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Can quantifying the relative intensity of a person's free-living physical activity predict how they respond to a physical activity intervention? Findings from the PACES RCT.

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What is already known on this topic

- Quantification of accelerometer-measured free-living physical activity in terms of both absolute intensity and intensity relative to a person's exercise capacity is desirable but cumbersome.

What this study adds

- Using relative intensity of a person's physical activity profile (i.e. the intensity of activities relative to their maximum physical capacity) to tailor physical activity intervention prescriptions may increase the likelihood of the intervention leading to an increase in the absolute intensity of 24-hour free-living physical activity.
- Open-source methods may facilitate assessment of both the relative and absolute intensity of free-living physical activity across the 24-hour physical activity profile.

How this study might affect research, practice, or policy

- These open-source methods enable development of individually tailored interventions that account for a person's baseline level of activity and, thus, their potential to increase their physical activity.

Abstract

Objectives: To determine whether quantifying both the absolute and relative intensity of accelerometer-assessed physical activity (PA) can inform PA interventions. We hypothesised that individuals whose free-living PA is at a low relative intensity are more likely to increase PA in response to an intervention, as they have spare physical capacity.

Method: We conducted a secondary data analysis of a 12-month randomised controlled trial, PACES (Physical Activity after Cardiac EventS), which was designed to increase PA but showed no improvement. Participants (N=239, 86% male; age 66.4(9.7); control N=126, intervention N=113) wore accelerometers for 7-days and performed the incremental shuttle walk test (ISWT) at baseline and 12-months. PA intensity was expressed in absolute terms (intensity gradient) and relative to acceleration at maximal physical capacity (predicted from an individual's maximal ISWT walking speed). PA outcomes were volume and absolute intensity gradient.

Results: At baseline, ISWT performance was positively correlated with PA volume (r=0.50, p<0.001) and absolute intensity (r=0.50, p<0.001), but negatively correlated with relative intensity (r=-0.13, p=0.025). Relative intensity of PA at baseline moderated the change in absolute intensity (p=0.017), but not volume, of PA post-intervention. Low relative intensity at baseline was associated with increased absolute intensity gradient (+0.5 standard deviations (SD)), while high relative intensity at baseline was associated with decreased absolute intensity gradient (-0.5SD).

Conclusion: Those with low relative intensity of PA were more likely to increase their absolute PA intensity gradient in response to an intervention. Quantifying absolute and relative PA intensity of PA could improve enables personalisation of interventions.

Introduction

Physical activity (PA) surveillance compares activity within and across groups who differ in many characteristics, e.g., health status, fitness, and age. To facilitate this, the measure of PA needs to be comparable despite these differences. An advantage of accelerometer-assessed activity is that movement is assessed directly and, unlike self-report, is not impacted by perceptions of PA, recall of PA, or cultural differences.[1] However, in groups with low physical capacity, assessment of only the absolute intensity of PA can be a blunt instrument. For example, analyses relying on absolute intensity cut-points can fail to capture PA which, despite not reaching the conventional threshold for moderate intensity in absolute terms (i.e., 3 metabolic equivalents (METs))[2], may be health-enhancing due to being at a moderate-to-vigorous intensity relative to a person's physical capacity.[3-4] Assessing only the absolute intensity of PA can also result in failure to detect the efficacy of interventions to increase moderate-to-vigorous intensity PA (MVPA), in individuals where physical capacity is limited due to disease- or age-related declines. Given this, a stable, or even declining, absolute PA intensity over time could conceivably represent an increase in the relative intensity of PA. In such a scenario, relying on absolute intensity thresholds could lead to a beneficial effect of an intervention aiming to increase (moderate intensity) PA being missed.[5] Typically, this has been dealt with by developing cut-points specific to groups with lower capacity;[6-9] however, this necessitates development of multiple sets of cut-points limiting comparability (the 'cut-point conundrum'),[10] while also not being specific to the individual's capacity. The intensity gradient[5] addresses the limitations of absolute intensity cut-points by describing the intensity distribution over the day in absolute terms. However, there is no analogous metric for describing intensity relative to an individual's capacity.

Orme et al.[4] recently proposed expressing the intensity distribution of the 24-hour profile of free-living PA in both absolute terms and relative to an individual's physical capacity. The intensity of PA is expressed relative to an individual's maximal sustained 1-minute acceleration output during an ambulatory-based maximal exercise test, the incremental shuttle walk test (ISWT). As the ISWT is commonly used in pulmonary and cardiac rehabilitation[11] it is feasible to add accelerometer wear to the test.[12] Where accelerometer data from a maximal test are not available, it is possible to predict the acceleration associated with a maximal effort, e.g., from VO_2max, or maximal speed in the ISWT[4,13] or multi-stage fitness test.[14]

Our aim was to assess whether the efficacy of a PA intervention depends on the relative intensity of free-living PA at baseline. We used data from a randomised controlled trial (RCT) which was designed to increase PA in people with coronary heart disease,[15] but showed no improvement in PA.[16] We hypothesised that those with low relative intensity of free-living PA at baseline were most likely to improve the volume or absolute intensity of their free-living PA in response to the intervention, as they have more 'spare' physical capacity to do so.

Methods

Equity, diversity and inclusion

The author team included six men and two women representing early, middle and late career researchers. The research participants were predominantly male (86%) and white (84%) or South Asian (15%).

Patient and Public Involvement

It was not appropriate or possible to involve patients or the public in the design, conduct, reporting, or dissemination of this analysis. However, the PACES intervention was informed by extensive patient and public involvement.[15] Further, development of the "glass half full" analogy by Orme et al.[4] for communicating this concept in a patient-friendly manner (see discussion and Figure 3) was informed by discussion groups with people living with chronic respiratory diseases.

Evaluation of activity intervention (PACES)

PACES was an RCT of a theory-driven group education programme with pedometer self-monitoring and subsequent text message support designed to increase habitual PA.[15] In brief, 291 participants aged $\geq$18 y, 12 to 48 months post diagnosis of a coronary artery disease related cardiac event gave informed consent and were randomised to a structured education programme or usual care. The programme consisted of two 2.5-hour (h) sessions delivered two weeks apart, followed by supplementary text message support. Baseline and 12-month follow-up data were assessed.

Physical capacity was assessed using the ISWT (12 levels; 12 minutes; maximum distance 1,020m).[17] The maximum speed and distance achieved were recorded. Free-living PA was assessed using the GENEActiv (ActivInsights Ltd, Cambridgshire, UK), initialised at 100 Hz, worn on the non-dominant wrist 24 hours/day for up to 7-days. The following variables were extracted for both time-points for those with free-living accelerometer data and ISWT data at baseline and 12-months: sex, age, height, mass, ISWT maximum distance, ISWT maximum speed, accelerometer files (raw .bin format). As an accelerometer was not worn during the ISWT, accelerometer output at maximum capacity was predicted from the final walking speed obtained in the ISWT, along with age, height, mass, and sex using generalised estimating equations generated from published data:[18] acceleration (m*g*)= 337.3 + (speed (km/h) x 96.1) + (age (y) x -1.1) + (height (cm) x -4.6) + (mass (kg) x 2.8) + (sex (male = -21.9, female = 0)).

Accelerometer data processing

Accelerometer data were processed in GGIR version 2.6-0.[19] The accelerometer metric was the average magnitude of dynamic acceleration corrected for gravity (Euclidean Norm minus 1 *g* (ENMO, m*g*)) averaged over 5 s epochs. Accelerometer files were excluded if they showed post-calibration error >10 m*g*), had fewer than three days of valid wear (defined as >16 h per day), or wear data were not present for each 15 min period of the 24 h cycle.[20]

Accelerometer outcomes (averaged across valid days) were:

- average acceleration (24 h day, proxy for PA volume, m*g*)
- intensity gradient (24 h day, intensity distribution of PA)[20]
- acceleration (intensity) above which a person's most active X minutes (MX metrics, where X = number of minutes (1-720 (12 h)), are accumulated (m*g*)[21]

The intensity gradient[20-22] describes the intensity distribution of PA. The time accumulated in incremental 25 m*g* acceleration bins is regressed on the mid-point of each intensity bin (m*g*), and both variables log-transformed to linearise the curvilinear relationship; higher values indicate a greater proportion of total PA is spent at high intensity (Figure 1, top).

Expression of physical activity in relative terms

The intensity gradient describes the distribution of the absolute intensity of PA,[20] but does not reflect the intensity of an individual's PA relative to their physical capacity. For example, two people may have an identical intensity gradient, but one person with a high physical capacity (Figure 1, Person A) and one person with a low physical capacity (Figure 1, Person B). For the person with a high capacity the intensity gradient will represent a low physiological burden (Figure 1, Person A, bottom), but for the person with a low capacity it will reflect a higher physiological burden (Figure 1, Person B, bottom). To describe the distribution of the intensity of PA across the day relative to maximum capacity, an analogous companion metric, the *relative intensity gradient*, was generated. Thus, the relative intensity gradient describes the individual physiological burden of the intensity distribution (Figure 1, bottom).

The relative intensity gradient was calculated using the epoch-level comma-separate values (.csv) files generated in GGIR and a custom-built R script, available at www.github.com/Maylor8/Relative-Intensity-Gradient. The procedure is analogous to calculation of the intensity gradient,[20] but time is regressed on relative intensity (intensity expressed as percentage of maximum acceleration) in place of absolute intensity. The time accumulated each day in incremental 5% intensity bins (5 to >300% of predicted acceleration at maximum physical capacity) was regressed on the mid-percentage of the

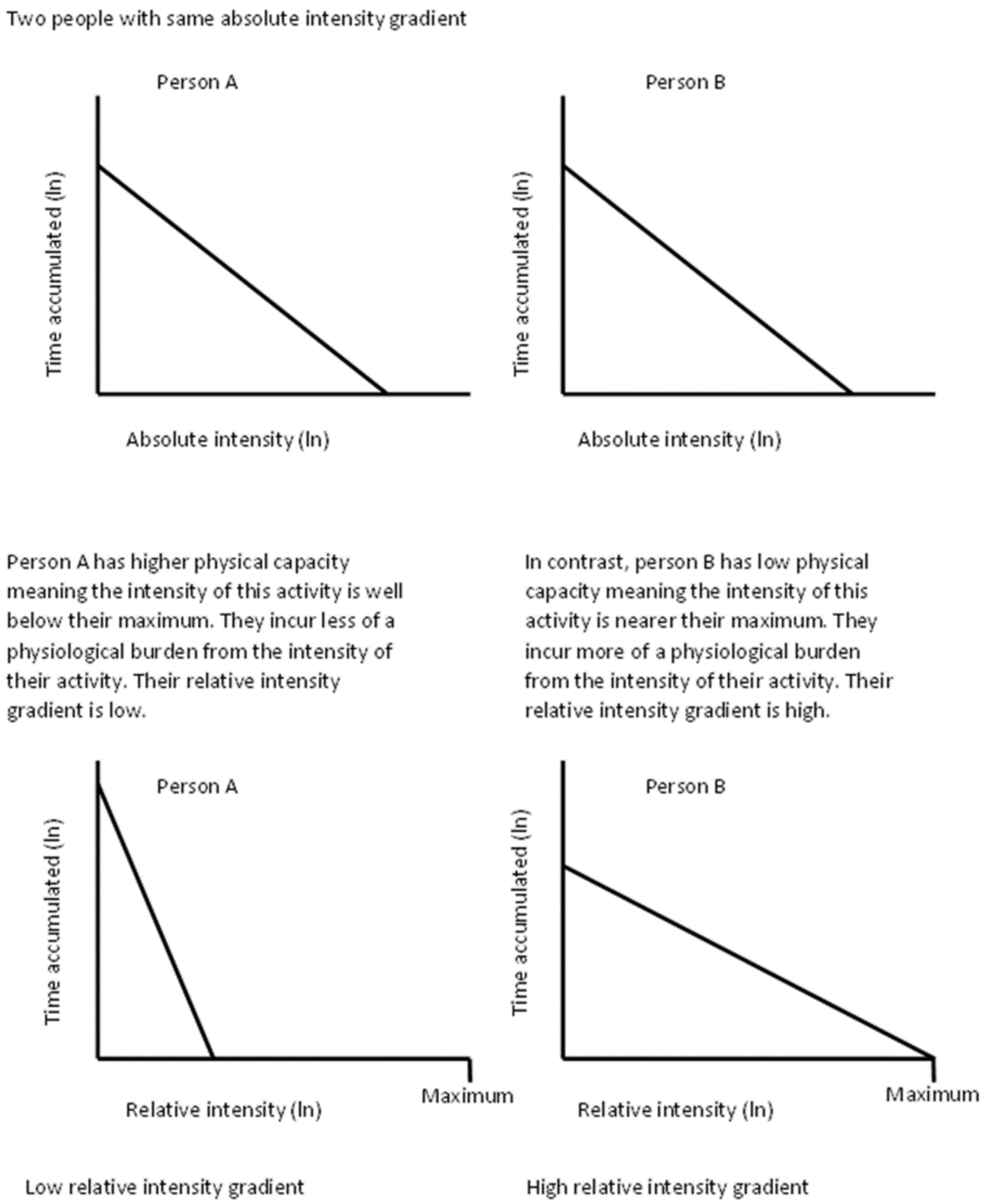

Figure 1. Comparison of absolute (top) and relative (bottom) intensity gradient for two people with the same absolute intensity gradient but differing physical capacity.

relative intensity bin, with both variables log-transformed to linearise the curvilinear relationship. Note, the incremental relative intensity bins go up to >300% as the intensity of PA accumulated across the day includes brief bursts of PA, thus will often be at a greater intensity than a person's predicted acceleration at maximum physical capacity, which typically refers to a continuous 1-minute period in the final stages of a maximal test. As with the standard intensity gradient, R^2, the constant and the slope were calculated per day for each participant. Individual days and/or files that had been flagged as invalid in GGIR were removed before averaging the relative intensity gradient across valid days.

The relative intensity of the MX metrics[21] was expressed by dividing the acceleration for each MX metric by the predicted acceleration (m*g*) at maximum capacity and multiplying by 100: MX_{REL} (%). Accelerometer metrics and their names in GGIR outputs are in supplemental Table S1.

Statistical analysis

Descriptive statistics were calculated using mean (standard deviation (SD)) for continuous variables and percentage for categorical variables, by group (intervention/control) and time-point (baseline, 12-months). Correlations between PA (volume, absolute intensity, relative intensity) and ISWT performance were determined.

Efficacy of the intervention was evaluated based on change in either of two outcomes: volume and/or absolute intensity distribution of PA (absolute intensity gradient). Both were included as each is independently associated with markers of health[22,23] and mortality.[24] Linear regression models, with a 'group by relative intensity gradient' interaction term, were used to determine whether the relative intensity distribution of PA at baseline moderated the impact of group (intervention/control) on change in PA volume or absolute intensity distribution. Co-variates were baseline PA (volume and absolute intensity distribution), sex, and ethnicity. Continuous independent variables were standardised (z-scores) before entry into analyses. Dependent variables, change in volume of PA and absolute intensity gradient, were expressed as SD of baseline volume or intensity gradient, respectively, for ease of interpretation. The variance inflation factor (VIF) was calculated to check for multicollinearity; values >5 indicated the effects of the predictors could not be reliably estimated.[25]

To illustrate significant moderator effects, we plotted change in PA by group (control/intervention) when the baseline relative intensity gradient was high ($\geq$1SD), low ($\leq$-1SD) and medium (>-1SD & < 1SD). To show where in the PA profile these changes occurred, we used radar plots to show marginal group means for change in the MX metrics for participants with low, medium, and high relative intensity gradient at baseline.

All analyses were conducted using Stata/SE v17.0 (StataCorp, TX, USA) and statistical significance was set at p<0.05 (two-tailed). Radar plots were generated in R using open-source code available at: www.github.com/Maylor8/RadarPlotGenerator.

Results

Table 1 shows descriptive characteristics by group for the 238 participants with complete data at baseline and 12-months (86% male; age 66.4(9.7) y; control N=126, intervention N=112). Data exclusions are in Figure S1.

Physical capacity and physical activity (volume, absolute intensity, and relative intensity)

At baseline, ISWT maximum distance was positively correlated with the volume ($r = 0.50$, $p<0.001$) and absolute intensity ($r = 0.50$, $p < 0.001$) of PA, but negatively correlated with the relative intensity ($r = -0.13$, $p = 0.025$) of PA.

Association between relative intensity of free-living physical activity at baseline and change in volume and absolute intensity of free-living physical activity

Table 2 shows associations of change in the volume and absolute intensity of PA (per SD of baseline value), with group and the relative intensity gradient. Analyses were adjusted for baseline PA (volume and absolute intensity distribution), sex, and ethnicity. No associations were evident for change in volume (Table 2, Figure 2a), or main effects for change in the absolute intensity distribution of PA. However, there was a group X relative intensity gradient interaction for change in absolute intensity gradient ($b = -0.24$, $p=0.015$). Figure 2b shows that, in the intervention group, the absolute intensity gradient improved by ~0.5 SD at 12 months in those who had a low relative intensity gradient at baseline ($\leq$-1SD). In contrast, the absolute intensity gradient decreased by ~0.5 SD at 12 months in those who had a high relative intensity gradient at baseline ($\geq$1SD). The VIF was <5 in all cases.

The increase in intensity of PA in those with a low relative intensity gradient at baseline occurred in the most active accumulated 1-30 minutes across the day (M1-M30) (Figure 2c (i)). This increase in intensity was most evident in the intervention group with the intensity of the most active 10-minutes (M10) and 1-minute (M1) increasing by 16.3 (8.4 (standard error of the mean)) m*g* and 41.3 (17.9) m*g*, respectively, compared to 4.8 (7.6) m*g* and 24 (15.7) m*g*, respectively, in the control group (Figure 2c (i)). The decrease in those with a high relative intensity gradient at baseline (Figure 2c (iii)), resulted from decreases in intensity of PA during the most active accumulated 1-120 minutes (M1-M120) of the day. Again, this was most evident in the intervention group with M10 and M1 dropping by 40.9 (12.4) m*g* and 80.8 (25.9) m*g*, respectively compared to 20.6 (7.8) m*g* and 36.1 (16.6) m*g*, respectively, in the control group.

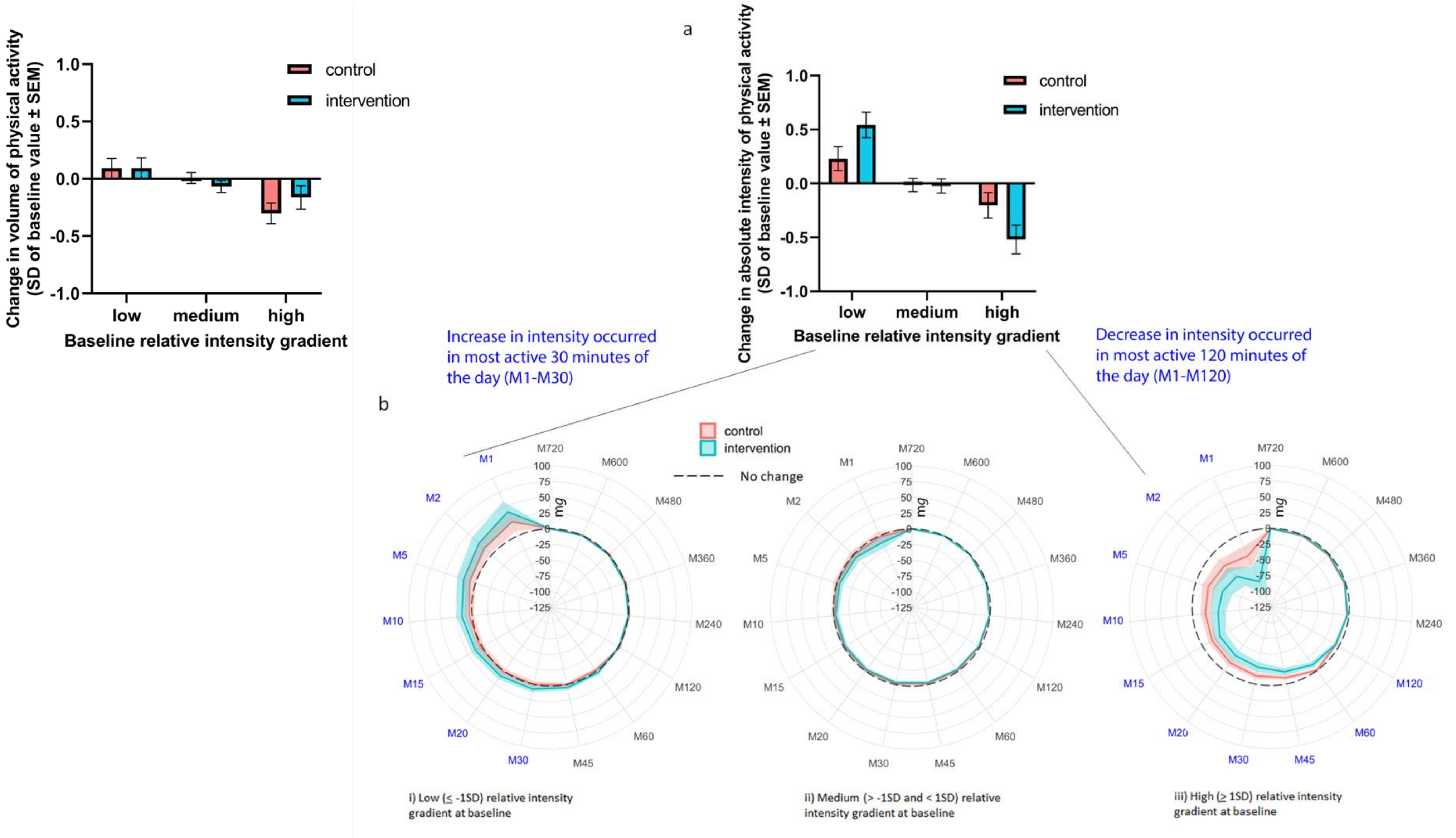

Figure 2. Change in a) physical activity volume b) the absolute intensity gradient and c) the absolute intensity of the most active 1 (M1) to 720 (M720) minutes at 12-months, by group, illustrated for those with low (≤1SD), medium (>-1SD and < 1 SD), and high (≥1 SD) relative intensity gradient at baseline. Marginal group means (± standard error of the mean) adjusted for baseline physical activity (volume and absolute intensity distribution), sex, and ethnicity. *Group by relative intensity gradient interaction p=0.015

Discussion

We demonstrate that quantifying both the absolute and relative intensity of free-living PA provides greater insight into intervention efficacy than either alone, offering potential for improved targeting and/or personalisation of activity interventions.

Those with a lower relative intensity of PA at baseline were most likely to respond to the PACES intervention[15-16] by improving the absolute intensity distribution, although not volume, of their free-living PA. Conversely, the intervention was shown to reduce the absolute intensity of free-living activity in those with high relative intensity at baseline. This suggests that behavioural physical activity interventions may be demotivating in those where habitual daily physical activity already represents a high physiological load; this is consistent with research indicating possible detrimental impacts of physical activity in individuals with reduced capacity due to long COVID.[26] In contrast, if both the absolute and relative intensity gradients are high, the intervention activities may represent a lower physiological load than baseline activity and thus contribute to a decrease in absolute intensity.

Previous exploratory analyses of data from the intervention group only in PACES[16] have suggested that time spent at an absolute moderate-to-vigorous PA ($\geq$3 METs) increased, but only in individuals not meeting the PA guidelines at baseline. However, notably, the improved intensity distribution evident herein was independent of baseline volume and absolute intensity of PA. This change resulted from an increase in intensity across the most active accumulated 30 minutes of the day, particularly the most active accumulated 10 minutes, with the acceleration magnitude likely reflecting an increase in walking pace.[18] This is significant as both the intensity gradient[23,24] and walking pace[27-30] are associated with markers of cardiometabolic health and lower risk of mortality.

These data support targeting of PA interventions at those with the spare physical capacity to respond. Indeed, those with a higher relative intensity of PA in the intervention group decreased their intensity gradient at follow-up by over three times as much as the control group, with the drop evident over the most active two hours of the day. This suggests that a blanket intervention approach could be more detrimental to those who are already active relative to their physical capacity than no intervention.

Orme et al.[4] proposed a "glass half full" analogy for communicating this targeting in a user-friendly manner. We have exemplified how this could be used to depict our intervention group at baseline by their relative intensity gradient in Figure 3. In the low relative intensity group, the "glass" (physical capacity) is less than "half full" (PA intensity) indicating plenty of scope to increase the intensity of PA, 'can do, doesn't do'; in our analysis these participants tended to respond positively to the intervention. In the high relative intensity group, the “glass” is “overflowing”, suggesting the intensity of free-living PA may already be causing over-reaching (‘can’t do, does do’); these participants tended to decrease the intensity of free-living PA following the intervention. Here, future research should explore whether it is more appropriate to focus on increasing physical capacity and/or decreasing sedentary time. Where people are undertaking their baseline daily physical activities at a high relative intensity, they may already be experiencing a training stimulus. If, despite this, their capacity is low it is possible that these people have ‘low sensitivity’ to physical activity / training and greater personalisation of training may be required.[31] Thus, targeting and tracking an intervention according to the absolute and relative intensity of a person’s PA may not only optimise the positive impact of an intervention, but also avoid a negative impact. However, it would not be possible to target an intervention in this way by considering either PA or physical capacity alone, a synergistic approach is necessary.

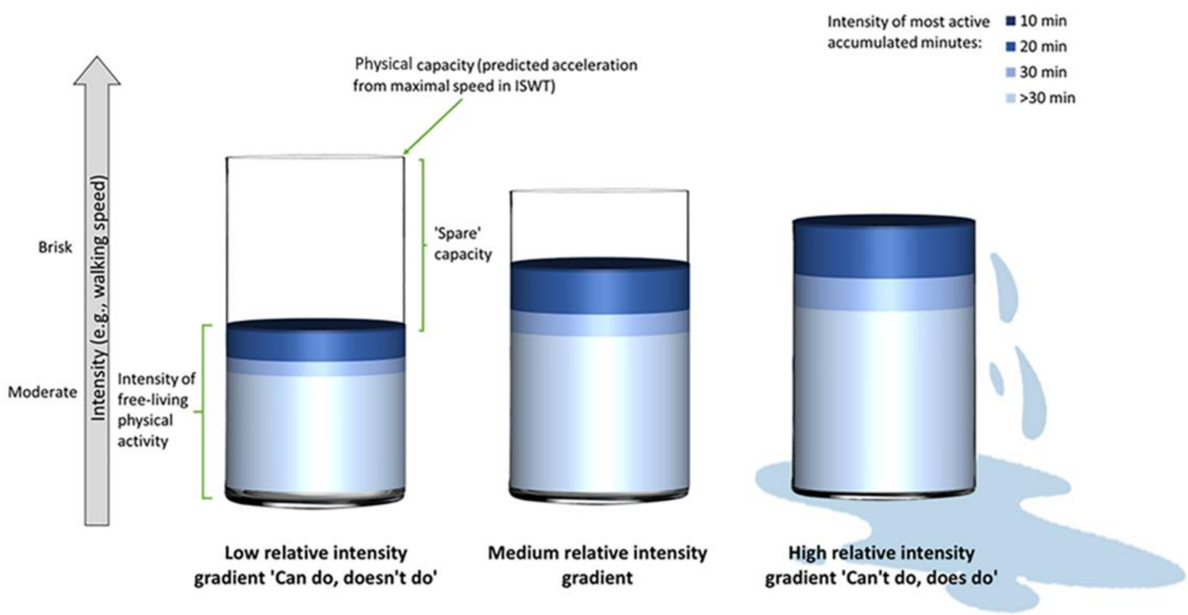

Figure 3. Example application of glass half full analogy4 for identifying and targeting people best placed to benefit from an intervention. Data shown are the intervention group at baseline categorised by their relative intensity gradient at baseline (low, medium, high). Physical capacity is represented by the size of the glass, and the extent to which the glass is filled with water represents the intensity of free-living physical activity. The low relative intensity group have spare capacity to increase the intensity of their free-living activity (the glass is only half full, ‘can do, doesn’t do’). In contrast, in the high relative intensity group there is no spare capacity, and the glass is already overflowing (can’t do, does do’).

Limitations

This is a secondary analysis of the PACES RCT, which was not designed to assess the associations investigated here. Additionally, prediction of acceleration at maximal capacity carries the limitations associated with the maximal exercise test deployed as well as prediction of acceleration. Notably, relative intensity would not be comparable across differing methods for predicting acceleration at maximal capacity. However, within a method the relative intensities should be comparable. Further, different prediction methods would likely impact the magnitude of relative intensity values, but not the pattern of results. Given that the relative intensity of the PA profile is shown, rather than only proportions of the profile spent at specific relative intensity categories, this should not impact appreciably on findings.

The ideal scenario would directly measure, rather than predict, acceleration during a maximal ambulatory test, e.g., the ISWT.[4 12-13] This would also capture the well-documented individual differences in acceleration for given speeds[32] increasing relevance to free-living data. However, this requires a maximal test with concurrent accelerometer measurement, which is currently only likely to be available in specific circumstances, e.g., in cardiac and pulmonary rehabilitation.[4 12-13] Finally, the sample included mainly white male participants limiting generalisability of the results.

Conclusion

Assessment of only absolute intensity of PA can be a “blunt” instrument, while assessment of only relative intensity can be misleading. However, both together have synergistic potential for enabling individual-tailoring and evaluation of rehabilitation programmes and PA interventions. The open-source methods presented facilitate assessment of the intensity of the PA profile in both absolute and relative terms. Further, the “glass half full” analogy[4] may enhance feasibility by communicating this concept in a patient-friendly manner. Those where habitual daily activity already represents a high relative intensity may need personalised approaches to physical activity interventions which requires further investigation.

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Figure 1. Comparison of absolute (top) and relative (bottom) intensity gradient for two people with the same absolute intensity gradient but differing physical capacity.

Figure 2. Change in a) physical activity volume b) the absolute intensity gradient and c) the absolute intensity of the most active 1 (M1) to 720 (M720) minutes at 12-months, by group, illustrated for those with low ($\leq$1SD), medium (>-1SD and < 1 SD), and high ($\geq$1 SD) relative intensity gradient at baseline. Marginal group means (± standard error of the mean) adjusted for baseline physical activity (volume and absolute intensity distribution), sex, and ethnicity. *Group by relative intensity gradient interaction p=0.015.

Figure 3. Example application of glass half full analogy (Orme et al.[4]) for identifying and targeting people best placed to benefit from an intervention. Data shown are the intervention group at baseline categorised by their relative intensity gradient at baseline (low, medium, high). Physical capacity is represented by the size of the glass, and the extent to which the glass is filled with water represents the intensity of free-living physical activity. The low relative intensity group have spare capacity to increase the intensity of their free-living activity (the glass is only half full, 'can do, doesn't do'). In contrast, in the high relative intensity group there is no spare capacity, and the glass is already overflowing (can't do, does do').

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Table S1. Accelerometer outcome metrics (averaged across all valid days)

Figure S1. Data exclusions in PACES (Physical Activity after Cardiac EventS) cohort

Contributorship: Conception/design: AR, MO; Data analysis/interpretation: AR, MO, BM, AK, TY; Data acquisition: MD, TY, KK, LH; Drafting/revision critically for important content: all authors. Final approval: all authors.

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Data availability statement: PACES data are available on reasonable request to researchers who provide a methodologically sound proposal, to achieve the aims outlined in their proposal. Proposals should be directed to melanie.davies@uhl-tr.nhs.uk. To gain access, data requestors will need to sign a data sharing agreement.

Code availability: Accelerometer data were processed using the open-source R-package GGIR (version 2.3-0, http://cran.r-project.org). Radar plots were generated in R using open-source code available at: www.github.com/Maylor8/RadarPlotGenerator. The relative intensity gradient was generated using open-source code available at www.github.com/Maylor8/Relative-Intensity-Gradient.

Ethics approval: The West Midlands-Solihull Research Ethics Committee and the UK Health Research Authority (Reference: 16/WM/0463) granted approval for the PACES study. All participants gave written informed consent prior to data collection.

Patient and Public Involvement: It was not appropriate or possible to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research. However, the PACES intervention was informed by extensive patient and public involvement.[15] Further, development of the glass half full analogy by Orme et al.[4] for communicating this concept in a patient-friendly manner (see discussion and Figure 3) was informed by patient discussion groups with people living with chronic respiratory diseases.

Table 1. Descriptive characteristics, fitness (physical capacity) and physical activity variables by group and time. Values are mean (SD) or N [%]

PACES				
Group (N)	**Control (126)**		**Intervention (112)**	
Sex (male)	109 [87]		96 [86]	
Ethnicity				
White	104 [83]		96 [86]	
South Asian	21 [17]		14 [13]	
Other	1 [1]		2 [2]	
Age (y)	66.3 (10.4)		66.4 (8.8)	
Height (cm)	169.9 (7.8)		169.1 (8.5)	
Mass (kg)	83.4 (13.0)		83.1 (16.5)	
Time-point	**baseline**	**12-months***	**baseline**	**12-months***
Fitness (Physical capacity)				
ISWT (m)	352.0 (147.1)	311.7 (149.7)	352.4 (122.0)	307.0 (127.5)
Accel predicted from ISWT max	302.4 (93.5)	269.3 (100.1)	308.5 (77.4)	272.4 (91.0)
Physical activity				
Volume (m*g*)	24.1 (8.1)	23.9 (7.8)	23.1 (6.2)	22.8 (6.2)
Intensity gradient	-2.687 (0.250)	-2.692 (0.255)	-2.728 (0.189)	-2.717 (0.200)
*Relative intensity gradient	-2.434 (0.200)	-2.356 (0.271)	-2.491 (0.149)	-2.414 (0.232)

*Sample size at 12 months reduced to 109 in control and 96 in intervention for fitness and relative intensity gradient

Table 2. Association between change in physical activity outcome (volume and intensity distribution, per SD of baseline value), group allocation, and relative intensity gradient at baseline (N = 239, control 126, intervention 113)

	Change in physical activity at 12-months			
	volume[a]		intensity gradient[b]	
	Coefficient	95% CI	Coefficient	95% CI
Group				
Intervention	-0.036	-0.172, 0.100	-0.012	-0.189, 0.165
Baseline relative intensity gradient[c]	-0.064	-1.165, 0.037	-0.038	-0.169, 0.093
Group X baseline relative intensity gradient[c]	-0.024	-0.169, 0.122	-0.242	**-0.432, -0.052**

[a]Volume = average acceleration (m*g*)
[b]Intensity gradient: Distribution of the intensity of activity, gradient of the regression line from log-log plot of intensity (x) and minutes accumulated (y).
[c]Relative intensity gradient: Distribution of the relative intensity of activity, gradient of the regression line from log-log plot of relative intensity (x) and minutes accumulated (y).
Models adjusted for baseline measures of physical activity volume, intensity gradient, sex, and ethnicity.
95% CI = 95% confidence interval
Continuous independent variables were standardised before entry into the analysis.
Dependent variables, change in volume of physical activity and intensity distribution, were expressed as standard deviation of baseline volume or intensity gradient, respectively, for ease of interpretation
Significant ($p < 0.05$) associations are denoted in bold

Table S1. Accelerometer outcome metrics (averaged across all valid days)

Outcome	Definition	Source
Average acceleration (m*g*)	Average acceleration over the 24 h day (proxy for physical activity volume)	GGIR part 2 daysummary: 'mean_ENMO_mg_024hr enmo_accel'
Absolute intensity gradient	Distribution of the absolute intensity of activity over the day; higher values indicate a greater proportion of total activity is spent at high intensity[1]	GGIR part 2 daysummary: 'ig_gradient_ENMO_024hr'
MX (m*g*)	Acceleration (intensity) above which a person's most active X minutes (MX metrics, where X is the number of minutes, 1-720 (12 h)) are accumulated (m*g*)[2]	GGIR part 2 daysummary: e.g., 'p50_ENMO_mg_024hr' and 'p9993056_ENMO_mg_024hr' where p50 = 50th percentile of 24 h range, i.e., M720 (12 h) and p 9993056 = 99.93056th percentile of 24 h range, i.e., M1 (1 minute)
Relative intensity gradient	Distribution of the relative intensity of activity over the day; higher values indicate a higher intensity relative to maximum exercise capacity, i.e., a greater physiological burden	Calculated using a custom-built R-script (at www.github.com/Maylor8/Relative-Intensity-Gradient) using: • participant-level 5 s csv epoch files (part 2 GGIR) • acceleration at maximum exercise capacity
Relative MX (MX_{REL} %)	Relative intensity (% maximum) above which a person's most active X minutes (MX metrics, where X is the number of minutes, 1-720 (12 h)) are accumulated (m*g*)	Calculated by dividing each MX metric by the acceleration (m*g*) at maximum exercise capacity and multiplying by 100

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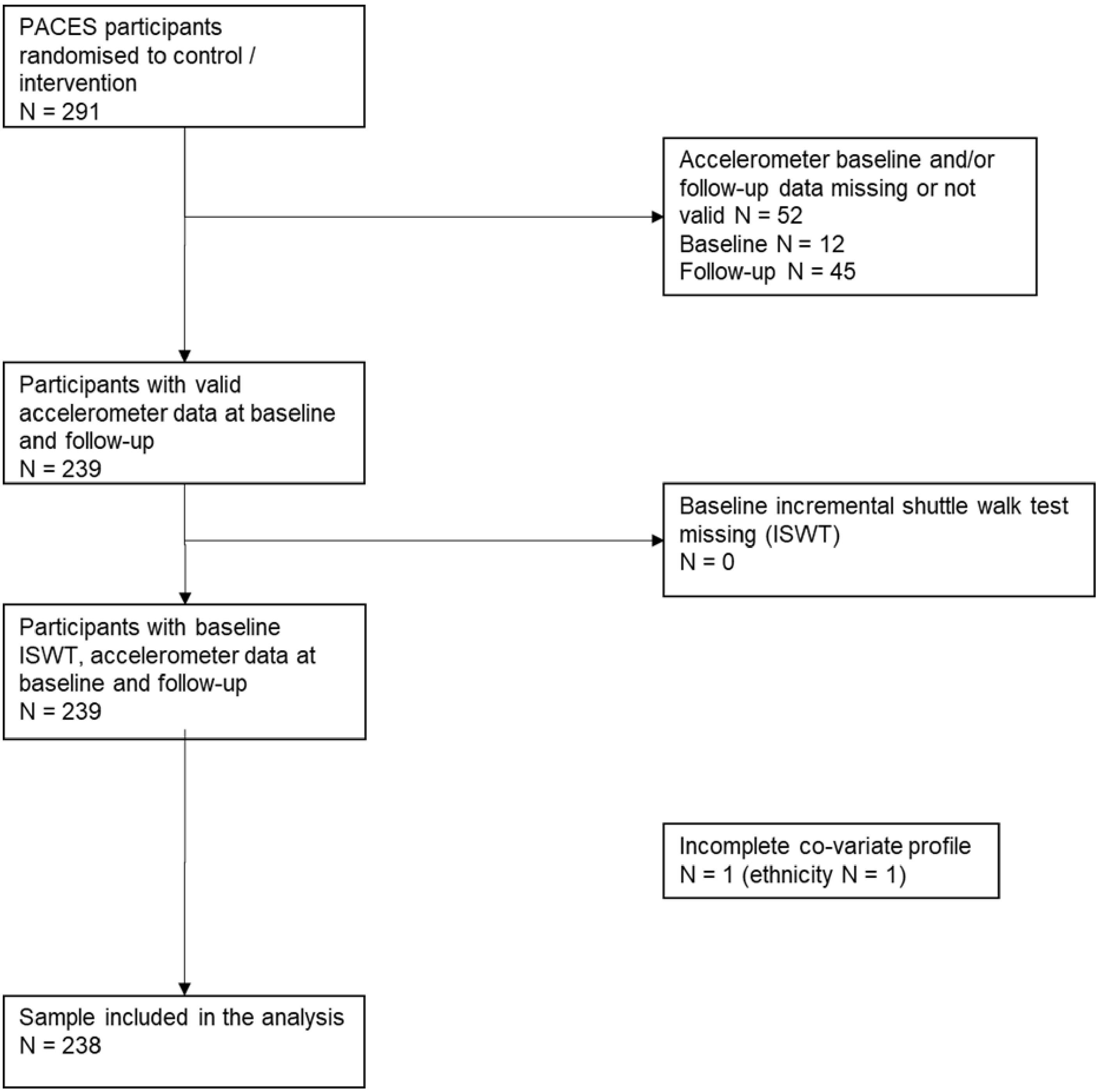

Figure S1. Data exclusions in PACES (Physical Activity after Cardiac EventS) cohort