Champions' were sent prior to the training visit, so suitable individuals could be identified (Appendix 2). In Malawi, the Local Coordinator selected the Field Team Supervisors in the two regions as the accelerometer champions.



Adapted from: *http://www.who.int/ncds/surveillance/steps/STEPS_Manual.pdf*

Figure 3: Team configuration (for accelerometer pilot)

4.6 FUTURE PROTOCOL RECOMMENDATIONS

A key consideration is that the host country needs to be provided with a complete overview of the resources required, from protocol design right through to data handling, which was also highlighted previously in the report describing pilot work on pedometers in Tonga (Chau, Keane, Bauman, Kelly, & Richards, 2017). Many of the decisions about protocol design and the likely resource requirements will be specific to the country and the local considerations. For example, for countries with suitable infrastructure, accelerometers could be returned via a postal service, whereas others will need to rely on fieldwork team members to collect monitors directly. If a country has good internet connectivity and speeds, then it becomes very feasible to use cloud storage to transfer accelerometry data and to provide ongoing review and data backup, whereas in other settings data may need to be physically transferred using suitably robust external hard drives.

These considerations can have large effects on the resources needed and on the fieldwork team members’ time demands. For example, ideally monitors should be collected as soon as possible after the wear period, as this reduces the risk of monitor loss, as well as the total number of monitors required for the study (because they can then be redeployed more quickly). However, in areas where participants are widely spread over a larger geographical area, it may be more efficient to collect monitors at a later date when fieldwork teams would next be in that area.

An important consideration is at what stage the accelerometry data collection should be included within the STEPS program. In this pilot study, the decision was taken to fit the accelerometers at the end of Step 3, rather than at Step 2, to avoid the physical activity measurement period being influenced by attending a clinic visit for Step 3. However, the protocol could be adapted to fit the accelerometer during Step 2, but delay the accelerometer data recording to only start say 24 hours later, so the monitor would start recording after the scheduled clinic visit for those taking part in Step 3. Although this would increase the time the participant was physically wearing the monitor to 8 days, the added participant burden is likely to be small. This adaptation of the protocol is also only feasible where the Step 3 measurement was carried out in relatively close proximity to Step 2. For example, within the Malawi STEPS program the clinic visit for Step 3 was usually scheduled for the day after the Step 2 measurements, making a delayed start feasible.

5 TRAINING

Accelerometry training was embedded into the STEPS training programme and delivered to the local Malawi fieldwork team by Soren Brage (SB) and Kate Westgate (KW) from the MRC Epidemiology Unit. Following discussion with the WHO and local co-ordinating centre, training was scheduled as one informal staff pre-pilot session and two more formal lecture/workshop sessions:

1. Staff pre-pilot session where members of staff wear the accelerometer for a day.
2. An initial formal session delivered to all data collectors (approx. 40) which provided an overview about the accelerometry sub-study (lecture style).
3. A more detailed practical training session delivered to the 'Accelerometry Champions' and a few other fieldwork team members who would be directly involved with the accelerometry data collection (six people in total). This session was designed as a small group workshop, where the 'Accelerometry Champions' would become familiar with all aspects involved in the accelerometry sub-study, as well as building in some resilience in case of staff absence. It covered the technical and practical aspects of initialising accelerometers on the laptops, downloading data from the accelerometers, and the basic principles of quality review to flag any issues relevant for ongoing field work (e.g. identifying a faulty monitor so it can be removed from the pool, avoiding it being used again).

5.1 PRE-PILOT SESSION – STAFF MEMBERS WEARING ACCELEROMETER FOR ONE DAY

Ten volunteers from the field team were asked to wear an accelerometer continuously (including overnight) until the following day's training session. This provided fieldwork team members with practical experience of wearing the accelerometers and promoted useful discussion, as well as providing 'real' data to download and investigate at the second training session.

5.2 SESSION 1 – OVERVIEW OF THE PHYSICAL ACTIVITY ASSESSMENT FOR ALL FIELD WORKERS

The whole group of field workers were given an introduction to objective physical activity monitoring in STEPS by a presentation covering:

- Introduction to accelerometry
- Overview of using the accelerometer and the data collection protocol
- What information is obtained from the accelerometer
- How to place an accelerometer on a participant
- How to provide an explanation to a participant
- Discussion, which included the experiences of those who had worn an accelerometer for the previous 24 hours.
- Frequently asked questions (FAQs) and responding to likely scenarios

Following demonstration and instruction on how to place the accelerometers on participants, field workers were provided with accelerometers and straps to explore in pairs. They were then provided with a Quick Reference Guide (see Appendix 4) and were asked to explain and attach the accelerometer to their partner in a role-play exercise, with facilitators checking these had been put on correctly.

5.3 SESSION 2 – WORKSHOP FOR THE 'ACCELEROMETRY CHAMPIONS'

The WHO local co-ordinator identified two fieldwork team leaders to become 'Accelerometry Champions' within the two chosen regions for the accelerometry sub-study. This second training session was aimed primarily at these 'Accelerometry Champions' who would be operating the PC software and setting up accelerometers during the field work, and other members of the fieldwork team who would be directly involved in the data collection (and who could step in as `Accelerometry Champion' if need be).

Training session:

- Working with the PC software ("OM GUI")
- Initialising accelerometers
- Downloading accelerometers
- Quality review (workshop looking at real data and selection of example files)
- Accelerometry record keeping (system logs etc)
- Logging information into 'Open Data Kit' (ODK) forms on the Android tablets
- Discussions on practicalities and logistics (e.g. collection of accelerometers)
- Data backup procedures (e.g. backing up onto external hard drives)

5.4 TRAINING EVALUATION

Overall, the training was well received. Fieldwork team members were interested in the training, as evidenced through lively discussions and engagement during both training sessions. Several team members volunteered to wear the accelerometers for a day as a "test-run" so they could see and download real data. This practical training provided reassurance that the participant burden was low, and that they were easy to use and wear. Enabling fieldwork team member to experience wearing accelerometers was very valuable, as this raised several issues they believed may be of concern to study participants. For example it demonstrated to them how robust the accelerometers were, as concerns about damage to accelerometers can result in non-wear.

5.5 TRAINING RECOMMENDATIONS

5.5.1 IT recommendations

Identification of a technical lead or IT contact with sufficient advance notice is key to ensuring IT requirements are in place prior to training being delivered. All IT equipment needs to be tested in advance of any training, so that fieldworkers can use the same hardware and the exact same version of the software that will be used within the study itself. This includes ensuring the latest versions of any electronic forms are installed on the tablets, so training can take place using the same processes that will be used during the study.

5.5.2 Attendee recommendations

The 'Accelerometry Champions' should be identified in advance of face-to-face training, so that they are prepared and motivated. It may be preferable for these to be data collectors rather than fieldwork team leaders, so they can focus on attending the accelerometry training (given team leaders have a number of other sessions to attend within the wider STEPS training week).

While all fieldworkers should be trained in explaining and fitting the accelerometers on study participants, only the 'Accelerometry Champions' need to be trained in the more technical aspects of the accelerometer use, such as initialising accelerometers, downloading data, reviewing data and identifying any accelerometer issues before a device is put back into circulation.

5.5.3 Content recommendations

Fieldwork documentation, such as FAQs, should be provided in advance of the training to give staff a good background and allow data collectors to become familiar with what is involved.

Training should include the complete process of accelerometry fieldwork, from deployment of devices through to data back-up. This ensures fieldwork team members are trained in all aspects of the data collection and handling, as well as checking processes and IT. It is recommended that the accelerometry deployment should be included during the run-through of the full STEPs program at the end of the training week.

It is extremely valuable for fieldwork team members to wear the accelerometer; it allows staff to become familiar with all parts of the process prior to actual data collection as well as giving them confidence to answer questions from study participants.

It is also very helpful if fieldwork team members can show study participants example data, as this can improve compliance. It can help study participants understand that researchers will be able to tell if the accelerometer is worn or not. It can also reassure study participants that researchers can only see activity intensity, not exactly what people are doing, which can help reassure them of their privacy.

Although the resources were not available for this pilot, videos would be an extremely useful way to improve training, reducing the need for face-to-face training requirements, as well as potentially improving consistency. Once produced, training videos could be made freely available via the web or physical copies could be shared in advance of fieldwork team training.

6 ACCELEROMETRY FIELDWORK

6.1 ACCELEROMETRY FIELDWORK MONITORING

The fieldwork monitoring process is outlined in Figure 4. Ongoing review of data collection during the fieldwork phase is essential for identifying issues early and allowing intervention to optimise adherence to protocols and minimise data loss. For example, spotting early that some participants would consistently take off their monitors at night necessitate reminding field workers of the precise instruction given to participants that monitors should be worn 24/7. Another example would be identifying faulty accelerometers as soon as they are downloaded so that these devices can be removed from the testing pool and not re-used. Ongoing data quality control can also identify missing data rapidly, increasing the chance of retrieval, for example if a particular computer or tablet device is not downloading or uploading data correctly, or an accelerometer file has only been partially downloaded.

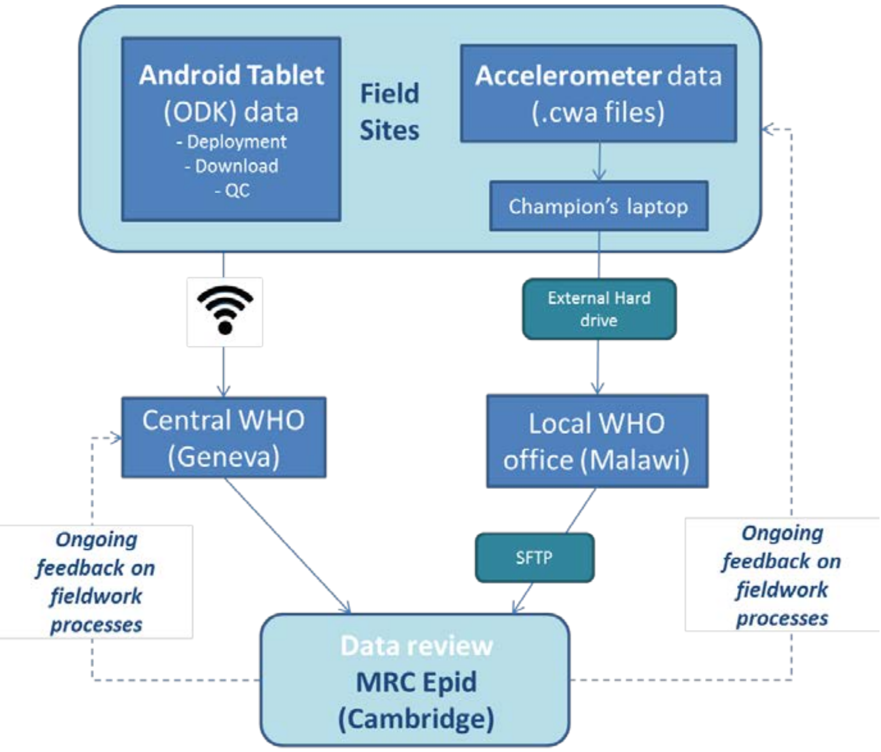


Figure 4: Plan for data review and support during data collection

At the point of downloading accelerometers it was intended for the fieldwork team members to do some basic quality control checks and record these on the ODK "Download" form on the tablet devices used in the field. This information included:

- Number of days of data recorded
- Compliance to wear protocol
- Successful downloading of the accelerometer (to help identify missing data files)
- Identification of technical issues (to prevent redeployment of a faulty accelerometer)

However, a key issue was that raw accelerometry files are relatively large, at approximately 350 megabyte per person for a 7-day recording. Accelerometers needed to be downloaded to laptops or PCs using a direct USB connection, so this was done by the accelerometer champions in the fieldwork team at their lodgings in the field. Accelerometry files were then backed up to external hard drives ready for physical transfer to the nearest WHO hub, as local internet speed and availability prevented online transfer.

Originally it was planned to send files electronically from the local WHO hub using secure file transfer protocol (sftp) over the internet to the MRC Epidemiology Unit to allow timely review whilst the pilot fieldwork was ongoing. However, this proved unfeasible owing to local logistical challenges, and ultimately data were physically sent on hard drives to Geneva, where files were then compressed and sftp was used to transfer the accelerometry files to the MRC Epidemiology Unit for review.

6.2 ACCELEROMETRY FIELDWORK EVALUATION

There were no technical issues with the accelerometers during the pilot, although a small number of straps were broken which may be an issue where manual labour or particularly demanding conditions are more common. A total of 19 monitors were lost during the pilot within the two regions, from a total of 475 instances of monitors being issued (4% loss rate).

In practice, accelerometer collection after the monitoring period was often carried out without the study participant being present because the study participant often left their accelerometer at the village for collection, to avoid having to wait at the village in person for the fieldwork team. This prevented a second check of the PA_ID number (monitor serial number) at the time of accelerometer collection and as the primary ID linkage system was not 100% failsafe, this meant that some data files downloaded from accelerometers could not subsequently be linked with study participant information. In total only 286 files (out of 456) had an ODK form completed with the additional participant ID check at collection; 99% of these did however have matching information to that collected at the point of issuing the accelerometer to the participant.

Communication proved to be challenging during the study, as the ‘Accelerometry Champions’ were almost exclusively based in the field and contact was intermittent due to limited internet availability. On completion of data collection from the first two EAs, the accelerometer data were scheduled to be transferred to the MRC Epidemiology Unit for review to identify protocol and technical issues. However, whilst the ‘Accelerometry Champions’ provided these data to their local IT team via external hard drives, the data were not then forwarded onto MRC using secure file transfer (SFTP) by the IT team owing to local logistical issues. Therefore, the MRC Epidemiology Unit was unable to assess data quality until the very end of the study, limiting the opportunity to intervene proactively during the data collection period.

The transfer of data from the electronic tablets used within the field to the WHO in Geneva was delayed due to internet connectivity issues across the field sites. On completion of the fieldwork it was identified that the data from one tablet device had not been uploaded due to a technical issue. However, as this was not identified until after the fieldwork was completed it was only possible to recover this data once tablet devices had been returned to Geneva.

6.2.1 Accelerometry fieldwork evaluation by study staff

The MRC Epidemiology Unit sought feedback from the 'Accelerometry Champions' and the local fieldwork co-ordinator at the end of the data collection period via questionnaire (Appendix 6). Overall fieldwork team members were very positive about the accelerometry fieldwork and commented they found it an interesting experience explaining accelerometers and physical activity data to volunteers.

One of the key logistical and time issues for fieldwork team members was the issue of needing a power supply for accelerometer set up. Power problems are common within this area of Malawi and electricity black-outs occurred frequently. The fieldwork team member's lodging had back-up generators, but this meant all accelerometry set up had to be done at the lodgings in advance. Accelerometers were initialised in batches of seven and it took 30 minutes to prepare all the accelerometers needed for an EA. If the accelerometers also needed to be downloaded, cleaned and re-initialised after use, then this extended the process to around an hour.

A further issue with accelerometers being initialised in advance was that this was before participants consented, so the accelerometers had to be set up without participant ID information. Fieldwork team members found it hard to keep track of accelerometers, so they developed a paper log to track which accelerometers were being worn by which study participant at any one time.

A benefit of accelerometry being part of Step 3 was that participants were typically grouped together in one location, which allowed fieldwork team members to explain the use of accelerometers to groups of participants rather than to each participant, which reduced the time burden on the fieldwork team.

However, with accelerometry happening at the end of Step 3, supervisors had to return to the previous EA for the last participants tested when accelerometer collection was due. This was easy when testing was in adjacent EAs, however, it was considerably more challenging to cover larger distances when EAs were further apart. Although participants were told the collection date and time in advance, some did not leave monitors for collection so these participants had to be visited at their homes, which again increased the cost and resource requirements. Ideally, accelerometers should be collected as close to the end of the monitoring period as feasible, to reduce the total number of accelerometers needed for the study and to minimise accelerometer loss (longer duration for accelerometer retrieval increases the risk of not getting accelerometers back).

6.2.2 Accelerometry feedback by participants

Only four out of the 479 individuals who were offered to wear the accelerometer refused to take part in this component of the survey. No formal feedback from participants was collected on their experiences with wearing the accelerometer. The following is an extraction of the incidental/anecdotal feedback participants relayed to the field staff and reported to us by the 'Accelerometry Champions'. In general, there were not many participant concerns because the accelerometry was explained well by the fieldwork team members. By default, the accelerometer straps were supplied in black, but for some participants this colour was associated with superstitions about vampires or Satanism. The same was true for certain monitor serial numbers (*666*) which were associated with the Devil. This was not identified sufficiently far in advance to be able to offer accelerometer straps in alternative colours (or swapping their monitor for one without triple 6 in the serial number). Some participants were also concerned that wearing a strap or coloured band would 'label' them in some way, such as the way they voted in elections. Whilst some were concerned that the accelerometer could track where they went or who they spoke to. Within the pilot the fieldwork team members were largely able to reassure participants about all of the identified issues related to wearing the accelerometers.

In some cases, it was clear to field staff that accelerometers had been removed and re-positioned. This issue is not uncommon in population studies and is difficult to completely avoid. Study participants may remove a monitor for a variety of reasons, such as curiosity or to keep the monitor safe (for example if they worry about getting it wet or damaged). This can be minimised by careful explanation and instruction at the beginning of the wear period as well as by providing information on how to re-fit the accelerometer in the event it is removed to ensure it is put back on in the correct position. Some study participants had an expectation of receiving 'tokens' or money, although this was not the case for the accelerometry component per se.

Participants will often express an interest in seeing their own data or receiving some feedback, such as how active they are in comparison to others. This is a common request and the fieldwork team members commented that study participants in this pilot also asked if they could see their data. However, this was not possible as field staff members were unable to download the accelerometer data at the time of collecting the accelerometer from the participant.

Providing some feedback about activity levels can be both interesting and helpful to the participant and can encourage individuals to take part as well as helping improve compliance with the wear protocol over the 7 days of monitoring. To date, only few large-scale population studies have provided participant feedback on activity levels. This is partly because of the logistics since accelerometry files need to be downloaded, followed by some level of interpretation or additional information to provide context, which cannot easily be done instantly. Therefore, providing feedback may also considerably add to study costs as it requires a mechanism to provide this information back to the participant, such as via a postal system or a password-protected online portal.

6.3 ACCELEROMETRY FIELDWORK RECOMMENDATIONS

The requirement to set-up accelerometers in advance with a direct USB connection to a laptop or desktop PC increased the fieldwork team burden significantly, especially as accelerometer set-up was restricted to times and locations where IT and power facilities were available. This limitation also meant accelerometers were set up in advance without knowledge of the participant ID, necessitating an alternative ID linkage method which was not perfect and thus resulting in some files that could not be linked. The planned additional ID check at download was also hard to implement in practice, as participants often left their accelerometer at the village for later collection.

Although not possible to do at the time when this pilot was conducted, it is now possible to set-up and download accelerometers using a USB cable connected to an Android tablet device, which would allow monitors to be set up in the field with the study participant present, for example in the clinic at Step 3. This would provide a significant time-saving for fieldwork members as monitors would not need to be set up in batches in advance; they only need to be charged. This tablet initialisation facility also allows the participant ID to be directly encoded in the accelerometry file, avoiding problems with linking accelerometry files with participant information. Using the same tablet devices as used for the other survey components would also reduce the need to train fieldwork staff in the use of specialist software, as well as avoiding the need for additional resources such as laptops / PCs which was needed for this pilot.

Theoretically, if fieldwork tablets are being used for accelerometer initialisation and download, it should also be possible to use the tablet devices as an inventory of which monitors were out in the field at any one time, on which study participant and where, avoiding the need for paper records to keep track of the accelerometers in use; this would make the monitor retrieval process smoother and with less scope for error. The download-to-tablet option does, however, realistically require transfer of the files to an external hard drive as tablet hard drives tend to be limited in capacity but this could easily be done by reworking logistics slightly, perhaps redefining the role of the Accelerometry Champions to be responsible for this task.

The MRC Epidemiology Unit has recently developed software to provide automated quality control checks at the point of accelerometry download by quick analysis of the accelerometer file. Amongst other things, this extracts the accelerometer serial number, whether data downloaded correctly, the number of days recorded, whether the accelerometer was working properly (data integrity), monitor battery health, etc. This would not only provide an early quality control check on the data being collected but also allow identifying monitors not working correctly so that these are not being put back into circulation in the study. This software is open source and available for anyone to use, and it is recommended that this or something similar is fully integrated within the wider WHO IT infrastructure in the future.

6.4 DATA HANDLING EVALUATION

The WHO provided data to allow linking accelerometer data with demographic information, such as sex, age and geographical location. This data matching was carried out using the accelerometer serial number and EA, in order to match to the participant identifier, as it was not possible to include the participant ID directly within the accelerometry file (as explained in section 4.3).

Standard pre-cleaning checks of the accelerometer files included:

- Duplicate file checks
- Filename errors
- Missing files
- All expected data files present

The most common errors were due to accelerometry files being set up with the incorrect EA. This could be checked post-hoc and if it was in conflict, it was corrected by checking the EA for the visit date in order to enable file matching on the pseudo ID (EA + serial number), also known here as the PA_ID. There were also errors with recording the accelerometer serial number into the ODK form. Some of these were obvious transcription or typing errors and could be cleaned and corrected because only a small number of monitors were in use within each EA thus narrowing down the possible numbers.

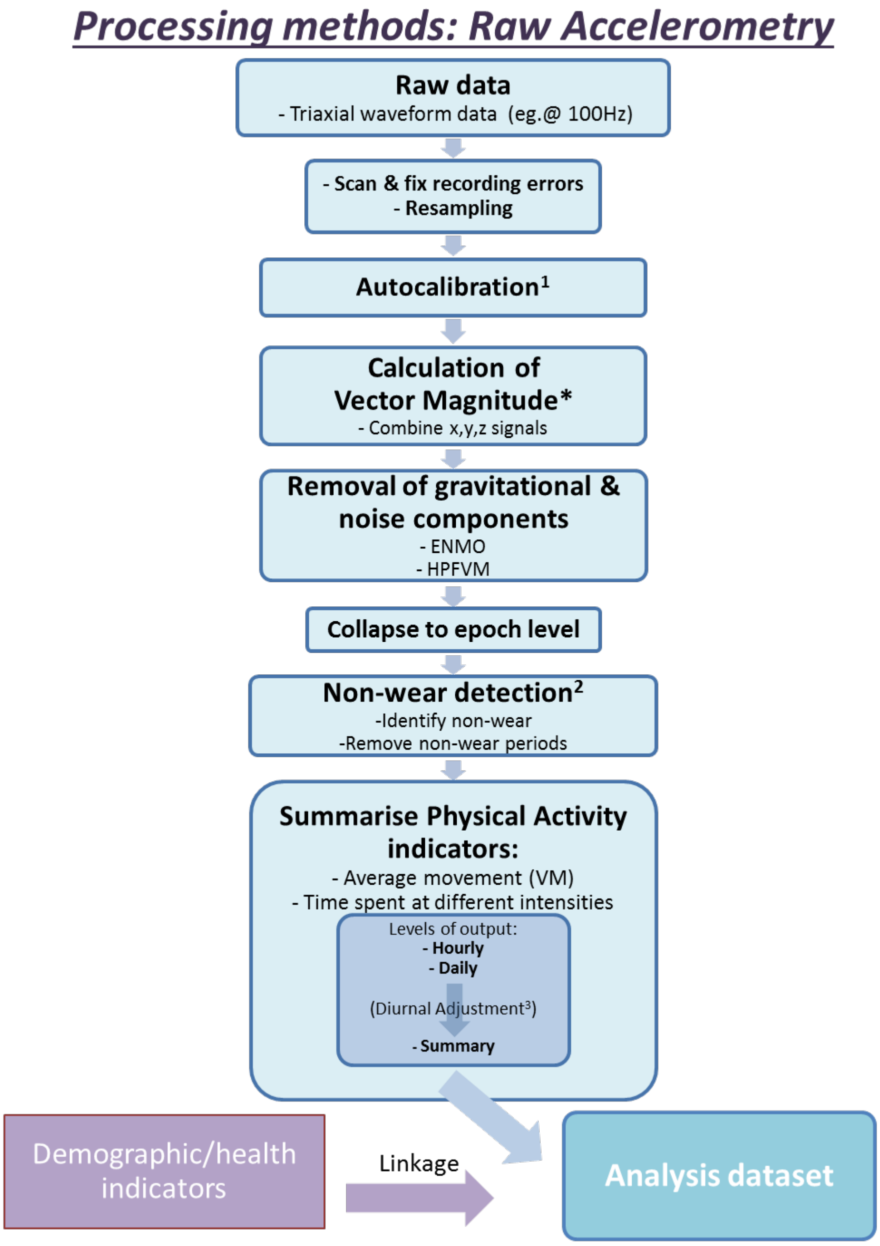
6.5 DATA HANDLING RECOMMENDATIONS

The total volume of data for this pilot (uncompressed) was approximately 155 GB for a total n=456 accelerometry files. This can be reduced slightly using file compression methods, such as zip files. However, given the file sizes involved, physical transfer of suitably robust hard drives may be more feasible than internet transfer or cloud storage, especially in countries or regions where internet availability and speeds may be limited.

If the process of setting up accelerometers in advance is to be used again, then additional systems need to be put into place to capture accelerometer serial numbers and limit missing data or transcribing errors. For example, the field-testing tablets could be used to scan a barcode on the accelerometer, similar to the QR code which has previously been placed on blood samples. Alternatively, the ODK form could be prepopulated with a list of current accelerometer serial numbers so the fieldwork team member just had to select the monitor number, reducing typing errors but possibly also increasing the risk of accidental monitor mismatch. As a further check ODK forms could be programmed so that specific fields are compulsory, such as monitor serial number, so as to avoid collecting accelerometry data that cannot subsequently be matched to a participant.

7 DATA PROCESSING METHODS FOR PHYSICAL ACTIVITY INDICATORS

Indicators of physical activity were derived from the collected accelerometry data as a proof of concept for this pilot. Raw accelerometer data files were processed using an open-source program ("pampro" http://www.mrc-epid.cam.ac.uk/research/resources/) according to standard procedures (see Figure 5) developed by the MRC Epidemiology Unit and follows the principle of complete transparency as recommended elsewhere (van Hees et al., 2016).



VM = Vector Magnitude
ENMO = Euclidean Norm Minus One
HPVVM = High-Pass Filtered Vector Magnitude

References: [1]van Hees, JAP 2014, [2]van Hees, PLoSOne 2011, [3]Brage, ICAMPAM Conference Poster 2013,

Figure 5: Key stages of raw accelerometer data processing

7.1 DATA INTEGRITY

Accelerometer data are stored on the memory chip in blocks and sectors. On-chip management systems usually keep track of potentially bad data sectors which should not be used, but this is not a completely failsafe system (but almost). Data integrity of raw accelerometer data is therefore always checked; a process which involves scanning each file for various data anomalies. These include major deviations in data sampling frequency, and different corruptions and interruptions in the time-stamps that are stored alongside the accelerometer measurements.

7.2 CALIBRATION TO LOCAL GRAVITATIONAL ACCELERATION

Raw data from Axivity AX3 monitors are not calibrated at the point of manufacturing but there is usually plenty of data in the files themselves to allow this standardisation of measurements. Raw acceleration data are calibrated using local gravity as a reference measure (van Hees et al., 2014). The method involves identifying segments in the data when the accelerometer is not moving, during which the vector magnitude of the three axes must equal 1 gravitational unit. Axes are scaled (calibrated) across the whole dynamic range of +/-8g, so that the agreement with 1g during non-movement is optimised; the specific method used for this stage of processing also compensates for temperature differences in the accelerometer`s sensitivity to acceleration.

7.3 CLASSIFICATION OF ACCELEROMETER WEAR AND NON-WEAR

Following calibration to local gravity, the accelerometry trace is classified for time segments of wear and non-wear, using the criteria of standard deviations of the acceleration in each axis all being lower than the intrinsic sensor noise level (10mg) for an extended period of time (>60 min). These wear/non-wear segments are taken into account when summarising the data for each participant, in such a way that wear data from the 24 hours in the day are weighted equally. This process, known as diurnal bias adjustment, reduces overall within-person time bias when there is at least some data available in all segments of the day (Brage et al., 2013).

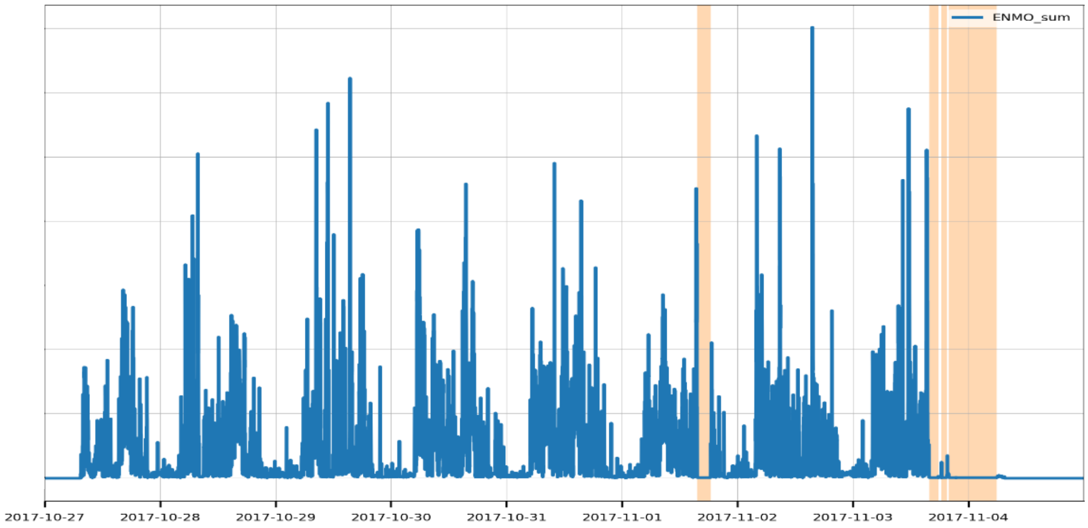


Figure 6: Example accelerometry trace from a participant (shaded areas indicate non-wear)

An example trace is shown in Figure 6 for one participant, with non-wear episodes indicated as blocks shaded in orange. This particular individual wore the device for about 8 days with the days and nights easily identified in the plot, as higher levels of activity recorded during the days and long bouts of lower levels of activity recorded during the nights.

Data included in this report was processed in 5-sec intervals (analysis epochs); note, however, that the data are plotted in 1-min epochs in Figure 6 for a smoother appearance.

Section 8.3 describes compliance with the wear protocol for the pilot sample. The inclusion criteria for the results in this report were set at >48 hrs of total wear, with at least 8 hours in each of the four time quadrants (00:00-06:00, 06:00-12:00, 12:00-18:00, and 18:00-24:00).

7.4 GENERATING PHYSICAL ACTIVITY INDICATORS

Each accelerometry file in the study is summarised to produce the following physical activity indicator variables:

- Overall physical activity volume (average ENMO aka movement intensity, in mg).
- Time spent at different movement intensities, which is further collapsed into broader categories of time spent in sedentary, light (LPA), and moderate-to-vigorous intensity activity (MVPA).
- A further summary variable for each participant to assess whether the participant accumulated at least 60 minutes of MVPA per day in 5-sec epochs is produced as an example of a binary classification of the participant being active or inactive.
- Averages for each hour of the day for each participant are also produced to illustrate what the diurnal profile of movement looks like.

The generated indicators of physical activity included here are not designed to be exhaustive in terms of what could be derived from raw accelerometry data as new inference methods are constantly being developed. The included results do, however, represent robust summary statistics which involve little or no inference, which should always be reported and is thus likely to stand the test of time.

7.5 LINKING ACCELEROMETRY AND MAIN SURVEY DATA

The full STEPS survey included 4,206 individuals, including 499 individuals from the two regions designated for the accelerometry pilot (Dowa and Lilongwe). Figure 7 shows a flow diagram of the survey and accelerometry data collected, linkage between them, and possible reasons for data loss. A total of 53 individuals of the 499 attending Step 1 and 2 within these two regions did not attend Step 3, leaving 446 participants eligible to wear an accelerometer. Only four individuals (<1%) declined to wear the accelerometer but one additional participant forgot to take the accelerometer with him before leaving the clinic, meaning 445 survey participants left the clinic with a monitor. Of these, 13 monitors were lost, and we would thus be expecting 428 accelerometer files. However, a total of 456 accelerometry files were collected and 19 monitors were lost during the pilot, which means that all in all 475 monitors were deployed (to 480 potentially eligible individuals if we add the four refusals and the one who forgot to bring it home). It is possible that the discrepancy is explained by a combination of factors, including the survey “gaining” a few participants at Step 3 who happened to have come along with a friend or family member, or that there were errors in the

Participant ID in the ODK data collected at Step 3 (a total of 463 raw data entries were made at Step 3 of which only 437 could be merged directly with Step 1 data). In any case, accelerometry data and ODK could be successfully linked for 410 recognised survey participants, of which 386 participants (87% of those eligible) are included in the final analysis; one file failed to calibrate and 23 participants were excluded because they did not wear the monitor for at least 48 hours and with 8 hours in each quadrant of the day.

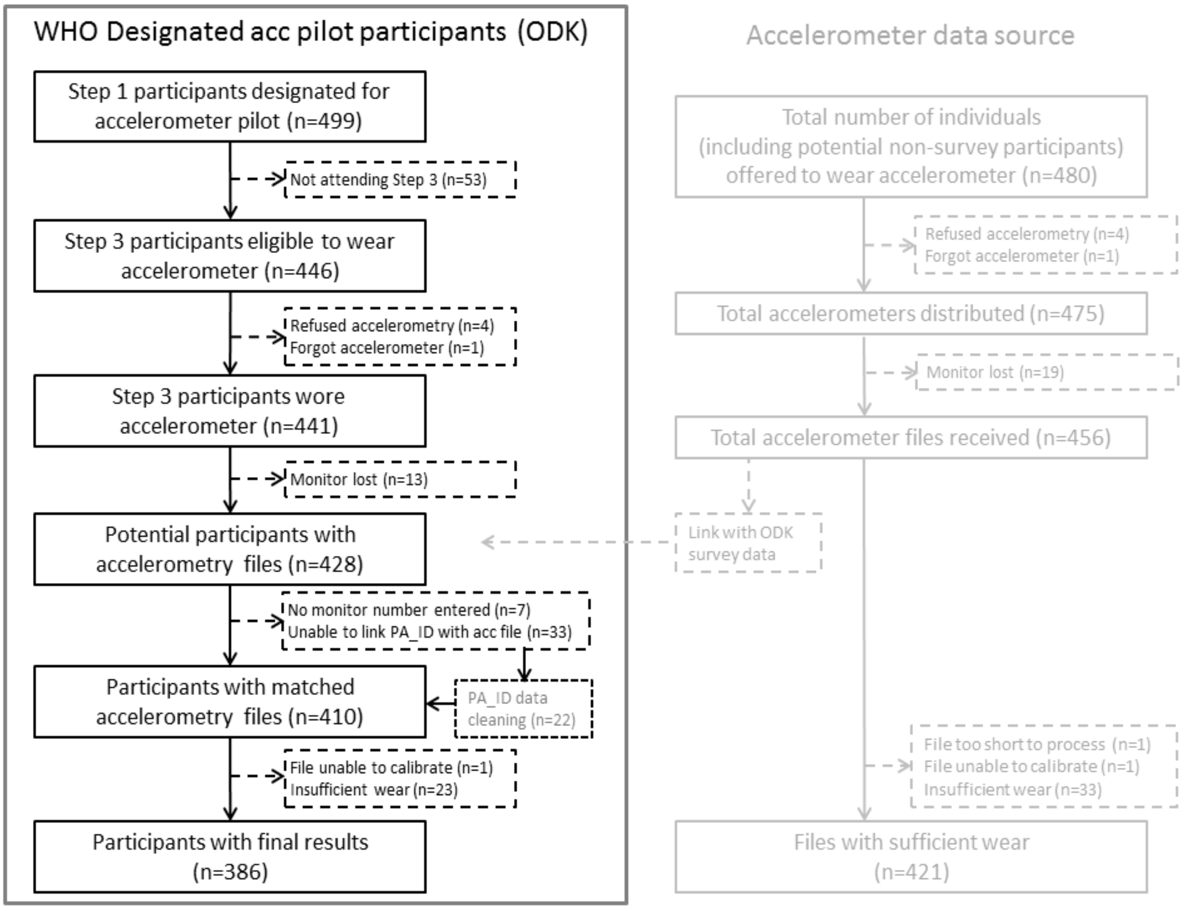


Figure 7: Data availability for accelerometry pilot

8 RESULTS

8.1 ACCELEROMETRY DATA INTEGRITY

The vast majority of the 456 accelerometer files retrieved were well-formed and of high technical data quality; only two (<1%) of these could not be processed by standard methods to produce summary activity indicators. One file had insufficient data to process (less than 1hr of data recorded in total), possibly due to error during download. Of all the anomalies checked for in the QC process, only 1 file had a data anomaly (technical fault in the device) that resulted in a significant proportion (78%) of the file being unusable; such files are still included if fulfilling wear time criteria. The impact of other anomalies was minimal, resulting in an average of only 0.8% of each file being unusable and leaving the majority of the data usable.

One file could not be calibrated to gravity as there was insufficient still bout data within the file and the accelerometer was only worn by one person before being lost, so calibration factors for this device could not be borrowed from other participants' files collected with the same monitor.

8.2 COMPLIANCE WITH MONITOR WEAR PROTOCOL

As indicated in figure 7, it is not straightforward to report what the participant compliance with the monitor wear protocol is, since it is challenging to work out the exact denominator from potentially conflicting pieces of information between the various components of the survey as per the issues highlighted in the data linkage section. Therefore, the following will report protocol compliance in a couple of different ways which makes different assumptions about the denominator population, whereas the numerator for the main reporting of this figure is the number of participants with valid accelerometer files defined as those which could be calibrated to gravity and contained at least 48hrs of wear and with >8hrs in each quadrant of the day.

A total of 446 survey members (as recognised by the WHO database) were offered to wear an accelerometer. Of these, valid accelerometer data could be reported for 386 participants, which yields a response rate of 87%. Whilst this number may be most informative for judging highest risk of possible selection bias of the information collected and reported (by multiplying with the overall response rate to the survey), it is not a fair representation of participant compliance per se. This is because 18 accelerometer files could not be linked to survey data due to issues with implementation of the id numbering system and/or errors in the ODK data from Step 3 and this phenomenon is most likely unrelated to participant-level factors that may causally impact compliance and selection bias. Therefore, based on the number of accelerometer files with sufficient valid data from recognised survey members who had a fair chance to be in the dataset, participant compliance was 90% (= 386/428). This denominator includes monitors lost by recognised WHO survey participants (n=13) and those that refused to wear a monitor (n=4) or forgot to bring it with them when leaving the clinic (n=1). The monitor loss rate was 2.9% (=13/441) as this is calculated on the basis of number of monitors deployed to participants.

A third alternative calculation of participant compliance is based on the total number of valid accelerometer files in the whole study as a percentage of all accelerometers issued/offered regardless of whether or not there was any accompanying survey database information; this denominator includes a total of 19 lost monitors, 4 refusals, and one forgetful participant, as well as the 456 retrieved accelerometer files and it is possible that not all of those were actual survey participants. This comes in at 88% (= 421/480). The advantage of this calculation is that it is not influenced directly by data linkage errors but the disadvantage is that it may not represent a random sample of the Malawian population to the same degree as the survey does. With this same caveat, the monitor loss rate across the whole study was 4.0% (=19/475).

Table 2 below lists compliance figures under these three main ways of calculating compliance outlined above including also results using stricter definitions of what constitutes valid accelerometer data in terms of monitor wear.

Table 2: Participant compliance by different wear time criteria

Wear-time inclusion criteria (total / quadrant)	Number of participants (% of total*) providing valid data	
	WHO recognised survey participants (denominators n=446 and n=428)	Total number of people offered to wear monitor in Malawi (denominator n=480)
48hrs / 8hrs	386 (86.5% and 90.2%)	421 (87.7%)
72hrs / 18hrs	381 (85.4% and 89.0%)	415 (86.6%)
96hrs / 24hrs	375 (84.0% and 87.6%)	408 (85.2%)
120hrs / 30hrs	372 (83.4% and 86.9%)	405 (84.6%)
144hrs / 36hrs	369 (82.7% and 86.2%)	400 (83.5%)
168hrs / 42hrs	352 (78.9% and 82.2%)	382 (79.8%)

*include participants who were offered but declined to wear a monitor and those who lost their monitors during wear

8.3 PARTICIPANT CHARACTERISTICS OF ANALYTICAL SAMPLE

Sample characteristics are presented for the 386 recognised survey participants included within the pilot study who had a sufficient amount of valid accelerometry data. Of those, two thirds were women and three quarters lived in rural areas. The two youngest age groups (18-29y and 30-44y) were the most represented in the dataset, with about a third each.

Table 3: Participant characteristics

	Total	**Men**	**Women**
N	386	133	253
Urban (%)	94 (24%)	27 (20%)	67 (26%)
Rural (%)	292 (76%)	106 (80%)	186 (74%)
Age (yrs)	38 (14)	38 (14)	38 (14)
18-29y	128 (33%)	42 (32%)	86 (34%)
30-44y	141 (37%)	52 (39%)	89 (35%)
45-59y	80 (21%)	22 (17%)	58 (23%)
60-69y	36 (9%)	16 (12%)	20 (8%)

Data are n (%) or mean (sd).

8.4 LEVELS OF PHYSICAL ACTIVITY IN MALAWI

Summary results are presented at two levels; participant-level and diurnal profile-level with stratification by age, sex, and urban-rural residency.

8.4.1 Participant-level estimates

Table 4 shows participant-level results by age and sex strata. Although the sample is too small to make firm assertions about differences, particularly for men, physical activity appears to decline with age as has been observed in other populations (Doherty et al., 2017; White et al., 2016). Younger men appear more active than women, whereas men and women are more similar at middle age and women are more active above 60 years of age in this sample.

Table 4: Accelerometer-assessed physical activity by age and sex

	Overall	Age group (yrs)*							
		18-29y		30-44y		45-59y		60-69y	
		M	W	M	W	M	W	M	W
N	*386*	*42*	*86*	*52*	*89*	*22*	*58*	*16*	*20*
Wear time (hours)	188 (21)	191 (12)	186 (21)	190 (18)	188 (21)	186 (31)	189 (22)	186 (24)	188 (8)
PA volume (mg)	45 (17)	54 (21)	44 (13)	51 (16)	44 (14)	47 (17)	44 (19)	23 (10)	41 (16)
Sedentary and sleep (hours/day)	16.3 (1.6)	16.2 (1.4)	16.1 (1.3)	16.3 (1.5)	16.1 (1.3)	16.8 (1.6)	16.2 (1.9)	18.9 (1.4)	16.2 (1.7)
LPA (mins/day)	341 (69)	309 (54)	358 (54)	316 (61)	361 (58)	299 (71)	361 (84)	265 (67)	376 (63)
MVPA (mins/day)	119 (57)	161 (68)	116 (46)	145 (54)	113 (44)	131 (54)	104 (56)	41 (37)	94 (55)
Prevalence of MVPA >60min/d**	328 (85)	41 (98)	76 (88)	49 (94)	80 (90)	21 (95)	43 (74)	4 (25)	13 (65)

Data are mean (sd). Total PA volume is expressed as the Vector Magnitude (Euclidian Norm) of the three axes minus 1G (Gravity) and reflects the activity-related acceleration, ie. the amount of movement (aka ENMO, Euclidian Norm minus One). Sedentary time is the proportion of the day spent at ENMO levels below 30 mg, LPA (light intensity physical activity) is the proportion of the day spent at ENMO levels between 30 mg and 135 mg, and MVPA (moderate-to-vigorous intensity physical activity) is the proportion of the day spent at ENMO levels above 135 mg (equivalent to 3 METs in UK adults observed during free-living). *One man outside the age range was excluded from age-stratified analysis. **Prevalence n(%) of MVPA>60min/d calculated as accumulating over 60 min/d of 5-second unbouted activity >135mg.

Figure 8 shows results further split by urban-rural residency. Rural dwellers are generally more active than urban dwellers across the age groups, with one exception of the oldest men. However, the sample size is very small within these older age groups. The pattern for MVPA is largely similar to that of total volume and absolute levels depend entirely on the chosen cut-point for MVPA.

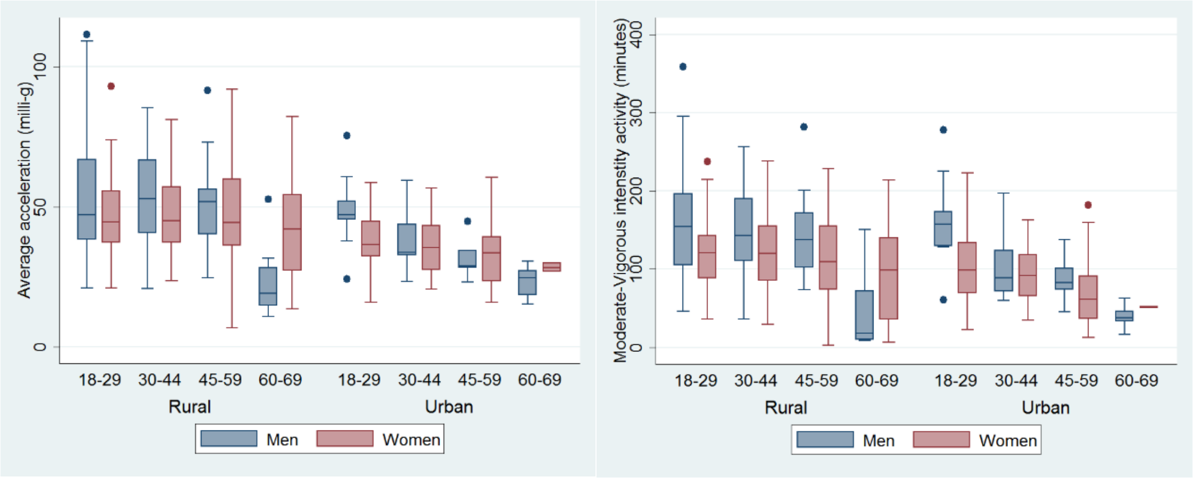


Figure 8: Total activity volume (average activity-related acceleration, left panel) and moderate-to-vigorous physical activity (right panel) by age, sex and urban-rural residency. Boxes represent 25th, 50th, and 75th percentiles, and whiskers indicate interval for most of the variability outside the upper and lower quartiles (individual outlier points plotted separately)

Figure 9 and figure 10 show the full intensity spectrum by age and urban-rural residency, respectively, from which it is clear that younger individuals and rural dwellers have positively-shifted distributions towards the higher end of the intensity spectrum.

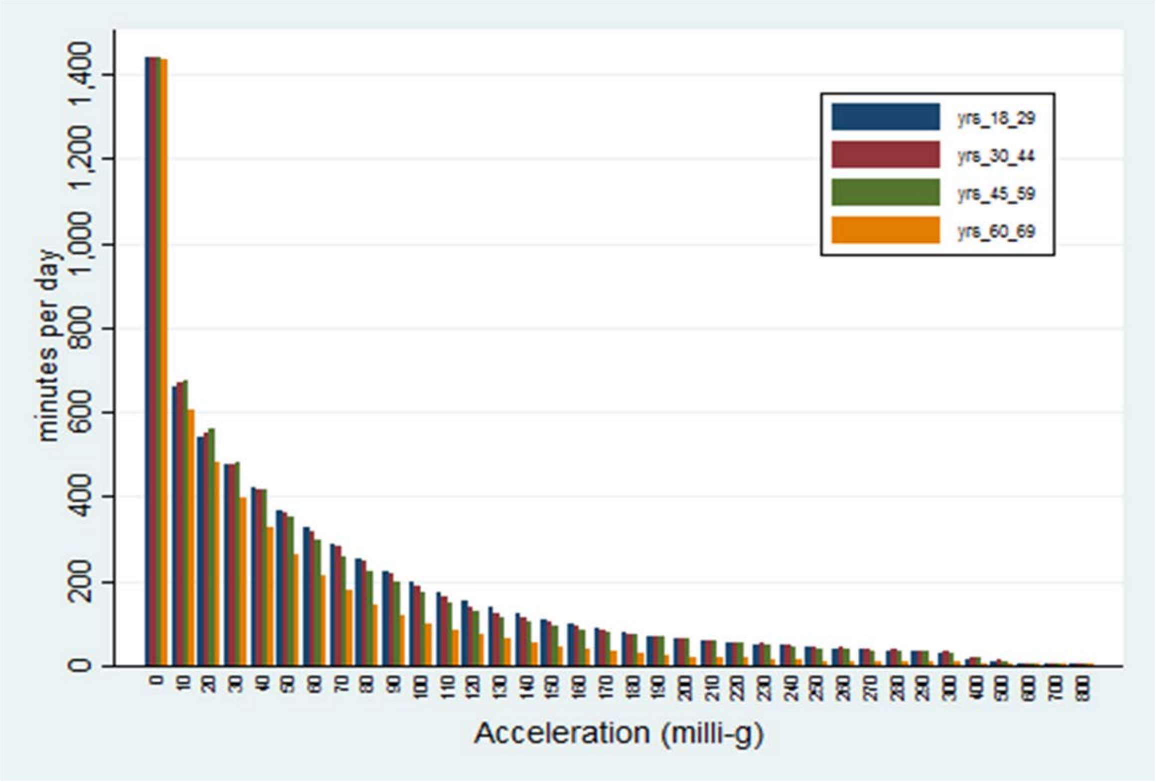


Figure 9: Physical activity intensity distribution by age group (bars represent median values)

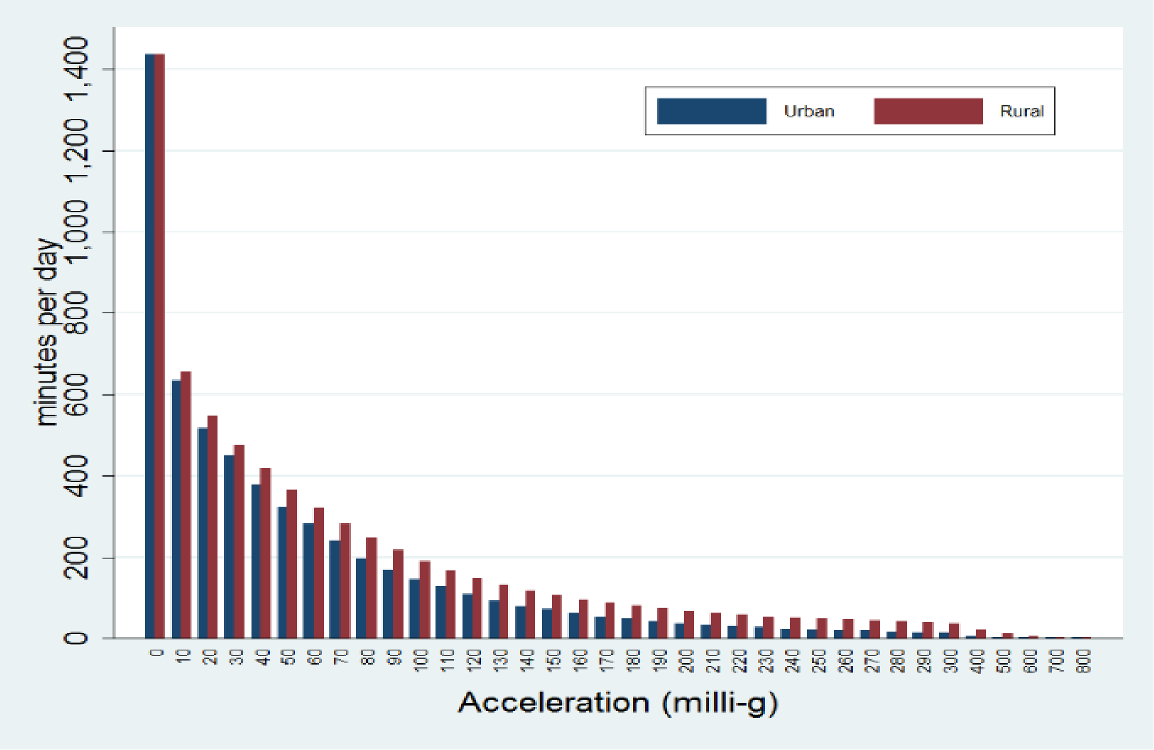


Figure 10: Physical activity intensity distribution by urban-rural residency (bars represent median values)

8.4.2 Diurnal profiles of physical activity

Time-stamped data from wearable sensors and the utilisation of continuous 24-hr wear protocols allow description of diurnal profiles of the population sample, as shown in Figure 11. These profiles indicate a bimodal pattern with a peak in the morning and a second peak in the afternoon/evening. Men and women had fairly comparable diurnal profiles in this sample. However, rural dwellers are much more active than urban dwellers in the early morning peak. They are also slightly more active, but to a smaller degree, in the afternoon peak, whereas lunch-time levels are similar between groups. In terms of age, it is the rural 45-59 yr olds who are most active in the morning peak, followed by the 30-44 yr olds and then the 18-29 yr olds. Conversely, it is the youngest age group of 18-29 yr olds who are most active in the afternoon/evening peak, with an ordered trend decrease across the other older age groups. Urban dwellers below 60 years are more similar to each other in the morning peak, and are more active than rural dwellers in the latest hours of the day.

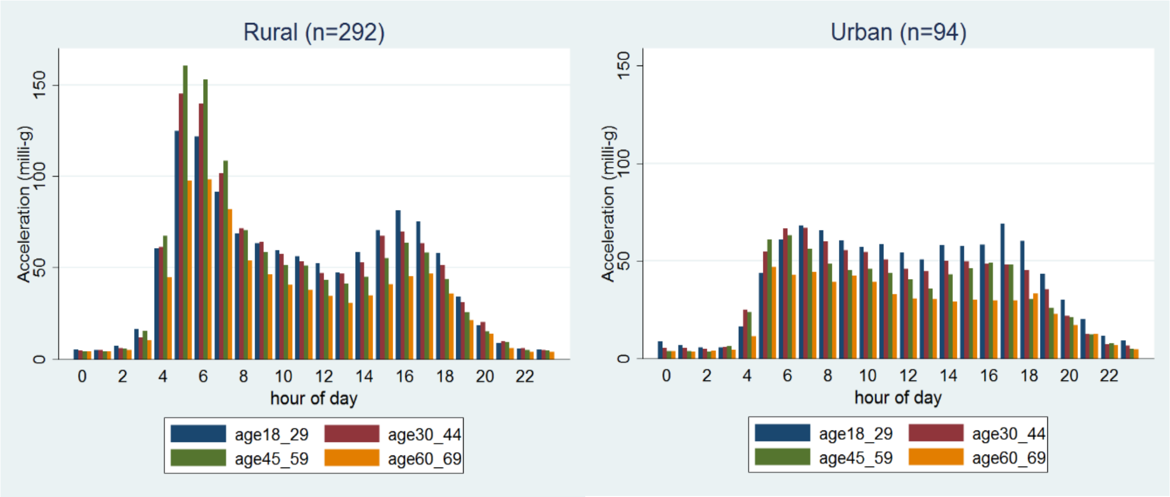


Figure 11: Diurnal physical activity profile of rural (left) and urban (right) dwellers, stratified by age group (bars represent mean values)

9 CONCLUSIONS

This pilot study was able to demonstrate that it is feasible to include objective measurement of physical activity using wrist-worn accelerometers within an existing STEPS data collection process in a setting such as Malawi.

The accelerometry data collection was well accepted by fieldwork team members. With fairly minimal training, the field staff were able to deploy the monitors with adequate explanation to the survey participants, so that the monitor wear protocol was largely followed, and only four participants (<1% of those eligible) declined to wear the device. A high level of participant compliance with the monitoring protocol was observed, and it may have been even higher if local cultural issues of superstition, for example around the colour black or the significance of certain monitor serial numbers being associated with the Devil (*666*) had been identified earlier, so that alternative straps could have been sourced. There were no major technical issues with devices, although a small number of wrist straps were damaged.

The linkage of accelerometer files to other survey data was another important limitation of the study design used for this pilot. A total of 499 participants were recruited for Step 1 and 2, of whom 446 returned for Step 3 measurements which was the part of the survey where the accelerometry component was implemented. In addition to the four refusals, one person forgot to bring the accelerometer with him when leaving and 13 lost their monitor, thus we would have expected 428 accelerometer files from these participants. However, a total of 456 accelerometer files were retrieved which suggests an issue with tracking survey participants through the survey steps in the first place and is likely explained by the fact that friends or family members may be tagging along to Step 3 measurements as this also included the blood tests and hence an opportunity to be diagnosed.

Out of those 456 files, only 410 files (90%) could be linked to survey participants and the difference of 18 (to the 428 which should have been linked) is explained by failure in the alternative ID linkage system; either monitor serial number was not entered or it was entered incorrectly in the tablet data at the point of giving the device to the participant. We did know in advance that this was the weakest point of the design as it is easy to mistype a serial number in a busy clinic during field work. This was one of the reasons why a second entry of the monitor serial number was built into the system, namely at the point of collecting the monitor from the participant after the monitoring period (the other reason being that monitor swaps between participants could be detected). However, this second entry of serial number did not work well in practice as often no re-contact with the individual participant was made as several participants from the same geographical area would have all left their monitors with a village contact person.

Future surveys therefore need an alternative and more robust system for linking accelerometry and general survey data. Fortunately, experiences from this pilot have led to development of software platforms that allow accelerometers to be set up from Android tablets at the point of issuing the device to the participant, which would reduce risk of this data linkage error and also simplify future fieldwork training. It will also simplify study logistics in terms of tracking which accelerometers are out with what participants and thus when they need to be collected, as the tablet ODK forms can be linked up with the tablet calendar functions. That said, further resources for the retrieval of monitors or careful survey planning and scheduling may be required in future data collections, when distances between geographical regions included in the survey are large, as the timing of monitor retrieval of the last participants recruited in one region is one week after the monitor deployment but this time may be after data collection in the next region has already started.

All but two accelerometer files could be processed with standard techniques to produce participant-level summary results. These provide detailed description of objectively measured physical activity patterns that could not be captured via self-report measures, including behavioural indicators such as overall volume of activity and time spent at different intensities which are all known to be important for human health. Sufficient valid data (defined as at least 48 hours of monitor wear time with reasonable diurnal representation) were available for 386 survey participants (87% of eligible).

Objective levels of physical activity in Malawi from this pilot study were about 50% higher than levels observed in the UK, Cameroon, and Brazil, and nearly twice that observed in Kuwait using similar methodology (Da silva et al., 2014; Doherty et al., 2017; van Hees et al., 2014; White et al., 2016) In Malawi, rural dwellers were more active than urban dwellers, particularly in the morning hours of the day. Men had higher activity levels compared to women, and there were decreasing trends with advancing age.

As the prevalence of non-communicable diseases continue to increase in several regions of the world, and physical activity is believed to play a part in the prevention of these disorders, it is paramount to gain a better understanding of current levels of physical activity and implement a robust surveillance system that is sensitive enough to detect changes over time as different interventions aimed at increasing activity levels are rolled out across the globe. The implementation of objective measures of physical activity in the WHO Steps Program has the potential to fulfil this goal, and the lessons learned from the present pilot study will help realise that ambition.

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11 APPENDICES

11.1 APPENDIX 1: MANUAL

App1_Field
Instructions (Acceler

11.2 APPENDIX 2: RESPONSIBILITIES OF ACCELEROMETRY CHAMPIONS

App2_Champion
Roles.pdf

11.3 APPENDIX 3: FREQUENTLY ASKED QUESTIONS

App3_FAQs.pdf

11.4 APPENDIX 4: QUICK MONITOR WEAR INSTRUCTION TO PARTICIPANT

App4_Quick_explana
tion_sheet_v2.pdf

NB: Page 2 shows a visual of example data which can be shown to testing staff and study participants, so they have a better understanding of what information is being captured, which can help reassure study participants. Showing this type of data can also improve compliance as study participants understand that researchers will know if the accelerometer has not been worn.

11.5 APPENDIX 5: SCREENSHOTS OF ANDROID TABLET DATA COLLECTION FORMS

App5_Screenshot
captures.pdf

11.6 APPENDIX 6: FIELDWORK TEAM MEMBERS QUESTIONNAIRE

App6_Feedback_que
stions_pilot.pdf