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Concurrent agreement between ActiGraph and activPAL in measuring moderate to vigorous intensity physical activity for adults

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Abstract

This study aimed to assess the ability of the activPAL monitor (commonly used for measuring Sedentary Behaviour (SB), sitting or reclining with low energy expenditure while awake) to measure moderate to vigorous physical activity (MVPA), by assessing its agreement with the concurrent measurement by ActiGraph monitor (commonly used for measuring MVPA) to identify if a single monitor could be used to measure both MVPA and SB. A convenience sample of 24 adults (79% female; aged 23-60) wore an ActiGraph GT3X+ and an activPAL3 concurrently for one day during free-living activities. Time spent in MVPA was calculated as an outcome measure using published methods (ActiGraph, n=6; activPAL n=4). Agreement was assessed between pairs of outcomes using the Bland & Altman method. Participants engaged in between 60 and 145 minutes of MVPA. The activPAL method summing time walking with a cadence ≥100 steps/min underestimated MVPA compared with the ActiGraph but had the lowest aggregate bias (-16 minutes). Other activPAL methods, based on acceleration counts and the embedded MET algorithm, overestimated MVPA compared to the ActiGraph. The study was limited by the lack of activPAL acceleration count methods developed for adults. With the recommended methods, the activPAL could be suitable for use as a single monitor to measure both SB and MVPA.

Keywords

physical activity; exercise; objective measurement; body-worn sensor; accelerometer; validation

Introduction[1]

[1] aP3: method of calculating MVPA from the activPAL monitor using a value of 3METs from the embedded MET algorithm; aP100: method of calculating MVPA from the activPAL using 100 steps/minute cadence; aP1418: method of calculating MVPA from the activPAL using an acceleration threshold of 1418; aP2997: method of calculating MVPA from the activPAL using an acceleration threshold of 2997; AG56: method of calculating MVPA from the ActiGraph monitor using a VM threshold of 56 counts per 1s epoch; AG1952: method of calculating MVPA from the ActiGraph monitor using a VT threshold of 1952 counts per minute (Freedson cut-points); AG2000 method of calculating MVPA from the ActiGraph monitor using a V T threshold of 2000 counts per minute (167 counts per 5s epoch); AG2020: method of calculating MVPA from the ActiGraph monitor using a VT threshold of 2020 counts per minute; AG2960 method of calculating MVPA from the ActiGraph

Lack of physical activity (PA) is a leading risk factor for mortality worldwide. A third (31%) of adults are physically inactive [1] causing approximately 3.2 million deaths every year [2,3] and representing a substantial global financial burden [4]. Engaging in a combination of moderate and vigorous PA (MVPA; ≥3 METs (metabolic equivalents) [5]) provides benefits for health, fitness and body composition [6] and forms a key element in worldwide PA guidelines. More recently, sedentary behaviour (SB; defined as sitting or reclining while awake [7]) has been investigated as a behaviour distinct from lack of physical activity (physical inactivity). SB has a detrimental effect on health, mortality and cardiometabolic disease [8,9], which may be independent of PA. Measurement of both PA and SB is required to monitor population levels (surveillance), and to assess the effects of epidemiological and intervention studies [10]. Long-term (e.g. 1 week) objective measurement of both PA and SB during daily life is available through use of body-worn sensors. However, a range of different monitors are available, differing by wear location and monitor output, with relative strengths and weaknesses [11-13]. This can make appropriate monitor selection for research difficult and may compromise direct comparison of outcome measures from studies using different monitors.

The most widely used accelerometer to measure PA for research is the ActiGraph (ActiGraph LLC, Pensacola, FL) accelerometer [14]. Usually worn at the hip, and sampled at 30-100Hz, the output is expressed as 'counts' (a proprietary value related to acceleration) aggregated over a user-specified 'epoch' (time interval) [15]. Acceleration counts are translated into meaningful output (e.g. time spent in MVPA) using 'cut-points', which are threshold values derived from calibration and validation studies against the corresponding MET value for the PA being performed [15]. Whilst the ActiGraph is acknowledged as an appropriate monitor to measure time spent in MVPA, the selection of cut-point is dependent on epoch length [16], and there is disagreement as to which are most accurate [15]. For measurement of SB, the ActiGraph uses a low count cut-point to distinguish sitting from light PA. Worn on the hip, the ActiGraph is unable to measure the posture of sitting, instead

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monitor using a VM threshold of 2960 counts per minute; AG3208 method of calculating MVPA from the ActiGraph monitor using a VM threshold of 3208 counts per minute; LOA: limits of agreement; MET: metabolic equivalent; MVPA: moderate to vigorous physical activity; PA: physical activity; SB: sedentary behaviour; VM: vector magnitude; VT: vertical axis.

measuring a lack of movement, which may misclassify some standing activities as SB, e.g. washing up [17].

An alternative monitor option, growing in popularity, is the activPAL (PAL Technologies Ltd, Glasgow, UK). This accelerometer-based monitor is worn on the anterior thigh and uses thigh inclination to distinguish between the postures of sitting and standing [18]. The activPAL has a sensitivity of 98% in adults for measuring SB against observation [19], and is regarded as the gold standard for measuring time spent in SB [20]. Whilst the activPAL also distinguishes between time spent standing and walking, with an accuracy of approximately 98% [21], time spent in MVPA is not one of its standard outputs. Options for converting activPAL output into time spent in MVPA are varied and have only limited validation. They include, use of the integral (embedded) activPAL output of METs generated from standard values for the posture or cadence of walking [22], use of cadence of walking to identify MVPA walking bouts [23] or use of the raw acceleration output to generate cut-points for MVPA [24].

Given the complex interplay between SB, PA and health [25], the simultaneous measurement of both SB and PA has become important in public health research. Many researchers opt to ask their participants to wear two monitors, one optimised to assess MVPA (e.g. the ActiGraph) and one optimised to measure SB (e.g. the activPAL). However, having a single instrument that is valid and reliable to measure both SB and MVPA would be more convenient and cost efficient [16,26,27].

Previous studies comparing concurrent measures of both the ActiGraph and the activPAL to a criterion measure (direct/video observation or a wearable camera), have been conducted only for the assessment of time spent in SB [19,20,28]. In each case, the activPAL provided a more accurate measure of time spent in SB (compared to the criterion) than the ActiGraph. For example, the Youden Index (combined effect of sensitivity and specificity) was 92% for the activPAL compared to 75% for the ActiGraph [28]. The activPAL is recommended for measurement of SB [20,28], and is frequently used as the referent standard to measure SB in studies assessing concurrent validity of the ActiGraph [e.g. 16,30,31]. The concurrent agreement of the ActiGraph and the activPAL to measure MVPA has not been evaluated in free-living studies (with or without a criterion measure).

The inherent inability of an ActiGraph worn at the hip to distinguish between the postures of sitting and standing [17], means that it may not be suitable for use as a single monitor to assess MVPA and SB. Therefore, the current study aimed to explore the ability of the activPAL to measure MVPA, by assessing the concurrent agreement of published methods to classify MVPA using the activPAL and the ActiGraph in a free-living environment.

Methods

Study Design. In this cross-sectional study, participants wore an ActiGraph and an activPAL monitor concurrently during one day of free-living activity, to assess the agreement in time spent in MVPA measured by the two monitors.

Participants. A convenience sample was recruited via email invitations to staff and students from the School of Health and Life Sciences, Glasgow Caledonian University. Participants were adults, aged between 18 and 65, without any upper- or lower- limb functional impairment, neurological conditions affecting upper- or lower- limb function or a known allergy to the material used to attach the monitors. Ethical approval was provided by the School of Health at Glasgow Caledonian University ethics committee, and informed consent was obtained from all participants before data collection.

Protocol. Participants were met on Day 0 by a researcher, and answered self-reported demographic questions (age, gender, height and weight). Two monitors (activPAL3; ActiGraph GT3X) were attached to the participant, and a diary to record wear times for the monitors was provided. Participants wore the monitors on Day1 (including overnight for the activPAL), and recorded sleep times and time for monitor attachment/removal in the diary. Participants met the researcher on Day 2 to return the monitors.

Participants wore an activPAL3 (27g; 3.8×3.7×1.8cm), programmed for immediate start and set to record for 3 days. The activPAL was worn on the midline on the anterior aspect of the thigh, at the midpoint between knee and hip joint, and was attached by the researcher using double sided hypoallergenic adhesive pads (PAL stickies, PAL technologies, Glasgow, UK). Participants were instructed to wear the monitor including overnight, but the monitor was not waterproofed and was removed for water-based activities.

Participants wore an ActiGraph GT3X (15g; 5.3×3.5×0.7cm), programmed to record data at 80Hz. ActiGraph monitors were worn on the axillary line of right iliac crest using an elastic strap provided by the manufacturer. Participants attached the monitor themselves and monitors were not worn overnight or during water-based activities.

Data Processing. Comparisons between the outputs of the two monitors were made within subjects using the data recorded on Day 1 in the period when both monitors were worn. The range of time was selected according to the attachment and removal times recorded in the diary.

All the methods used in this study to classify MVPA have been previously published (Table 1). Four methods for classifying MVPA using the activPAL monitor were included, using three different types of monitor output (activity count from the raw acceleration data; MET values generated from activPAL's embedded formula; cadence of walking events). The two activity count methods were not developed for an adult population, but since there were no other methods that used the activPAL's activity count, they were included in the current study. Therefore, ActiGraph methods developed for both adult and non-adult populations were also selected for inclusion. As there is no agreement as to which ActiGraph cut-point is best, six published ActiGraph methods to derive MVPA were included in the current study.

ActivPAL data were downloaded using the activPAL professional software (version 6.4.1). MVPA was derived according to published methods, using the specified activPAL output. For the two methods deriving MVPA from the activPAL raw acceleration (count) data [24,27], the 15s epoch output was used. Both of these cut-points were developed using uniaxial activPAL monitors, therefore in this study only activity counts in the channel 1 (x-axis), the common channel shared by activPAL (uni-axial) and activPAL3 (tri-axial) monitors [32], were used to calculate MVPA. Each 15s epoch was categorised as MVPA if the activity count was above the specified cut-point (Table 1).

The sum of duration of 15s epochs categorised as MVPA was used to derive outcome measures of total time spent in MVPA.

The PAL embedded algorithm to calculate METs assigns METs values based on activity classification (sit/lie: 1.2METs; standing: 1.4MET; walking: varying linearly with cadence, walking at 120 steps/minute is 4METs [33]). For the method deriving MVPA from the embedded MET algorithm [22], data were first reprocessed to change the embedded MET algorithm so that data categorised as standing was classified as 1.5METs. Data was exported as an event file and was then extrapolated in to 1s epochs using an R package (*activpalProcessing*) [34]. The 1s epochs were categorised as MVPA if the METs calculated by the embedded activPAL algorithm were >2.99METs. The sum of duration of 1s epochs categorised as MVPA was used to derive outcome measures of total time spent in MVPA.

For the method using cadence, the event output was used to calculate MVPA. Each event is defined as a continuous period of categorised activity [18]. Although a cadence of 100 steps/minutes has been advocated as a cut-point for moderate physical activity when walking (derived from validation studies [35-37]), the use of this cut-point as a measure of MVPA in activPAL derived walking had not been validated. An excel macro (HSC PAL analysis software V2.21) was used to firstly create walking events from consecutive stepping events and calculate average cadence (number of steps in the event/event duration), and secondly to separate output into sedentary, standing and walking events. Walking events with an average cadence ≥100 steps/min were categorised as MVPA, and total time spent in MVPA was calculated as the sum of the duration of all such walking events.

ActiGraph data was downloaded using ActiLife software (version 5.10.0), and was exported in 1s epochs. The six published ActiGraph cut-points selected for this study, varied in the epoch length over which counts were aggregated, the count cut-point used to define MVPA and the monitor axes used to provide the count value (vertical axis only (VT) or vector magnitude (VM)). Specific values for these characteristics for each method can be found in Table 1. The vector magnitude (VM) was calculated from three axes (square root of the sum of squares of each axis [38]). Different epochs were subsequently created by summing up the 1s epochs on either vector magnitude (VM) or vertical axis (VT). The sum of duration of appropriate epochs classed as MVPA (if greater than the cut-points for VT or VM, as appropriate) for each method was used to derive outcomes measures (one per method) of total time spent in MVPA.

Statistical analysis. The outcome measures were total time spent in MVPA, calculated using four different activPAL methods and six different ActiGraph methods, reported as mean and standard deviation. The Bland-Altman method was used to assess agreement between each pair of methods to derive MVPA. Data are presented as mean and standard deviation of bias, and 95% Limits of Agreement (LOA; mean bias ±1.96 standard deviation), Bland-Altman diagrams for selected pairs are presented in the supplemental material. To show the direction of bias, absolute difference was not used to calculate agreement.

Results

Twenty-five adults participated in this study. One set of activPAL data was missing due to technical issues (data did not download), therefore data from twenty-four individuals were included in this analysis. Participants were mostly women (n=19; 79%), with an average age of 38±11 (23 to 60) years. Four participants did not disclose their height and/or weight, and the remaining participants were on average overweight (mean BMI 27.92±2.79 kgm^{-2}).

The mean time spent in MVPA ranged between 60 and 145 minutes (Table 2), with both the lowest and the highest times reported by activPAL methods. The six ActiGraph methods were more comparable, with mean time spent in MVPA ranging from 64 minutes to 94 minutes, whilst those that used the vertical axis only (VT) were spread across only 12 minutes (between 64 and 76 minutes). Grouping methods of defining MVPA by development population (refer to Table 1), the four methods developed for children and adolescents reported higher average time spent in MVPA (102±41 minutes) than methods developed for adults (73±37 minutes).

In general, the cadence-based activPAL method (aP100) tended to underestimate MVPA compared to the ActiGraph, whereas the other methods (based on METs and activity counts) tended to overestimate MVPA relative to ActiGraph methods (Table 2). As expected, the activity count methods with the lower cut-points categorised more time as MVPA than those with higher cut-points. Amongst all activPAL methods, aP100 had the smallest average bias (-16±28 minutes) against all ActiGraph cut-points, compared with aP3 (17±27 minutes), aP2997 (18±28 minutes), and aP1418 (69±44 minutes). There were several specific pairs of methods with a small bias (Figure 1), the smallest bias was between aP3 and AG56 and between aP2997 and AG56. However, as bias was calculated on signed (as opposed to absolute) data, this should be treated with caution due to the large 95% LOA. The smallest 95% LOA (range <90minutes) were between the cadence-based active PAL method (aP100) and the ActiGraph methods based on the vertical axis (AG1952, AG2000, AG2020). The aP1418 methods had the largest bias (50 to 80 minutes) coupled with large ranges between the 95% LOA (160 to 180 minutes).

In general, methods using vector magnitude reported more time spent in MVPA than those using the vertical axis. The ActiGraph methods based on the vertical axis agreed relatively closely with each other (bias <12 minutes, range of 95%LOA <40minutes, Table 3). In particular, AG1952 and AG2020 (Figure 1e) were the most comparable methods with bias of -2 minutes and 95% LOA from -6 to 2 minutes. These two methods differed only in the activity count cut-point (~3%), whilst the epoch and axis used were the same. Two of the vector magnitude methods (AG56 and AG2690), had reasonable agreement with each other but not with the three vertical axis methods. However, the vector magnitude-based AG3208 appeared to agree better with the three VT methods than the other two VM methods.

In contrast to ActiGraph methods, the four ActivPAL methods showed little comparability with each other (Table 4). For example, the pair of aP3 and aP100 had a bias of -33±19 minutes (95% LOA -72 to 5 minutes). The pair of aP3 and aP2997 had a zero bias (Figure 1f), but the 95% LOA were large (range ~60minutes).

Discussion

The current study aimed to examine the agreement in measuring MVPA for adults in a free-living environment between two objective monitors, the ActiGraph and the activPAL, using pre-existing published methods to calculate MVPA. The ActiGraph monitor is commonly used to measure MVPA in adults, and the study therefore aimed to assess whether the activPAL was also an acceptable tool to assess MVPA. Across the ten methods tested, reported MVPA varied considerably, between 60 and 145 minutes (±40% of the mid-value). As this was an agreement study without a criterion measure, the actual value of MVPA was not known. In general, the activPAL cadence method (aP100) underestimated MVPA compared to ActiGraph methods, but had the smallest bias (-16 minutes), and 95% LOA (<90 minutes). Comparison with individual methods could be smaller, for example the bias of the aP100 method was -6 minutes compared with the popular 'Freedson' cut-points (AG1952). A bias of 16 minutes between methods can be considered large in terms of the amount of MVPA performed in a day, where achieving 22 minutes of MVPA each day would be sufficient to meet many PA guidelines. However, this level of agreement was also similar to that between different pre-existing ActiGraph methods. The use of activPAL to measure time spent in MVPA can therefore be placed within the same conversation as the relative merits of the different ActiGraph methods for measuring MVPA.

The embedded MET equation in the activPAL has been shown to both significantly under- and over-estimate actual energy expenditure in METs in adolescent and young adult females [26], and in young children [27]. However, while the value of the embedded activPAL MET algorithm might not provide an accurate estimate of energy expenditure, it can be used in adults to accurately categorise activity into SB and MVPA using the embedded METs estimates [22]. It should be noted, however, that the value that the embedded MET equation ascribed to standing was changed (from 1.4 to 1.5 METs) from the default settings within the activPAL software. It is possible that further refinement of the internal algorithm may improve MET classification. Indeed, Harrington et al [26] found that the acceleration count output of the activPAL was better correlated to energy expenditure (r=0.76) than cadence (r=0.59). However, in the current study, the cut-point for MVPA derived from counts (in adolescent females, aP2997) did not perform better than the method based on the embedded MET algorithm (aP3).

The embedded MET algorithm method (aP3), when assessing MVPA, is based on the cadence of activity categorised as walking, with 3METs defined as being at a cadence of 74 steps/minute. As the aP100 method consistently underestimated, and the aP3 consistently overestimated, time spent in MVPA compared to the ActiGraph it is possible that defining a value between 74 and 100 steps/min to represent MVPA would improve the calculation of time spent in MVPA. In both methods, only periods of walking could be characterised as MVPA. Any MVPA undertaken at other times, for example when standing or seated, would not be picked up. However, it is unclear whether there would be sufficient hip acceleration for the ActiGraph to classify such periods as MVPA. In the current study, such activity is likely to have been missed by both monitors.

The predominant predictor of time spent in MVPA for each ActiGraph method appeared to be the axes used to generate counts (vertical axis or vector magnitude). The exception was the AG3208 VM-based method, which performed more like the VT methods than the other VM methods. One possible explanation for this is that this method was developed using artificial neural networks, as opposed to the more standard statistical methods of linear regression or optimising receiver operating characteristic curves used for all the other ActiGraph methods. Except for development population, other aspects of the studies to derive cut-points were similar (e.g. oxygen consumption used as the criterion measure; walking and running always included in the protocol).

Many methods, for both activPAL and ActiGraph monitors, were developed on data from a uni-axial monitor. In the current study, only tri-axial monitors were used, and it was assumed during data processing that using the specified single axis value in the tri-axial monitor was equivalent to using a uni-axial monitor. However, any differences in the sensing units and data processing hardware between monitor models might affect the validity of that assumption. For activPAL, no studies have compared the value of the acceleration output between uni-axial and tri-axial models. It is therefore unclear if any differences in value of the x-axis between the monitors exist, and thus whether the use of these activPAL cut-points developed using activity counts in a uniaxial activPAL are valid for a tri-axial activPAL. However, the agreement in classification of activity (sit, stand, walk) between uni-axial and tri-axial activPAL monitors, was good for standardised activities for children, adults [39] and older adults [40], but lower during simulated activities of daily living (ADL) for children and adults [39]. It is therefore possible that those differences in the value of x-axis acceleration might arise in a free-living environment, affecting the results of the current study.

All the VT cut-points of the ActiGraph were developed on uni-axial versions of the monitor. In adults, there were no significant differences in vertical axis counts between a GT1M uniaxial ActiGraph and a GT3X tri-axial ActiGraph, when walking and running on a treadmill [41]. Bland and Altman analysis indicated a bias of 50 counts per minute between the monitors with 95% LOA of approximately ±700 counts per minute. In children, using a 1 second epoch, agreement in vertical axis was good for static postures and walking, but was significantly higher in the GT3X for running and Wii boxing tasks [42]. For walking and running-based MVPA in adults, then, it seems reasonable to use the ActiGraph axes interchangeably.

Many studies have been conducted to examine the agreement between ActiGraph and activPAL in classifying SB [16,30,31], using activPAL as the reference standard, with the aim of identifying find the most comparable ActiGraph cut-points to measure SB. It is, however, clear that the ActiGraph does not adequately assess postural sitting, due to the nature of measuring acceleration at the hip [17,20,28]. Other than a lack of previous research interest, there is no equivalent reason to assume that the activPAL cannot adequately measure MVPA. Therefore, a key strength of the current study was that it investigated a potentially realistic option for using a single monitor to adequately assess both MVPA and SB.

The study also had several weaknesses. The study had a small sample size drawn only from a higher education setting, and therefore may not be generalisable to a wider population. However, the use of concurrent measurement meant that comparison was made between monitors on the actual activity of the participant, regardless of how typical. Another weakness was the lack of a criterion measure, so there was no knowledge of the actual MVPA of participants in the study. This means that all assessment of agreement between methods was relative and not absolute. However, there are limited options to provide an adequate criterion method for free-living activity over a longer period (e.g. a day); indirect calorimetry cannot be comfortably worn for extended periods, and direct observation is potentially intrusive and time consuming to achieve. In a study aiming to assess the potential of one monitor method to agree with another established monitor, concurrent measurement is an acceptable methodology.

A particular weakness of the current study was the inclusion, in a study with adult participants, of methods to derive MVPA developed for younger populations (adolescents and children). This decision was driven by the lack of cut-points using activity count developed for the activPAL for adults, coupled with the desire to assess the potential utility of such methods for the calculation of MVPA. It is unclear how different an adolescent population might be from the relatively young adults who participated in the current study, although the development of the adolescent cut-point including only female participants is an additional limitation. However, in the current study, this method (aP2997) performed relatively similarly to one of the other activPAL methods derived for adults (aP3). It is clear that the methods designed for children resulted in higher values of time spent in MVPA. In particular, the method derived for the activPAL for 4-6 year olds resulted in a value of MVPA 50 minutes greater than any other outcome (145 minutes vs 94 minutes). Further research is required to elucidate how different an activPAL cut-points using activity count developed for adults would be, and how well it would agree with ActiGraph assessments of MVPA.

Conclusion

The agreement of different methods of calculating MVPA (four using the activPAL monitor and six using the ActiGraph monitor) were assessed on concurrently measured free-living data in adults. Using a cadence of 100 steps/minute underestimated MVPA compared to ActiGraph methods, and had the lowest aggregate bias (-16 minutes). Pairs of methods could have smaller bias, for example, the cadence method (aP100) and the ‘Freedson’ cut-points (AG1952) had a bias of -6 minutes. Other activPAL methods, based on acceleration counts and the embedded MET algorithm, overestimated

MVPA compared to the Actigraph. However, the study was limited by the lack of activPAL acceleration count methods developed specifically for an adult population. The current study found that the comparisons between measuring MVPA using the activPAL were in the same range as comparisons between different ActiGraph cut-points. As previous research has established that the activPAL is preferable to the ActiGraph for the measurement of SB, these results showing its comparability with ActiGraph for measuring MVPA, suggest that the activPAL may be suitable to use as a single monitor to adequately measure both SB and MVPA.

Highlights

- Different activity monitors measure moderate to vigorous physical activity (MVPA) in different ways, meaning comparison between studies can be difficult.
- ActiGraph and activPAL can achieve good agreement in measuring MVPA by using particular pairs of methods.
- Differences in MVPA measured between activPAL and ActiGraph monitors were comparable to differences between different ActiGraph methods.
- Using the threshold of 100 steps/min to measure MVPA in activPAL had best agreement with ActiGraph, and is therefore recommended to be used to measure MVPA.
- ActivPAL can be used as a single monitor to measure both physical activity and sedentary behaviour since it is good for measuring sedentary behaviour, and this study showed it can measure MVPA in good agreement with ActiGraph. .

Figure Captions

Bland -Altman plots of mean bias in time spent in MVPA and 95% limits of agreement for time spent in MVPA measured by (a) aP3-AG56 (b) aP2997 - AG56 (c) aP100-AG2020 (d) aP100-AG1952 (e) AG1952-AG2020 (f) aP3-aP2997.

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Ethical approval

This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was provided by the School of Health at Glasgow Caledonian University ethics committee (reference number HLS12/50), and informed consent was obtained from all participants before data collection

Declarations of interests

LFRL none, PMD has previously received grant income from PAL technologies outside of the submitted work.

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Table 1: Characteristics of previously published methods to categorise time spent in MVPA (as used in the current study).

Reference	Monitor	Acronym	output	axes	Cut-point value	Epoch	Development Population
[22]	activPAL	**aP3**	MET	--	2.99	1s	Adults
[35-37]		**aP100**	cadence	--	100	per event	Adults
[27]		**aP1418**	activity counts	thigh	1418	15s	Children
[24]		**aP2997**	activity counts	thigh	2997	15s	Adolescents
[43]	ActiGraph	**AG1952**	activity counts	VT	1952	60s	Adults
[44]		**AG2000**	activity counts	VT	166.7[1]	5s	Children
[45]		**AG2020**	activity counts	VT	2020	60s	Adults
[42]		**AG56**	activity counts	VM	56	1s	Children
[41]		**AG2690**	activity counts	VM	2690	60s	Adults
[46]		**AG3208**	activity counts	VM	3208	60s	Adults

MET: Metabolic equivalent; MVPA: moderate to vigorous physical activity; VT vertical axis; VM: vector magnitude. Time spent in MVPA reported as mean ± standard deviation. [1] Threshold values calculated as 2000 counts per minute/12 to provide value for 5s epochs.

Table 2: Mean time spent in MVPA, bias and 95% limits of agreement for MVPA between pairs of activPAL and ActiGraph methods

			activPAL			
		method	METs	Cadence	Activity Counts	
		acronym	aP3	aP100	aP1418	aP2997
		[Mean ± SD]	[93 ± 41]	[60 ± 32]	[145 ± 58]	[93 ± 43]
ActiGraph						
axes	acronym	[Mean ± SD]	Bias (95% LOA)	Bias (95% LOA)	Bias (95% LOA)	Bias (95% LOA)
	AG1952	[66± 36]	27 ± 23 (-18 to 72)	-6 ± 22 (-50 to 37)	79 ± 43 (-4 to 163)	27 ± 25 (-22 to 77)
VT	AG2000	[76± 31]	17 ± 24 (-30 to 64)	-16 ± 23 (-61 to 28)	69 ± 42 (-14 to 152)	17 ± 26 (-34 to 68)
	AG2020	[64 ± 35]	29 ± 23 (-16 to 74)	-4 ± 21 (-46 to 38)	81 ± 43 (-3 to 166)	29 ± 26 (-21 to 80)
	AG56	[94 ± 30]	-1 ± 30 (-61 to 58)	-35 ± 32 (-97 to 28)	51 ± 44 (-35 to 137)	-1 ± 29 (-58 to 56)
VM	AG2690	[87 ± 41]	6 ± 32 (-56 to 69)	-27 ± 36 (-98 to 43)	58 ± 45 (-31 to 147)	7 ± 31 (-55 to 68)
	AG3208	[67 ± 36]	26 ± 30 (-32 to 84)	-8 ± 31 (-68 to 52)	78 ± 46 (-13 to 168)	26 ± 28 (-30 to 82)

LOA: limits of agreement; METs: metabolic equivalent; MVPA: moderate-vigorous physical activity; SD: standard deviation; VT: vertical axis; VM: vector magnitude. Data presented as bias (activPAL method – ActiGraph method) mean ± standard deviation, and 95% LOA.

Table 3: Bias and 95% limits of agreement for MVPA calculated between pairs of ActiGraph methods

Axis		VT			VM	
	acronym	AG1952	AG2000	AG2020	AG56	AG2690
VT	AG2000	10 ± 10 (-9 to 30)				
	AG2020	-2 ± 2 (-6 to 2)	-12 ± 10 (-32 to 7)			
VM	AG56	28 ± 21 (-12 to 69)	18 ± 16 (-13 to 50)	30 ± 20 (-10 to 70)		
	AG2690	21 ± 19 (-16 to 57)	11 ± 19 (-27 to 49)	23 ± 20 (-15 to 61)	-8 ± 16 (-38 to 23)	
	AG3208	1 ± 14 (-27 to 29)	-9 ± 16 (-40 to 22)	3 ± 15 (-25 to 32)	-27 ± 14 (-54 to 0)	-20 ± 10 (-40 to 1)

VT: vertical axis; VM: vector magnitude. Data presented as bias (row - column) mean ± standard deviation (95% limits of agreement), data reported in minutes.

Table 4: Bias and 95% limits of agreement for MVPA calculated between pairs of activPAL methods

Output		**METs**	**cadence**	**activity counts**
	acronym	aP3	aP100	aP1418
cadence	aP100	-33 ± 19 (-72 to 5)		
activity counts	aP1418	52 ± 27 (-1 to 105)	85 ± 42 (3 to 168)	
	aP2997	0 ± 15 (-28 to 29)	34 ± 25 (-16 to 83)	-52 ± 24 (-98 to -6)

METs: metabolic equivalents. Data presented as bias (row - column) mean ± standard deviation (95% limits of agreement), data reported in minutes.

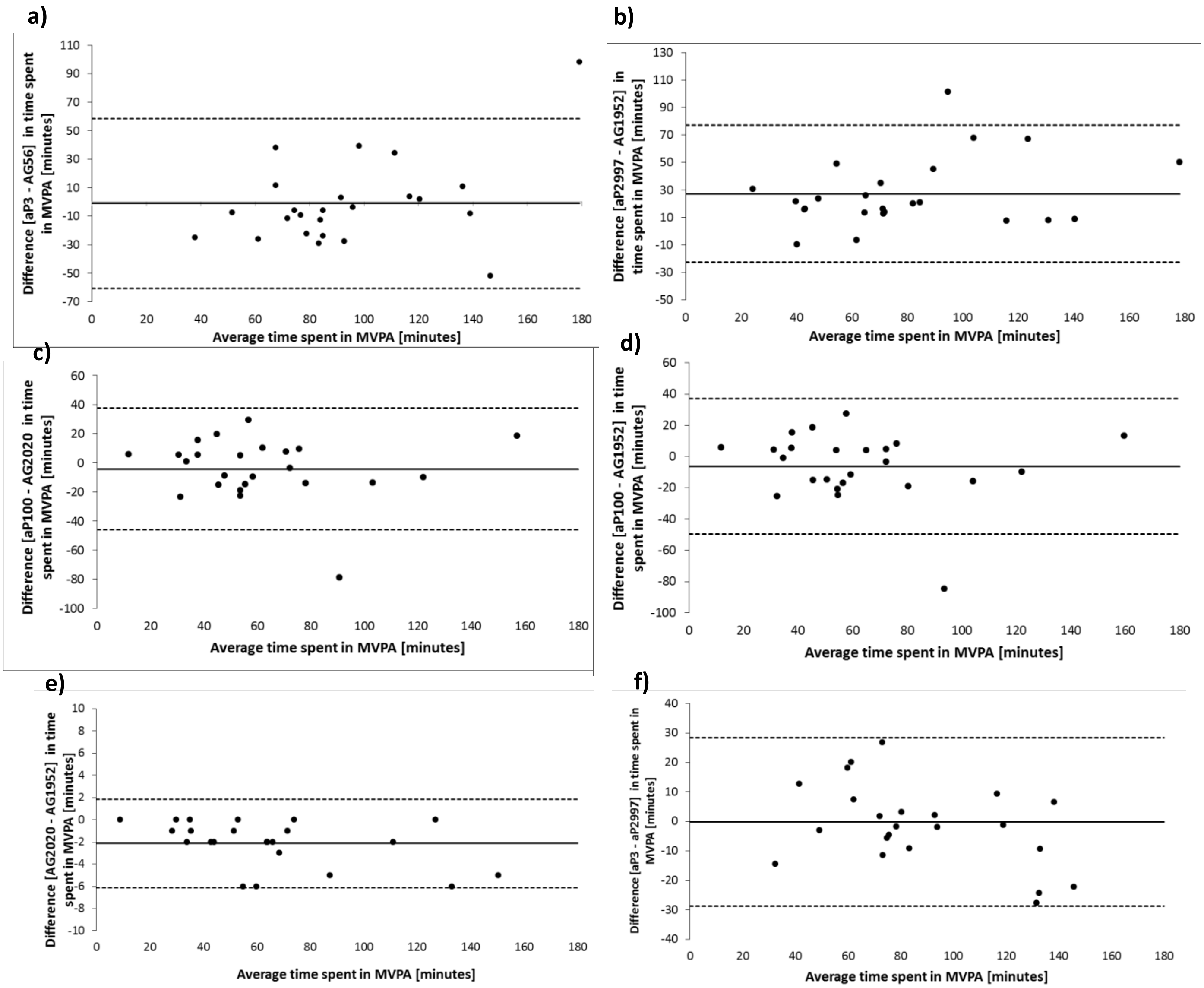

Figure Captions

Figure 1 Bland -Altman plots of mean bias in time spent in MVPA and 95% limits of agreement for time spent in MVPA measured by (a) aP3-AG56 (b) aP2997-AG56 (c) aP100-AG2020 (d) aP100-AG1952 (e) AG1952-AG2020 (f) aP3-aP2997.