Succeeding with prolonged usage of consumer-based activity trackers in clinical studies: A mixed method approach

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Abstract

Background*:* Physical inactivity is a leading risk factor for death and several non-communicable diseases. Despite this, more than one fourth of adults worldwide do not follow the World Health Organization physical activity (PA) guidelines. As part of a feasibility study to test a complex intervention for increasing PA, we included a consumer-based activity tracker as part of the intervention, and as a tool for measuring PA outcomes. The purpose of the present study was to identify elements that increases wear adherence when using a consumer-based activity tracker as part of a PA intervention.

Methods: Sixteen people with obesity, aged 55-74 years, with sedentary lifestyle and elevated cardiovascular risk, were recruited to a 12-month feasibility study for a planned randomized controlled trial. Participants wore a Polar M430 activity tracker during a six-month intervention period and for six months of follow-up, to collect continuous PA data. We performed qualitative interviews mid-way in the intervention and six months after intervention end, to investigate how individual wear-time was linked to participant responses.

Results: From one year of tracking, mean number of valid wear days were 293 (SD=86). Several technical issues arose due to the long recording period, especially related to loss of connection between participants' activity tracker and smartphone. Some participants found it motivating to track progress and identify effective PA types, but most wore the Polar activity tracker because they were asked to. Participants' major sources of annoyance were tracker inaccuracy and limited usage training. Furthermore, tracker complexity and appearance were frequently addressed.

Conclusions: Adherence to wearing a consumer-based activity tracker was high. Results indicate that it is feasible to use a consumer-based activity tracker to measure PA over a longer period. Potential success factors for increased wear time includes adequate participant training on the activity tracker, allowing participant to choose between different activity tracker designs, and using trackers with accurate measurements. To identify accurate trackers, validation studies using available activity trackers in the target cohort may be needed.

Trial registration: U.S. National Library of Medicine, Clinical Trial registry: NCT03807323; Registered 16 September 2019 – Retrospectively registered, https://clinicaltrials.gov/ct2/show/NCT03807323

Background

The World Health Organization (WHO) recommends at least 150 minutes of moderate physical activity (PA) or 75 minutes of vigorous PA each week for adults [1]. Physical inactivity is a leading risk factor for death and a range of non-communicable diseases, including cardiovascular disease, diabetes, and some cancers [2]. Worldwide, in the adult population, 23% of men and 32% of women were physically inactive in 2016 [3, 4, 5]. Physical inactivity is more prevalent in high-income countries, and together with obesity, they are increasing globally [3, 4]. At the population level, increased PA provides health and economic benefits [6], and achievement of the PA recommendations have shown to reduce both cardiovascular disease mortality and total mortality [7].

Most lifestyle intervention studies use traditional research instruments (e.g. accelerometers, pedometers, doubly labelled water, and calorimetry) for objective PA data collection [8], but the number of studies using consumer-based activity trackers are increasing [9]. Validation studies on such activity trackers show different results, but several recent reviews show that some metrics for some activity trackers are accurate enough to measure PA in research settings [9, 10, 11, 12, 13]. In addition, a recent meta-analysis by Brickwood et al. [14], indicates that including an activity tracker as part of a PA intervention, may both increase PA participation and assist in participant monitoring. This is also supported by earlier systematic reviews, where De Vries et al. [15] found an increase of PA in adults with overweight and obesity, and Lewis et al. [16] found similar findings among intervention studies on adults.

However, few studies utilizing activity trackers use tracker output as outcomes, and recording time is mostly limited to the intervention period [8]. However, exceptions includes Schrager et al. [17] who used a Fitbit Flex to collect PA over one month (secondary outcomes), Carmichael et al. [18] who used a Garmin Vivofit 3 to collect PA (primary outcome) for up to one month of follow-up, and Patel et al. [19] who used a Fitbit Flex in a 12-week intervention, with 12-weeks of follow-up. Although long time follow-up with consumer-based activity trackers are uncommon, such studies are likely become more common going forward. For instance, Halse et al. [20] are planning an RCT where participants will be asked to wear an activity tracker for six months as part of an intervention, with six additional months of follow-up.

Measuring long-term effects of a PA intervention by requesting participants to return for additional measurements several months after intervention end, can be expensive, time consuming, and add to the participant burden. To understand the long-term effect of PA interventions better, future research should include activity trackers and collect PA data during- and beyond- the intervention period. There is a need to identify success factors that can contribute to the adaptation of this approach. Phillips et al. [21] identified a range of challenges associated with using activity trackers in research. They grouped challenges into participants' challenges, challenges with the research setting, and challenges with the activity tracker.

In the planning of a randomized controlled trial (RCT), the RESTART trial, with a complex lifestyle intervention for lasting lifestyle changes, we conducted a feasibility study including a Polar M430 (Polar oy, Finland) activity tracker to track PA for one year. The goal of the present study was to identify factors that can contribute to increased wear time when collecting PA data over an extended period using an activity tracker.

Having access to both quantitative and qualitative data from the same study gives an opportunity to gain a more complete understanding of the research topic by comparing and combining different perspectives [22]. To look further into some of the areas identified by Phillips et al. [21], we used a qualitatively driven mixed method approach where we analysed qualitative participant interviews together with an analysis of relevant quantitative PA recordings. In this paper, we describe our findings and provide recommendations for future research.

Method

Sample

For the feasibility study we invited 75 randomly selected participants from the seventh wave of the population-based Tromsø Study [23] with inclusion criteria age ≥55 years and above, body mass index ≥30 kg/m^2, with a self-reported sedentary lifestyle, and increased cardiovascular risk. Sixteen participants (participation 21%) were recruited for a 12-month feasibility study on lasting life-style change.

Participants in the feasibility study were exposed to a 22-week intervention of two 1-hour group-sessions per week with instructor-led gradually intensified exercise sessions (endurance and strength), three 2-hour group counselling sessions with nutritionist (Nordic Nutritional Recommendations [24]) and psychologist (Implementation Intention-based strategies [25]). Participants wore a Polar M430 activity tracker during the intervention period, and for six months of follow-up. The primary aim for the feasibility study was to examine whether the intervention was feasible to progress to a definitive RCT, regarding recruitment, adherence, and side effects. Participants received written and oral instructions on how to wear each activity tracker.

<u>Qualitative interviews</u>

To gain a deeper understanding of participant experiences with the Polar M430, we used a qualitative approach as qualitative methods are well suited for accessing participants experiences and perceptions [26]. We performed semi-structured interviews, as described by Kvale & Brinkmann [27]. All participants took part in individual interviews at two time-points, mid-way in the intervention and six months after intervention end. Interview guides were developed and used during the interviews to secure that all relevant aspects were covered. An excerpt of the interview guides, with questions related to activity tracker experiences, is given in in Table 1.

<u>Physical activity recording</u>

We equipped participants with a Polar M430 activity tracker one week before intervention start and instructed them to wear it for the duration of the intervention study (i.e. six months).

The Polar M430 was released in 2017. It has a six LED (light-emitting diode) wrist-based photoplethysmograph, i.e. optical pulse sensor, and a 50 Hz triaxial accelerometer for tracking PA. It is waterproof, weighs 51 grams, and has up to 20 days of battery life. In a previous study we have shown that the Polar M430 gives valid results for total energy expenditure (TEE) in a wider age- and weight-range, when compared to an ActiGraph wGT3X-BT accelerometer (ActiGraph, Pensacola, FL, USA) [28].

In addition, participants also wore an ActiGraph for eight days at baseline and eight days at the end of the six-month intervention. For each participant, we therefore recorded up to 16 days of simultaneous recording with the ActiGraph and the Polar M430. ActiGraph output was used to monitor change in PA and testing the validity of the Polar M430 in the present cohort for relevant variables (i.e. MVPA, steps, and TEE). The ActiGraph is extensively used in PA research, and is considered valid for PA intensity [29], step counting [30], and EE recording [31].

The ActiGraph (firmware version 1.9.2) was setup using ActiLife version 6.13.3 (ActiGraph, Pensacola, FL, USA). Output variables were generated using ActiLife. MVPA variables were calculated using triaxial activity count cut-offs at 2690 or above, as suggested by Sasaki et al. [13]. Steps were calculated by the ActiGraph itself and exported directly. TEE variables were calculated using “Freedson VM3 Combination '11” (Sasaki 2011 [13] + Williams Work-Energy).

Polar M430 setup and usage

For each participant we created a de-identified account on Polar Flow [32], Polar’s online activity storage solution, containing only demographic data (i.e. sex, year of birth, weight, and height). No identifiable information was stored on the accounts, and participants did not have access to account credentials. All notifications and feedback messages were disabled, except sleep, which was impossible to disable. GPS (global positioning system) was disabled to reduce battery consumption and for privacy reasons. We initially asked participant to wear the activity tracker for the duration of the study (i.e. six months).

Due to the long recording period, we asked participants who owned a smartphone to install the Polar Flow mobile application on their private phones. Polar Flow is used to transfer data between the activity tracker, a smartphone, and Polar’s online cloud storage. We assisted participants to connect the activity tracker to their smartphone and aided in any issues related to the activity tracker throughout the study period.

We instructed participants to initiate data synchronization (between activity tracker and smartphone) and charging every Sunday. This bring-your-own device (i.e. smartphone) approach has been shown to improve the experience and engagement of participants [33]. For participants who did not own a smartphone, we linked each activity tracker to a project smartphone. Data synchronization between the project smartphone and activity trackers were initialized every few weeks during the weekly exercise sessions.

The first author met with participants regularly to assist in connectivity issues with the activity tracker. During these sessions, spontaneous discussions between the researcher and participants about the activity tracker occurred. Relevant information from these discussions is reported and addressed in the discussion together with other experiences from the researcher perspective.

After intervention end, we asked participants to continue to wear the Polar M430 for an additional six months, for a total wear time of 12 months. Participants without a smartphone meet with a researcher every 2-3 months to download data from the activity tracker. After study end, we offered the Polar M430 to the participants for their private use. We did not inform participants that they would receive the watch, until after study end. We collected no further data after the handover.

Analysis

The second author performed the verbatim transcriptions of the *mid-way interview* audiotaped sessions, while a professional firm (Digforsk AS) performed the transcriptions of the *six-months after* audiotaped sessions. We used the computer software QSR NVivo 12 Plus (QSR International, Pty Ltd) as a tool for structuring data in the analysis process. We used thematic analysis when identifying and reporting themes and patterns in the data, a widely used method among health researchers [26]. Comments mentioned by only one participant were given equal weight as comments mentioned by multiple participants. We used the six steps defined by Braun and Clarke [34] for thematic analysis: data familiarization, initial coding, generating themes, reviewing themes, defining and naming themes, and writing up report. We used a deductive approach to identify themes in the data and semantic approach for explicit content analysis.

As part of the intervention, we downloaded daily values for steps, TEE, MVPA, and hours of wear time, from the Polar M430 through the Polar Open AccessLink API (application programming interface). This API facilitates automatic data extraction from consenting Polar users, i.e. the pre-created de-identified Polar accounts. We analysed hours of *wear time* to define valid days for the full year of recording. A day was considered valid if the activity tracker had at least 10 hours of wear time [35]. Wear time was analysed descriptively, reporting number of valid days for each participant, mean number of valid days, and number of valid days for participants who used the activity tracker for the whole 12 months of recording. In addition, wear time was analysed with participant comments. Participant characteristics were also described descriptively.

As suggested by Phillips et al. [21], we also tested the validity of the Polar M430 to check whether it was valid in the current cohort of participants. We used repeated measures correlations [36], with bootstrapping, to calculate correlations between the Polar M430 activity tracker and the ActiGraph wGT3X-BT accelerometer. We used correlation cut-offs suggested by Evans [37], i.e. very weak: <0.2, weak: 0.2-0.4, moderate: 0.4-0.6, strong: 0.6-0.8, and very strong: >0.8. We also calculated mean absolute percentage error (MAPE) for each variable, using 10% error as cut-off for acceptable error in free-living studies. Finally, we used Bland-Altman limits of agreements to assess consistency between instrument outcomes [38]. Statistical analyses were performed using R version 3.5.3.

Results

Participant characteristics

Among the 16 participants, 11 (70%) owned a smartphone and could connect their phone to the activity tracker. Participant characteristics at baseline are given in Table 2. Recording was performed between

October 2017 and September 2018.

Polar M430

Wear time

From the available 365 days of tracking, mean number of valid days was 293 (SD=86), i.e. 80%. Half of the participants had 30 or less non-valid days for the whole year of recording. Two participants (number 14 and 15 in Figure 1) stopped using their activity tracker at the end of the intervention (after six months of wear time). Mean number of valid days when excluding these participants was 314 (SD=69), i.e. 86%. We observed no clear difference in wear time between the different months, except one participant (8) who stopped using the activity tracker during the summer holiday (July), and one participant (13) who mostly stopped using the activity tracker after the intervention but resumed wearing it after the summer month. An overview of valid days for all participants for the whole year of recording is given is Figure 1.

The two participants who terminated use of the activity tracker after six months reported similar reasons for this. One participant reported being very conscious about wearing the activity tracker during the intervention and said that he/she became more disciplined by wearing it, which resulted in an increase in motivation. However, after the intervention ended, he/she "*just felt done with it*". Two specific reasons were that it was too complicated, and he/she had trouble with the connected mobile phone, and therefore did not have easy access to all the metrics. As stated in the interviews, "*I could not see the results I wanted on my iPad*" and "*My daughter has a watch I like better … it is simpler*". The other participant reported mainly using the activity tracker as a tool to keep track of pulse zones during instructor led exercise sessions. In addition, he/she did not have a connected smartphone, and felt the activity tracker was too complicated, especially without access to the instruction manual. "*When you don't know … how to use the watch … if I had the instruction manual I could see [how to use it]"*.

Polar M430 validity

We used output from overlapping days of Polar M430 and ActiGraph usage to test the validity of the Polar M430 in the present study. One participant did not wear both devices simultaneously and were excluded from analysis. Remaining participants had 8 to 16 valid days of simultaneous recordings. All analyses are based on data from 203 days of measurements distributed among 15 participants.

We found a strong correlation between the ActiGraph and the Polar M430 for step count, and a moderate correlation for MVPA and TEE. On average, the Polar M430 over-reports steps and time in MVPA, and under-reports TEE. Only TEE had a borderline acceptable MAPE. Details for each variable are given in Table 3.

Participant perspective

We identified four themes after initial coding of each interview and further refinement of codes into themes: Motivation, activity tracker usefulness, activity tracker annoyances, and activity tracker improvements.

Motivation

This theme explores if and how participants were motivated by wearing an activity tracker during- and after the intervention. Some participants mentioned the activity feedback from the activity tracker, and the possibility of directly observing progress, as the primary motivation to wear it for such a long period. For these participants, this feedback was an opportunity to push themselves harder, especially during the instructor led exercise session.

One participant stated that being able to measure progress, when he/she did not think there would be any progress, was very motivating and gratifying, and stated: "*I reached my goals … it was very gratifying … I did not think I would [reach my goals]*". Another participant highlighted that the ability of using the activity tracker to push himself/herself into working harder and harder each session was motivating, and said that "*It was interesting to follow progress, … I have never used this [technology] before, … nice to observe that … yes, now I have pushed myself*".

However, for most participants the main reason for wearing the activity tracker for such a long period was that they were asked to do it. Most participants were very happy with being invited to the project and wanted to contribute to the research by sharing their data. Some expressed willingness to share for a longer period if asked. As expressed by two participants, "*I know how important research is … so that you will get reliable data*" and "*I was willing to make the 'sacrifice' for you and the research".*

Activity tracker usefulness

This theme encapsulates how and why participants used the activity tracker, as well as their perceived effects of using it. Most participants reported mainly using the activity tracker to get continuous feedback on heart rate zone during instructor led workouts. One participant highlighted the usefulness of the activity tracker by saying, "*I had to pay attention to how I performed, so I could increase resistance to get to the [heart rate] level I was supposed to be at".* However, not all who said they used it to track changes during a workout payed much attention to it, as illustrated by one participant who said, "*I didn't put too much into it, but it was fun to keep track [of the activity]*".

In addition, many participants used it as a timepiece, and replaced their existing wristwatch with the supplied activity tracker in order to accommodate the study. An often-mentioned useful feature was the ability to track sleep quality and sleep interruptions during the night. For some this was an acknowledgement of what they already knew about their sleep patterns, prompting responses like "*I look at sleep … I am awake a lot*" and "*I can see how little sleep I get*". For others it constituted a source of confusion because the activity tracker was perceived as inaccurate, resulting in quotes like "*tracking sleep … but I don't always think it is accurate*".

The reported effects of wearing the activity tracker were different for most participants, and only a few mentioned specific behavioural changes because of the activity tracker. However, one participant said, "*I became more disciplined*". Another participant mentioned that he/she became more conscious about daily activity levels and which types of activity that were effective and stated, "*I am more conscious about moving more while at work …. Itake the stairs instead of the escalator*", and "… *more aware of what is effective and what isn't*". One participant highlighted this learning effect by saying, "*I learned something from the watch. Things that I thought was [effective] … the watch showed me that it actually wasn't*".

In addition, during ad-hock discussions with participants when performing technical support on the activity tracker, some participants stated that they compared activity tracker output with each other and found that interesting.

Activity tracker annoyances

This theme summarizes issues that participants found annoying about the activity tracker. Technical challenges were a major source of annoyance, where participants experienced disconnects between their phone and activity tracker, and often found that the activity tracker was difficult to use without assistance. This was repeatedly mentioned during the interviews, prompting responses such as, "*negative about the watch … we got no instructions on how to use it*", and, "*a lot of information at once, considering I hadn't used this [technology] before*". Several participants mentioned that it could be helpful to have access to the activity tracker instruction manual. As stated by one participant: "*It was too complicated … but I didn't spend too much time on it anyway … because we didn't have the instruction manual".*

Activity tracker inaccuracies was also a major source of annoyance, and sleep feedback was repeatedly mentioned as a source of annoyance because they often felt it was inaccurate. Two participants who had contradictory experiences may best describe this. One participant said, "*The only thing that annoys me … when I feel that I have slept very well … it reports how bad I have slept*", and the other said, "*the sleep thing … I almost got annoyed sometimes … I woke several times per night, and sometimes I am out of bed three-four times ... and it reports that I have slept well*".

One participant also noticed that the pulse sensors was not always accurate, and he/she got somewhat frustrated about this, saying that, "*I got very caught up in the [low] pulse measurements … resting at 39 [beats per minutes] during the day? I don't get it*". Another participant also wondered about the accuracy during exercise sessions, and mention that, "*Iwonder if the watch is correct … it's not correct … much lower pulse … not even close*".

Finally, for participants who did not own a smartphone, we could not connect their activity tracker to their phone. One such participant pointed out that he/she felt this made it more complicated to use the activity tracker and said, "*It was hard to use the watch … did not get results on my phone … I think those who saw their results on their phones got more out of it*".

Activity tracker improvements

The final theme captures suggestions that participants reported regarding the choice of activity tracker. Most participants were happy to wear the activity tracker during the intervention, both day and night, and reported no major issues with the day-to-day usage. However, some participants mention that the activity tracker could have been more attractive, and some felt it was too large, prompting comments such as, "*It is [for instance] not good looking during the Christmas holiday*" and "*I wished it was more attractive, because it is not good looking when at festive gatherings*". Other participants were not too concerned about the design of the activity tracker, and one even made a point of saying that, "*I could not be bothered to wear another watch when at parties*".

Although the activity tracker had more features than we informed participants about, some pointed out that they knew other people with more advanced activity trackers with more interesting features. One participant said, "*My daughter has a more advanced [watch], with all possible features ... but they are of course more expensive*". On the other hand, another participant, who had a daughter with a less complex activity tracker, thought it would be better to use a less complicated activity tracker and comment that, "*I liked it better … it was easier to use*".

Discussion

Summary of findings

In this feasibility study with 12 months of PA recording, we analysed participant adherence to the wear protocol and reported participant experiences. Wear adherence was high throughout the study. The most frequent reason for increased wear adherence was that they were asked to do it, but some participants were motivated by tracking activity progress. Most participants mainly used the activity tracker as a timepiece, but some also used it to measure heart rate and sleep tracking. Reported positive effects of using the activity tracker were being more conscious about their day-to-day activity and gaining a better understanding of the effect of different activity types. Two major sources of annoyance were sleep- and -heart rate inaccuracy, and limited training on the activity tracker. The most frequent complaints were that the Polar M430 was big, unattractive, and too complicated to use.

Challenges and solutions

In the following, we discuss challenges and potential solutions, drawn from participants' feedback together with experiences from the researcher perspective, and results from the objective data analyses.

<u>Motivation and activity tracker usefulness</u>

Most participants were enthusiastic about being invited to participate in the study. Because of this and because collecting data from the activity tracker was presented as an important part of the intervention, it is not overly surprising that wear time was high during the intervention. This high wear time is in alignment with a similar study, where Duignan et al. [39] conducted a shorter intervention study (three months) in a younger sample (mean age: 23.4, SD: 2.8). In this study, 73% of participants still wore an activity tracker after 87 days, with an average wear time of 79 days (90%) among remaining participants. Reasons for loss of participants were mostly technical (e.g. data synchronizing) and loss of activity tracker. However, in a observational study by Hermsen et al. [40] they saw a slow exponential decline in wear time of a hip-worn Fitbit Zip, also mostly due to technical reasons, where only 12% still wore the activity tracker after 300 days. Although anecdotal, this indicates that being part of an intervention with close follow-up of participants increases wear time, as compared to studies where participants are only observed.

Most users, when buying a new activity tracker, tend to stop using it after a few months, mostly due to loss of motivation [41]. In the present study, only two of 16 stopped using the activity tracker after six months (i.e. intervention end). The main reason participants in the present study wore the activity trackers for a full year, was because they wanted to contribute to the study. While some reported irritation with sleep and heart rate inaccuracies, we think most participants were not majorly concerned with activity tracker accuracy, but more concerned about understanding how to use the activity tracker and having access to all collected data to review progress.

Similarly, we found that some participants sometimes compared activity tracker output with each other. This indicates that having access to activity output for self-monitoring and being able to compare and compete with others was a possible source of motivation. In addition, for participants who found the activity trackers useful during exercise sessions, and those who found it useful for learning which types of activity that were effective, it is likely that these features contributed to the increased wear time. It is apparent that activity tracker output is important for many, and unless there are specific reasons to *not* displaying these outputs, researchers should use an activity tracker that can show output that participants would find relevant to track their own progress (e.g. steps).

<u>Activity tracker annoyances</u>

We found several sources of nuisance among participants, where problems were mostly related to technical problems, activity tracker inaccuracy, and activity tracker complexity.

Technical problems during phone and activity tracker setup are likely to occur because of the large variation in participant phone models. It is therefore necessary to schedule enough time available for setup and have a technically skilled researcher available who can resolve any issues directly. In addition, some participants did not bring their phones for the setup meeting, and several participants' phones were out of power. Participants should have been reminded to bring a fully charged phone, and we should have brought charging equipment to the initial meeting. In addition, some participants lost their charging cable, and one misplaced the activity tracker for a period, showing that replacement equipment should also be available.

We did not specifically ask participants to clean the activity tracker regularly. Because of the long recording period, this caused the optical pulse sensor to become unclean and therefore unreliable. This sensor emits light onto the skin and estimates pulse by analysing changes in light waveform from the reflecting light. The reflecting light is affected by change in blood volume under the skin. Annoyances about heart rate inaccuracy could have been avoided, at least partly, by instructing participants to clean the activity tracker regularly. In addition, the Polar M430 regularly misclassified sleep and non-wear time. Our main reason for selecting the Polar M430 was that it had a very good optical pulse sensor (according to Polar). However, we did not consider that being unable to disable sleep notifications could cause annoyance. We did not perform sleep validation on the Polar M430, which we (in retrospect) should have done to be able to inform participants about the possible inaccuracy of this metric.

Inaccuracy was mentioned as an individual issue and as a source of curiosity when participants compared activity tracker output between themselves and saw different results for the same activity. People are different and activity tracker output will be different for each person. However, one additional possible source of this difference may be activity tracker firmware, which are routinely updated by vendors. How these updates affect activity tracker output are mostly company secrets. We therefore avoided updating the firmware unless we could update all activity trackers simultaneously. However, participants who connected the activity tracker to their own phone was able to do this update more frequently, which resulted in several weeks where participants had different firmware.

Several participants requested an easier way to view activity tracker output. The Polar M430 does not show daily step count automatically. This was annoying to several participants. Activity output would likely have been more accessible for participants if we had provided them with the instruction manual, which shows how to access this information. The main reasons for not providing the instruction manual were to prevent participants to change settings (e.g. turn on GPS (global positioning system) tracking) or be affected by activity tracker output. However, since wearing an activity tracker is likely to only affect short term behaviour [14] we suggest providing participants with the instruction manual for long-term measurements. Privacy issues with GPS tracking must be considered. The importance of having access to the instruction manual and that lack of instructions are a source of annoyance is also supported by previous studies on activity tracker use in older adults [42]. In the present study, some participants said that the Polar M430 was too complicated. However, in a study by McMahon et al. [43], a study on older adults using an activity tracker to increase PA, they showed that although older adults require more time to adopt new technology and needs more technical support [44], they found activity trackers easy to use and useful for PA self-tracking. Although this study used a Fitbit One, a less complex activity tracker compared to the Polar M430, adequate training in the present study would likely empower participants to use the activity tracker as intended.

Activity tracker improvements

Participant feedback regarding the activity tracker was mostly related to activity tracker design and available outputs. When considering activity trackers in future studies, researchers should consider appearance and usability, and not only price, accuracy, battery life, etc. Many vendors offer multiple versions of the same activity tracker, with different colours, shapes, and material. Allowing participants to choose between multiple designs may increase wear time. This may be more important in a study with a younger population, as younger participants are more likely to own an activity tracker and may be resistant to replace it or start wearing an additional device. Similarly, because some participants said the activity tracker was too complicated and others said it was too simple, it could be beneficial to have more than one activity tracker available for participants to choose between, at least if the goal is to increase wear time. The drawback is that it is more complicated to compare activity levels between participants using different activity trackers.

Polar M430 validity

In a systematic review on Polar activity trackers [45], we have previously reported that Polar activity trackers show mixed results depending on activity tracker, study setting, and study sample. Furthermore, compared to findings in a previous Polar M430 validation study [28], with a wider range of weight, height, and age, all correlations were lower in the present cohort. This difference shows that it is good practice to perform a separate validation study with similar characteristics as the sample under study.

Recommendations

From the above discussion, we have extracted the following recommendations that should be considered when planning and performing a study where participants are equipped with an activity tracker over a prolonged period. We have grouped recommendations into three phases: 1) the preparation and planning phase, 2) the setup and training phase, and the 3) recording phase.

Preparation and planning phase

- Budget for a technician who can provide technical support throughout the study and during follow-up.
- Offer activity trackers that can easily display relevant metrics, unless there are specific reasons not to display output.
- Allow participants to choose from multiple activity tracker designs, both in terms of complexity and in terms of appearance.
- Validate recent activity trackers in the relevant cohort, if no such study exists, to identify acceptable activity trackers.
- Validate all metrics on the selected activity tracker and consider informing participants about untrustworthy metrics.

Activity tracker setup and participant training phase

- Plan for adequate time for training and follow-up of participants.
- Remind participants to bring a fully charged phone (and bring charging equipment for common phones types) before connecting participants’ phones to their activity tracker

- Instruct participants to clean the activity tracker regularly, to avoid inaccuracy in pulse measurements.
- Provide activity tracker instruction manual to participants, unless there are specific reasons not to.

Recording phase

- Close follow-up of participants increased wear time.
- Have replacement activity trackers and charger equipment available.
- Avoid updating the activity tracker firmware during study or follow-up if possible.

Future work

In this feasibility study, we only included 16 participants. Parts of the PA tracking solution would not scale well to a larger study sample, as we manually created one Polar Flow user account for each participant. A solution that scales better is to ask participants to create their own Polar account and authorize access to a PA collection system. Participants may need support to do this, so additional resources should be considered for this approach. This system would require additional attention to privacy issues. This system can also potentially be used to collect PA data at the population level over a longer period, by collecting data already being collected by participants wearing smart watches or activity trackers.

Strengths and limitations

The main aim of this paper was to identify factors that contributed to the wear time of the activity tracker. This implies a strictly focused study, contributing to a high degree of credibility [46]. The participants in the study were recruited from a large ongoing population study, with a well-defined sample in terms of age, lifestyle habits, and health risks. This adds to the study’s transferability as the results could be transferrable to similar population groups in similar societies (42). The mixed method approach and the long recording period allowed us to identify challenges from multiple perspectives and identify challenges that would not necessarily be detected in a shorter study. The main limitation is the limited transferability to other populations and age groups. Further, the RESTART trial participants were recruited from a population-based health study, and although the attendance was 72% in this age-group [47], this may introduce selection bias.

Conclusions

In this study, adherence to wearing a consumer activity tracker was high. Results indicate that it is feasible to use a consumer-based activity tracker to measure PA over a longer period. Potential success factors for increased wear time includes providing adequate instructions on how to use the activity tracker, allowing participant to choose between different activity tracker designs (appearance and complexity), and offer activity trackers with accurate measurements. Validation studies on recent activity trackers may be needed for the target cohort, to identify such trackers.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Helsinki declaration. The Regional Committee for Medical and Health Research Ethics in Northern Norway (Reference 1100/2017) approved the study. All participants signed an informed consent.

Consent for publication

Not applicable

Availability of data and materials

The data/transcripts used during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors’ contributions

All authors contributed to the design of the study. AH drafted the manuscript with critical review by all authors. AH (objective) and ASS (interview) collected the data. AH performed the data analysis together with ASS and LH. All authors read and approved the final manuscript.

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Abbreviations

GPS: Global positioning system

MAPE: Mean absolute percentage error

MVPA: Moderate-to-vigorous physical activity

PA: Physical activity

RCT: Randomized controlled trial

TEE: Total energy expenditure

WHO: World Health Organization

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Tables

Table 1. Excerpt from interview guides with questions related to the activity tracker

Interview	Question	Question
Mid-way	1	How was your experience with using the activity tracker?
Six months after	2	How did you use the activity tracker? (Only during workouts, or also other times? Pulse zones? As a watch?)
Six months after	3	Did the activity tracker motivate you to work out more often? Harder?
Six months after	4	Was there anything special about the activity tracker that made you more motivated?
Six months after	5	What motivated you to wear the activity tracker (for an extended period)?
Six months after	6	Is there anything you wish was possible with the activity tracker, which could have motivated you to wear it longer?

Table 2. Participant characteristics at baseline. The RESTART feasibility study 2017-18.

Characteristics	
Age, years	66 (57-74)
Male sex, %	70 (11)
Body mass index, kg/m^2	36 (29-51)
Current smoking*, %	13 (2)
High total cholesterol, %	50 (8)
Low HDL cholesterol, %	25 (4)
Hypertension, %	19 (3)

Values are mean (range) or percentage (number).

HDL: high-density lipoprotein

Current smoking: self-reported daily smoking; High total cholesterol: total cholesterol ≥5 mmol/L; Low HDL cholesterol: HDL cholesterol <1.3 (women) or <1.0 (men) mmol/L; Hypertension: blood pressure ≥140/90 mmHg.

*missing values: 1 participant

Table 3. Mean data for Polar M430 and ActiGraph, and correlation, p-value, mean absolute percentage error, and Bland-Altman mean difference and limits of agreements (LoA), for steps, moderate-to-vigorous physical activity, and total energy expenditure. N = 203.

	Polar	ActiGraph	Correlation (95% CI)	p-value	MAPE	Mean difference	Lower LoA	Upper LoA
Steps	8956 (5106)	5165 (3230)	0.625 (0.44, 0.70)	<0.001	119.5%	3791	-4860	12442
MVPA	143 (97)	44 (32)	0.495 (0.31, 0.53)	<0.001	373.9%	99.0	-80.4	278.4
TEE	2868 (581)	2967 (458)	0.446 (0.50, 0.69)	<0.001	10.6%	-98.7	-948.5	751.1

Numbers are means (standard deviations). MVPA: Moderate-to-vigorous physical activity. TEE: Total energy expenditure. Correlation: Repeated measurement correlation with 95% confidence interval. MAPE: Mean absolute percentage error. LoA: Limits of agreement.

Figures

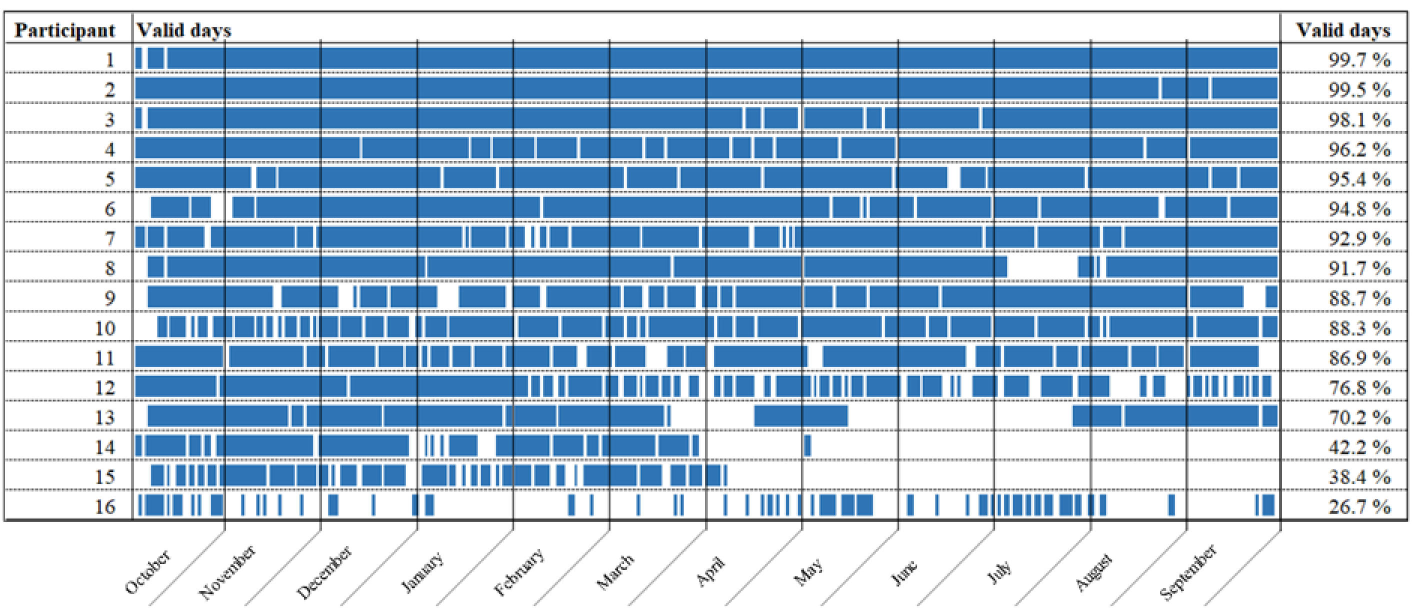

Figure 1

Activity tracker wear time for one year of recording.

Supplementary Files

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