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Effects of ActiGraph's filter, epoch length and non-wearing time algorithm on step counts in people with COPD

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ABSTRACT

The influence of the ActiGraph® processing criteria on estimating step counts in chronic obstructive pulmonary disease (COPD) remains uncertain. This study aimed to assess the influence of filters, epoch lengths and non-wearing time (NWT) algorithms on steps/day in people with COPD. ActiGraph GT3X+ was worn on the waist for seven days. Steps were detected using different filters (normal and low-frequency extension [LFE]), epoch lengths (15s and 60s), and NWT algorithms (Choi and Troiano). Linear mixed-effects model was applied to assess the effects of filter, epoch length, NWT algorithm on steps/day. Lin's concordance correlation and Bland-Altman were used to measure agreement. A total of 136 people with COPD (107 male; 69 ± 8 years; FEV_1 51 ± 17% predicted) were included. Significant differences were found between filters ($p < 0.001$), but not between epoch lengths or NWT algorithms. The LFE increased, on average, approximately 7500 steps/day compared to the normal filter ($p < 0.001$). Agreement was poor (<0.3) and proportional bias was significant when comparing steps/day computed with different filters, regardless of the epoch length and NWT algorithm. Filter choice but not epoch lengths or NWT algorithms seem to impact measurement of steps/day. Future studies are needed to recommend the most accurate technique for measuring steps/day in people with COPD.

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KEYWORDS
Pulmonary disease, chronic obstructive; accelerometry; physical activity

Introduction

Chronic obstructive pulmonary disease (COPD) is a heterogeneous lung condition characterised by chronic respiratory symptoms (dyspnoea, cough, sputum production) due to abnormalities of the airways (bronchitis, bronchiolitis) and/or alveoli (emphysema) that cause persistent, often progressive, airflow obstruction (Global Initiative for Chronic Obstructive Lung Disease GOLD, 2024). COPD is one of the main causes of morbidity and the third leading cause of mortality worldwide (Global Initiative for Chronic Obstructive Lung Disease GOLD, 2024; Safiri et al., 2022; World Health Organization, 2020). Physical inactivity is a well-known risk factor for exacerbations and mortality in people with COPD (Gimeno-Santos et al., 2014). Step counts is a simple and meaningful indicator of physical activity (PA) levels (Bassett et al., 2017), being the most commonly reported PA outcome in COPD research (Burge et al., 2020; Byrom & Rowe, 2016). Accurate step detection is essential to prevent misclassification, ensuring precise information for PA interventions and effective assessment of their impact in people with COPD (Demeyer et al., 2021; Tudor-Locke et al., 2013).

Objective measurement of PA is commonly conducted using accelerometers. ActiGraph GT3X+® is one of the most widely used accelerometers (Byrom & Rowe, 2016) and has been previously validated in COPD (Rabinovich et al., 2013; Van Remoortel et al., 2012). ActiGraph GT3X+ measures body acceleration, which can then be processed into a step count in the ActiGraph data analysis software, ActiLife (ActiGraph, LLC, Pensacola, United States). The acceleration recorded by the ActiGraph accelerometer is digitized by a 12-bit analogue-to-digital converter at a user-specified rate, ranging between 30 and 100 Hz (John & Freedson, 2012; John et al., 2012). The ActiLife software post-processes collected raw data and the user needs to select several criteria to derive step counts, including the filter, epoch length, and non-wearing time (NWT) algorithm. Previous studies, in COPD (Rebelo et al., 2023; Webster et al., 2021) and non-COPD (Migueles et al., 2017) populations, indicate that these choices significantly influence ActiGraph outputs, namely, on sedentary time (Webster et al., 2021) and time spent in moderate-to-vigorous PA (Rebelo et al., 2023). Nevertheless, the influence of these choices on steps/day in people with COPD remains unexplored.

The choice of the filter is required. The filter acts as a band-pass filter, attenuating signal frequencies outside the normal human activity frequency bandwidth (John & Freedson, 2012; John et al., 2012). In recent versions of the ActiLife software, a low-frequency extension (LFE) filter was made available to increase the sensitivity of the default filter (normal filter) to low-intensity movement (ActiGraph, 2018) as factors like gait speed can affect accelerometer step detection accuracy (Chow et al., 2017; Storti et al., 2008). Since people with COPD have a slow walk

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speed, the recommendation for use in older individuals (ActiGraph, 2018) also makes it a suitable choice for this population. It is, however, unclear to what extent this choice will affect daily steps estimation of people with COPD.

The band-pass filtered acceleration from the vertical axis is then used to detect step counts using the ActiLife's internal algorithm (John et al., 2018). An epoch length, between 1s and 240s, must be selected; however, this is unlikely to affect step count as this is calculated before data aggregation.

Another step involves choosing an algorithm to identify periods when the device was not worn. The device may be removed during sleep, water-based activities or forgotten to be used. Hence, precise discrimination between wearing time and NWT is vital, as the sample size for analysis, along with the estimated number of steps and other PA, relies on the duration of wearing time (Banda et al., 2016; Syed et al., 2020). Troiano's and Choi's algorithms are two NWT algorithms available in the ActiLife 6 software (ActiGraph, 2020b). There is uncertainty regarding the selection of the most suitable algorithm. Troiano's algorithm has been recommended for people with COPD based on literature consensus (Byrom & Rowe, 2016) but Choi's algorithm has shown to be more accurate at identifying NWT in the elderly (Choi et al., 2012; Keadle et al., 2014; Knaier et al., 2019). The choice of the NWT algorithm has been shown to impact sedentary time but not moderate-to-vigorous PA in older women (Keadle et al., 2014); however, the impact on step counts is unknown. In addition, both the choice of NWT algorithm and epoch length may significantly influence estimated wearing time and, consequently, PA estimates (Banda et al., 2016). While the effect of the NWT algorithm as well as the epoch length on step counts is likely to be small compared to other criteria (e.g., filter), it may increase if the algorithms lead to different number of valid days to be included in the analysis. The extent to which this interaction effect affects steps/day in people with COPD is unknown.

This study aimed to assess the impact of different choices of ActiGraph's filter, epoch length and NWT algorithm on daily step counts in people with COPD under free-living conditions.

Methods

This cross-sectional study comprised data collected between 2019 and 2022 from two projects (NCT04223362; NCT03799666), which included a convenience sample of people with COPD referred to community-based pulmonary rehabilitation in the centre region of Portugal. The Ethics Committees from *Unidade Investigação em Ciências da Saúde – Enfermagem* (Ref. P620–10/2019), *Centro Hospitalar Baixo Vouga* (Ref. 15 May 2019), *Administração Regional de Saúde do Centro* (Ref. 73/2016 and 16/2020), and the National Committee for Data Protection (no. 7295/2016), approved the study. Participants provided researchers with informed consent and their privacy was assured following the European Union General Data Protection Regulation 2016/679 (GDPR). The STROBE guidelines for cross-sectional studies were followed (von Elm et al., 2008).

Eligible participants were referred by their medical doctor during routine appointments at hospital or primary healthcare centres and were included if a diagnosis of COPD was confirmed (post bronchodilator forced expiratory volume in the first second [FEV_1]/forced vital capacity [FVC] <0.70) (Global Initiative for Chronic Obstructive Lung Disease GOLD, 2024) and PA data using ActiGraph was collected.

Participants were instructed to wear the ActiGraph GT3X+ attached to an elastic belt on the right side of the waist 24 h/day for seven consecutive days, except during water-based activities, to improve adherence to the use of the device (Byrom & Rowe, 2016; Migueles et al., 2017). The device was initialized using the ActiLife software v6.10.3 to start data collecting the day after the assessment at a sampling frequency of 30 Hz (Demeyer et al., 2021; Migueles et al., 2017). ActiGraph data before pulmonary rehabilitation was used as the standard for analysis. Post-rehabilitation accelerometer data were only included for participants who did not meet the wearing time criteria at baseline to preserve sample size. Data were downloaded from the device and stored as *.gt3x raw data files using ActiLife v6.10.3. Raw data files were converted into post-filtered/post-accumulated in *.agd files. In this process, the raw acceleration was band-pass filtered using the normal and LFE filters. Steps were then obtained based on the data from the vertical axis using the ActiLife's internal algorithm and aggregated in epoch lengths of 15s[7] and 60s (Byrom and Rowe 2016; Eliason et al., 2011; Hunt et al., 2013; Loprinzi et al., 2014; Orme et al., 2019; Park et al., 2020). This process resulted in four *.agd files. The *.agd files were screened for NWT using the algorithms of Choi – periods of 90 minutes minimum of 0 counts per min (cpm) with the allowance of 2 minutes of interruptions plus two 30-minute windows of 0 cpm before and after that interruption (Choi et al., 2011) and Troiano – periods of at least 60 minutes of 0 cpm with an allowance of 2 minutes of interruptions of less than 100 cpm (Troiano et al., 2008). This resulted in the implementation of eight unique processing techniques. Participants needed to have at least 4 valid days with a minimum of 8h of wearing time for at least one of the processing techniques to be included, following the recent task force recommendations for standardized PA data collection in people with COPD (Demeyer et al., 2021). The outcome of interest was daily step counts derived by averaging the steps taken across valid wearing days.

Sociodemographic (age and sex), anthropometric (height and weight to compute body mass index) and clinical data were collected by physiotherapists at baseline for sample characterization. Clinical data included smoking status, number of hospitalisations and acute exacerbations of COPD in the previous year, lung function with spirometry, severity of airflow limitation and symptom burden and risk of exacerbation as defined by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) (Global Initiative for Chronic Obstructive Lung Disease (GOLD), 2024) comorbidities using the Charlson comorbidity index (Charlson et al., 1987) medication, activity-related dyspnoea using with the modified British medical research council (mMRC) dyspnoea scale (Bestall et al., 1999) impact of disease assessed with the COPD assessment test (Jones et al.,

2009) and functional capacity with 6-minute walk test (Holland et al., 2014).

Continuous normally distributed variables were presented as means ± standard deviation. Ordinal and non-normally distributed data were reported as medians [interquartile range]. Categorical variables were expressed by absolute frequencies and percentages. Linear mixed-effects model with random intercepts was used to assess the effects of filter, epoch length, NWT algorithm and the interaction effect of these factors on daily steps. Quantile-quantile plot and Shapiro-wilk test were used for visual inspection and to test residuals' normality assumption. Both factors and full model variance contributions were provided with marginal and conditional R^2. Inclusive R^2 was estimated to quantify the proportion of variance explained by each factor (Stoffel et al., 2021). Reliability and agreement between techniques were assessed using Lin's concordance correlation coefficient and by visual inspection of Bland-Altman plots, respectively. Fixed bias was considered significant if zero was not within the 95% confidence interval (CI) for the mean difference. Proportional bias was determined by fitting a linear regression model of differences on means. A concordance correlation coefficient above 0.99 was interpreted as near perfect agreement, between 0.95 to 0.99 as substantial, between 0.9 to 0.95 as moderate and values below 0.9 as poor agreement (McBride, 2005). Statistical analyses were conducted in R (version 4.1.2, R Foundation for Statistical Computing, Vienna, Austria) considering a significance level of 0.05.

Results

A total of 147 people with COPD were eligible (Figure 1). Eleven participants did not fulfil the criterion for wearing time for any processing technique and were therefore excluded from the analysis. Additionally, two participants did not have valid wearing time when Troiano's algorithm was applied, and three when the normal filter and Troiano's algorithm were used.

Of the 136 people with COPD included in the analysis, 79% were men ($n = 107$), with a mean age of 69 ± 8 years, presented an FEV_1 of 50.7 ± 17% predicted, most exhibited moderate to severe airflow obstruction (GOLD grades 2–42% and 3–44%), pertained to GOLD group B (57%) and with moderately impaired functional exercise capacity (6-min walking distance, 403.4 ± 99.1 m) (Table 1).

Daily wearing time ranged from 860.57 [727.71–1020.43] to 1167.24 [799.89–1368.66] minutes/day (Table 2). Daily steps obtained using the LFE filter was more than double of the steps detected by the normal filter, independently of the choice of epoch length and NWT algorithm (Table 2). The epoch length and the NWT method yielded comparable daily steps when fixing the filter (Table 2). This behaviour was observed across most individuals (Figure 2).

The linear mixed-effects model explained 94% of the variance (marginal R^2/conditional R^2, 0.46/0.94; inclusive R^2 for filter, NWT algorithm and epoch length were 0.46, 9.42×10^{-6}, 6.17×10^{-7}, respectively). Analysis of variance for the fixed effects revealed no statistically significant three-way interaction among the effects of filter, epoch length and NWT algorithm ($F = 3\times10^{-4}$, $p = 0.986$), neither two-way interaction (EpochxFilter: $F = 3\times10^{-4}$, $p = 0.986$; EpochxNWT: $F = 0.01$, $p = 0.905$; FilterxNWT: $F = 0.05$, $p = 0.825$). Significant differences were found between normal and LFE filters in daily step counts ($F = 8320.35$, $p < 0.001$, $\eta^2_{partial} = 0.9$), but not between epoch lengths of 15s and 60s ($F = 0.01$, $p = 0.906$), nor between Choi's and Troiano's algorithms ($F = 0.24$, $p = 0.627$). Examination of the model's coefficients indicated that step counts are on average 7513.36 steps/day higher when using the LFE filter than with the normal filter (estimate:

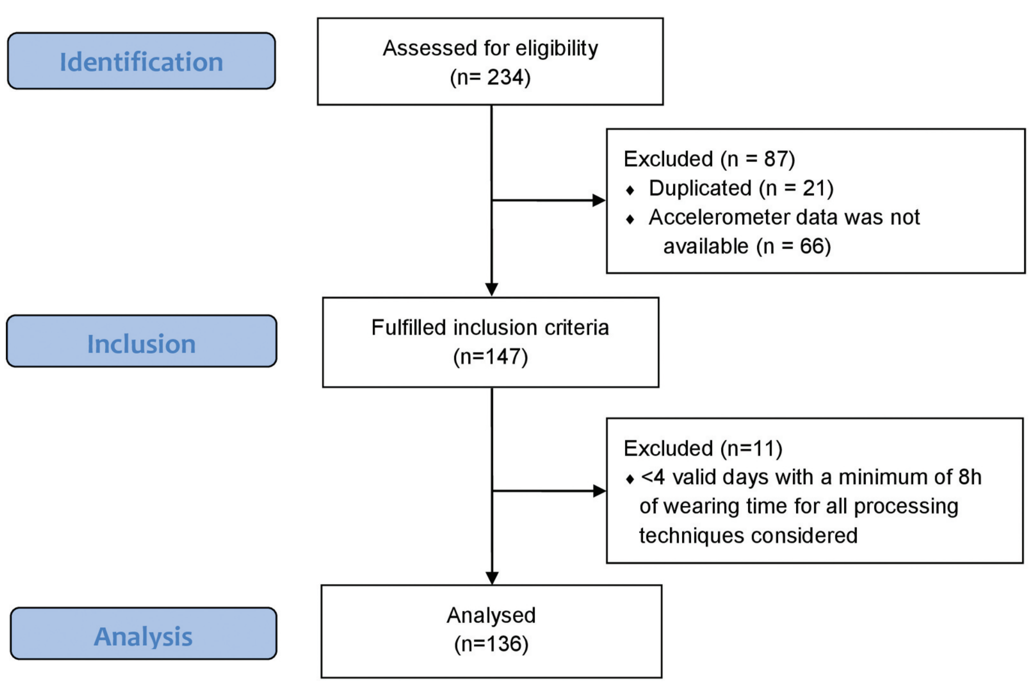

Figure 1. Study flow diagram.

Table 1. Sociodemographic and clinical characteristics of participants with chronic obstructive pulmonary disease included in the analysis ($N = 136$).

Characteristics	Overall ($N = 136$)
Age, years	68.7 ± 8.3
Sex, male, n (%)	107 (78.7)
BMI, kg/m^2	27.1 ± 5.3
Smoking status, n (%)	
Current	23 (17)
Former	82 (60.7)
Never	30 (22.2)
Packs/year	31.5 [10–70]
Exacerbations/year [1]	0 [0–1]
Hospitalisations/year[1]	0 [0–0]
Lung function (post-bronchodilator)	
FEV_1, L	1.3 ± 0.5
FEV_1, % predicted	50.7 ± 17
FVC, L	2.5 ± 0.9
FVC, % predicted	74.2 ± 18.8
FEV_1/FVC, %	52.8 ± 11.4
GOLD grades, n (%)	
1	8 (6)
2	56 (41.8)
3	59 (44)
4	11 (8.2)
GOLD groups, n (%)	
A	37 (27.2)
B	78 (57.4)
E	21 (15.4)
CCI, n (%)	
Mild (1–2)	16 (11.9)
Moderate (3–4)	80 (59.3)
Severe (≥5)	39 (28.9)
Medication, n (%)	
Bronchodilators	
SABA	17 (12.5)
SAMA	8 (5.9)
LABA	16 (11.8)
LAMA	41 (30.1)
LAMA/LABA combination	43 (31.6)
ICS	17 (12.5)
ICS/LABA combination	46 (33.8)
ICS/LABA/LAMA combination	14 (10.3)
LRTA	11 (8.1)
Xanthines	10 (7.4)
Expectorants	17 (12.5)
mMRC, grade	2 [1–3]
CAT, points	14.7 ± 8.3
6MWD, metres	403.4 ± 99.1
6MWD, % predicted	86.8 [69.3–98.8]

Values are presented as mean±standard deviation or median [interquartile range], unless otherwise stated. [1]past-year.

BMI: body mass index; CAT: COPD assessment test; CCI: Charlson comorbidity index; FEV_1: forced expiratory volume in one second; FVC: forced vital capacity; GOLD: Global Initiative for Chronic Obstructive Lung Disease; ICS: inhaled corticosteroid; LABA: long-acting beta-agonists; LAMA: long-acting muscarinic antagonist; LRTA: leukotriene receptor antagonist; SABA: short-acting beta-agonists; mMRC: modified medical research council questionnaire; SAMA: shortacting muscarinic antagonist; 6MWD: 6-minute walk distance.

7513.36, 95% CI: 7189.47; 7837.25, $p < 0.001$), when the remaining variables are held constant (Table S1 in the Appendix).

Poor concordance (<0.30), large and significant biases (mean difference above 7400 steps/day) and wide limits of agreement were observed whenever different filters were compared, regardless of the epoch length and NWT algorithm (Table 3). The proportional bias was significant between processing techniques using difference filters, i.e., the difference in steps between techniques using different filters increased proportionally to the average values (coefficients ranging from −0.44 to −0.43, all $p < 0.001$) (Table 3, Fig. S1 a-d in the Appendix).

On the contrary, when the filter was fixed and only the epoch length or NWT algorithm varied, the concordance was near perfect (>0.99) and biases below 45 steps/day with narrow limits of agreement (Table 3). Bias was not significant for most comparisons between processing techniques using the same filter, except for Choi/Normal/60s *versus* Troiano/Normal/60s (Table 3). The proportional bias was not significant when comparing epoch lengths and holding constant the filter and the NWT algorithm (Table 3, Fig. S1 e-h in the Appendix), and when comparing NWT algorithms using the same filter and epoch length (Table 3, Fig. S1 i-l in the Appendix).

Discussion

Our findings show that the filter selection in ActiLife, not epoch lengths or NWT algorithms, has a significant impact on step counts in people with COPD under free-living conditions, with the LFE filter resulting in twice as many steps as detected by the normal/default filter.

The LFE filter substantially increased daily step counts by an average of approximately 7500 steps/day compared to the normal filter, yielding low concordance (<0.3), large limits of agreement, regardless of the epoch length and the NWT algorithm. Furthermore, bias between filters tends to increase with the number of steps taken, which is to be expected since the LFE was developed to enhance ActiGraph sensitivity to capture body movement during slow activities (ActiGraph, 2018). These results are consistent with previous findings in healthy adults, which found a difference of 5000 daily step counts between ActiGraph's default and LFE filter (Cain et al., 2013; Feito et al., 2017; Wanner et al., 2013). Unfortunately, determining which filter is more accurate in this study is not possible due to the absence of a criterion method. Previous research using

Table 2. Descriptive statistics of average wear-time in minutes per day and number of steps per day on valid days for the different ActiGraph processing techniques analysed, i.e., normal and low-frequency extension filters, epoch lengths of 15s and 60s and non-wearing time algorithms of Choi and Troiano in people with chronic obstructive pulmonary disease under free-living conditions.

Non-wearing time algorithm	Filter	Epoch length	Wearing time, minutes/day	Number of steps/day
Choi	Normal	15s	1054.62 [796.15–1298.29]	5292.41 ± 3131.85
		60s	1054.62 [796.15–1298.29]	5292.39 ± 3131.87
	LFE	15s	1167.24 [799.89–1368.66]	12772.39 ± 4773.36
		60s	1167.18 [799.89–1368.66]	12772.33 ± 4773.44
Troiano	Normal	15s	946.96 [764.25–1154.31]	5363.80 ± 3174.57
		60s	860.57 [727.71–1020.43]	5392.74 ± 3193.63
	LFE	15s	1017.30 [771.34–1199.36]	12877.98 ± 4766.67
		60s	902.62 [775.35–1107.08]	12894.57 ± 4743.81

LFE:Low-frequency extension.

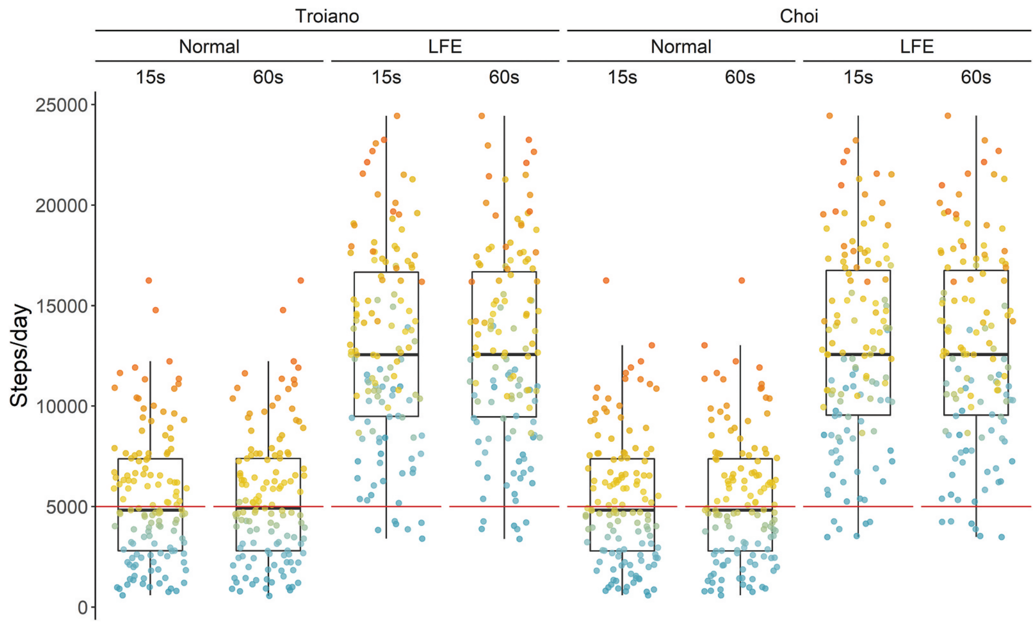

Figure 2. Distribution of daily step counts for each ActiGraph processing technique analysed, i.e., combination of filter (normal and low-frequency extension), epoch length (15s and 60s) and non-wearing time algorithm (algorithms of Troiano and Choi) in people with chronic obstructive pulmonary disease under free-living conditions. Points are coloured by individual. Red line represents the 5000 steps/day target recommended for populations with chronic illnesses. LFE: low-frequency extension.

Table 3. Agreement between ActiGraph processing techniques holding two of the criteria constant, i.e., filter (normal and low-frequency extension filter), epoch length (15s and 60s), and non-wearing time algorithm (Choi's and Troiano's method) to detect number of steps in people with chronic obstructive pulmonary disease under free-living conditions: Lin's concordance correlation coefficient (95% confidence interval), mean difference (95% confidence interval), bland-altman 95% limits of agreement and proportional bias: if the linear regression model of differences on means has a slope that differs significantly from zero. Mean differences and limits of agreement were calculated by subtracting the processing technique in first column by the processing technique in second column.

						Proportional Bias	
			CCC (95% CI)	Mean difference (95% CI) in steps/day	95% limits of agreement in steps/day	Slope	*P*
Filter Normal *vs* LFE	Choi/Normal/15s	Choi/LFE/15s	0.295 (0.238; 0.35)	−7479.99 (−7907.36; −7052.61)*	−12419.39, −2540.58	−0.44	<0.001
	Choi/Normal/60s	Choi/LFE/60s	0.295 (0.238; 0.35)	−7479.94 (−7907.32; −7052.56)*	−12419.42, −2540.46	−0.44	<0.001
	Troiano/Normal/15s	Troiano/LFE/15s	0.297 (0.239; 0.353)	−7515.18 (−7944.19; −7086.18)*	−12417.47, −2612.9	−0.43	<0.001
	Troiano/Normal/60s	Troiano/LFE/60s	0.299 (0.241; 0.356)	−7507.27 (−7940.08; −7074.45)*	−12415.07, −2599.46	−0.43	<0.001
Epoch length 15s *vs* 60s	Choi/Normal/15s	Choi/Normal/60s	1 (1; 1)	0.02 (−0.02; 0.05)	−0.35, 0.38	-7.03×10^{-6}	0.170
	Choi/LFE/15s	Choi/LFE/60s	1 (1; 1)	0.06 (−0.04; 0.17)	−1.17, 1.29	-1.74×10^{-5}	0.124
	Troiano/Normal/15s	Troiano/Normal/60s	0.999 (0.999; 1)	−16.63 (−36.28; 3.01)	−239.44, 206.17	8.51×10^{-4}	0.786
	Troiano/LFE/15s	Troiano/LFE/60s	0.999 (0.999; 0.999)	−16.59 (−50.57; 17.39)	−406.40, 373.23	4.81×10^{-3}	0.186
Non-wearing time Choi *vs* Troiano	Choi/Normal/15s	Troiano/Normal/15s	0.999 (0.998; 0.999)	−25.17 (−53.12; 2.78)	−344.53, 294.19	7.86×10^{-3}	0.080
	Choi/Normal/60s	Troiano/Normal/60s	0.998 (0.997; 0.999)	−42.22 (−76.18; −8.26)*	−427.28, 342.85	6.98×10^{-3}	0.199
	Choi/LFE/15s	Troiano/LFE/15s	0.998 (0.998; 0.999)	−21.83 (−67.65; 23.98)	−547.34, 503.67	2.45×10^{-3}	0.618
	Choi/LFE/60s	Troiano/LFE/60s	0.998 (0.997; 0.998)	−38.49 (−91.78; 14.80)	−649.74, 572.76	2.38×10^{-3}	0.677

LFE: low-frequency extension; CCC: Lin's concordance correlation coefficient; CI: Confidence interval.
*Significant fixed bias – Mean difference differs significantly from zero, zero is not within the 95% confidence interval for the mean difference.

DynaPort accelerometer, which has been validated against manually counted steps in COPD (Andersson et al., 2014; Langer et al., 2009), hasreported daily step estimates more similar to the normal filter than the LFE filter (Blondeel et al., 2020; Boutou et al., 2019; Dueñas-Espín et al., 2016; Koreny et al., 2021). This study suggests that the LFE filter might overestimate steps in people with COPD under free-living conditions, despite its reported accuracy in detecting steps compared to the default filter in people with slower walking speeds (ActiGraph, 2018; Ngueleu et al., 2022; Webber & St John, 2016). Nonetheless, the normal filter has also shown to underestimate daily steps in non-COPD populations (Cruz et al., 2017; Feito et al., 2015). These conflicting results warrant validation studies to determine which ActiGraph filter provides more accurate estimates of daily steps in people with COPD.

Reporting of processing criteria for obtaining PA is, therefore, crucial to facilitate a fair comparison of findings across studies. This is essential to avoid misleading conclusions about PA in individuals with COPD. For instance, considering the target 5000 steps/day recommendation proposed for people with chronic illnesses (Tudor-Locke et al., 2013) if steps were processed using the LFE filter, more than 90% of our sample would be classified as being physically active, whereas only half would be considered physically active when using the normal filter (Figure 2).

The choice of epoch length did not have an influence on step counts in people with COPD, with differences between epoch lengths being non-significant and yielding strong concordance, as well as small constant bias (<17 steps/day) with narrow limits of agreement. These results are aligned and add to previous literature that have demonstrated that step counts collected by ActiGraph GT3X+ in healthy subjects did not change significantly by varying the epoch length (Gómez-García et al., 2022). These findings also confirm that the choice of the epoch length seems to mainly influence PA variables whose calculations are performed after data aggregation (e.g., time spent in sedentary behaviour and in different intensities of PA) (ActiGraph, 2020a; Banda et al., 2016; Gómez-García et al., 2022; Rebelo et al., 2023). Nevertheless, it is noteworthy that when comparing epoch lengths of 15s and 60s using Choi's algorithm to identify NWT, higher level of agreement was observed in daily steps than when Troiano's algorithm was employed. This difference may be attributed to the impact of the NWT algorithm and epoch length on identifying periods when the device was not worn (Banda et al., 2016). In fact, Choi's algorithm provides epoch-independent wearing time estimates in comparison with Troiano's algorithm (Banda et al., 2016).

Similarly, step counts did not differ significantly between NWT algorithms, a high degree of agreement and mean differences below 45 steps/day were observed. To the best of our knowledge, no previous study has investigated the influence of the NWT algorithm on step counts. A negligible effect of the NWT algorithm has been shown for estimating time in light PA and moderate-to-vigorous PA in older women, but substantially impacted sedentary time (Keadle et al., 2014). While the NWT algorithm choice did not significantly affect daily step estimates, smaller biases and limits of agreement were observed between Choi's and Troiano's algorithms with shorter epoch lengths, possibly due to an interaction effect. Troiano's algorithm, unlike Choi's, demonstrated a significant impact of epoch length on wearing time, with differences increasing at longer epoch lengths (Banda et al., 2016). Choi's algorithm consistently provided longer wearing time periods, including more participants with valid wearing time compared to Troiano's. Nevertheless, wearing time estimates between Choi's and Troiano's algorithms showed greater similarity for epoch lengths of 15s than 60s, potentially explaining their stronger agreement on daily step counts with shorter epoch lengths. It is important to carefully choose the NWT algorithm relative to the epoch length to be used.

This study has some strengths and limitations which need to be acknowledged. This is the first study investigating the effect of Actigraph's processing criteria on daily steps in people with COPD under free-living conditions with a relatively large sample. However, the sample was imbalanced in terms of sex, GOLD groups and grades and only comprised people with COPD referred to community-based pulmonary rehabilitation, and thereby results of this study may not be generalizable to all people with COPD. We were unable to confidently recommend an ActiGraph technique for measuring daily steps in people with COPD in free-living conditions due to the absence of a gold-standard method or validated devices for comparison.

In summary, filter choice, not epoch lengths or NWT algorithms, significantly affects accelerometer-measured daily step counts in people with COPD during free-living conditions. The LFE filter yields over twice as many steps per day compared to the normal filter, potentially misclassifying PA levels. Additional studies are required to confirm these findings and determine the optimal processing technique for detecting step counts in COPD during free-living conditions.

Abbreviations

FEV_1	Forced Expiratory Volume in One Second
FVC	Forced Vital Capacity
GOLD	Global Initiative for Chronic Obstructive Lung Disease

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Data availability statement

The data that support the findings of this study and research materials are available from the corresponding author, AM, upon reasonable request.

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