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Introduction

If accelerometer-based measurement of step count is to be incorporated into rehabilitation programmes for critical illness survivors, its validity must be determined. Two studies have investigated the validity of accelerometry to quantify step count in critical illness survivors, comparing accelerometer quantified step count to observed step count. (1,2) A mean difference of 0.92 steps (95% limits of agreement -3.27 - 5.11 steps) was determined for the ankle mounted AMP 331 accelerometer. (1) However, a thigh mounted activPAL accelerometer underestimated steps in hospitalised critical illness survivors, with a median (interquartile range) absolute percentage error for total step count of 70.1% (28.6%). (2)

Other ankle mounted accelerometers, such as the Actigraph GT3X+ have demonstrated validity in quantification of step count in hospitalised elderly populations who walk at slow speeds, when the low frequency extension data filter is activated. (3) When this filter is activated, sensitivity of the accelerometer to low intensity movements is increased. (4) The validity of any Actigraph accelerometer model to quantify step count within populations recovering from critical illness has not undergone investigation.

This study aimed to investigate the validity of the Actigraph GT3X accelerometer, in quantification of step count during self-selected distances and walking speeds in ward based hospitalised adults recovering from critical illness.

Methods

The study was prospective and observational and registered on the database ClinicalTrials.gov (NCT03295630). Participants were recruited consecutively from

September 2016 to April 2017, within a large NHS teaching hospitals Trust. The study was conducted on the ward they were admitted to following discharge from the intensive care unit. Ethical approval was granted from the East Midlands NHS Research Ethics Committee (REF: 16/EM/0210/198965) and York St John University Research Ethics Committee (REF: 129091178_Anderson_15052016).

Adults aged 18 years or over who had required greater than 48 hours of mechanical ventilation and able to mobilise independently or with assistance of one person or a walking aid were eligible to take part. Participants were included if they could understand the study information sheet and provide written, informed consent. Participants were excluded if they were unwilling to wear the accelerometers for three hours or if they refused to be observed throughout this period.

A semi-structured movement protocol was performed, not exceeding three hours duration, involving supine and side lying, postural transfers, periods of time spent sitting in a chair and walking self-selected distances. The activities could be completed in any order, with rests as needed.

Participants wore two tri-axial Actigraph GT3X accelerometers (Actigraph LLC, Pensacola, Florida, USA); each measuring 3.8 x 3.7 x 1.8cm; weighing 27g. The low frequency extension data filter was activated on both accelerometers to increase sensitivity to low intensity movement. (3,4) Single patient use broad elasticised bands secured with Velcro were utilised as a method of attachment. One accelerometer was positioned on the anteromedial thigh, the other on the lateral aspect of the ankle (above the lateral malleolus). The non-dominant leg was chosen based on recommendations of manufacturers of other lower limb mounted models which quantify physical activity. (5)

Thigh and ankle placement sites have previously undergone investigation of their validity in quantification of step count in both acutely hospitalised older adults and critical illness survivors. (1-3, 6,7)

When participants undertook the walking aspect of the protocol, a single observer (the chief investigator) walked with them, counting their steps until participants decided to stop. The duration of the walk was noted to the second, using a Precision™ radio-controlled alarm clock (Model AP004: Peers Hardy Group, Solihull). Time synchronization was achieved between the accelerometers and the clock by ensuring that the time on the clock was identical to that on the laptop computer used to programme the accelerometers to capture step count. Observed step count was compared to step count data captured by the ankle and thigh mounted accelerometers for the identical time stamped periods.

Bland Altman analysis was used to determine agreement between observed step count and accelerometer quantified step count. (8) Mean differences (95% limits of agreement) were calculated for both the thigh and ankle placement to understand if there was a superior placement site. Absolute percentage error between accelerometer quantified step count and observed step count was calculated, using the formula: (accelerometer data for step count – observed data for step count) / observed data for step count x 100, for both the ankle and thigh placements. This formula was previously used in another study investigating the validity of a thigh mounted accelerometer (activPAL) to quantify step count within acutely hospitalised older and stroke populations. (7)

An intraclass correlation coefficient analysis was undertaken (two-way random, absolute agreement) to evaluate intermethod reliability between accelerometer quantified

step count and observed step count. (9) Calculation of the 95% confidence interval was also undertaken as part of this analysis. All statistical analyses were undertaken using the International Business Machines, Statistical Package for the Social Sciences (IBM SPSS), version 20.

Results

Twenty-four hospitalised adults were invited to take part in the study. Four patients declined participation. Of these, one participant was already enrolled in other study and three did not feel physically ready to undertake aspects of the semi-structured movement protocol. Twenty patients (age: mean 62.3, SD 11.5) provided written, informed consent to participate. Some participants could mobilise independently (n = 6), others used a wheeled walking frame (n = 5), a single walking stick (n = 4), hand held assistance of one person (n = 3), a three wheeled walking frame (n = 1) or two Fischer sticks (n = 1). Table 1 presents the demographic data for all hospitalised adults who consented and participated.

Table 1 Demographic data for the study population to go here

Thirty-one separate walking episodes were analysed as some participants chose to undertake a second walk. A mean (SD) of 45.87 (± 19.72) steps was calculated for observed step count (range 15 - 90). Table 2 details the results of Bland Altman analysis for agreement between accelerometer quantified step count and observed step count for the isolated ankle and thigh placements. The results of correlational analysis are also detailed in Table 2.

Table 2 Results of Bland Altman and correlational analysis for the ankle and thigh accelerometer placement sites to go here

Accelerometer quantified step count for the ankle placement was superior to the thigh. These findings were demonstrated in the mean differences and 95% limits of agreement for both placement sites. The ankle placement was strongly correlated with observational step count. (9) A moderate correlation was determined for the thigh placement; however, the range of values calculated for the 95% confidence interval was wide (-0.10 - 0.78).

Figures 1 and 2 present the scatterplots created during Bland Altman analysis comparing ankle and thigh accelerometer quantified step count against observed step count. The scatterplot in Figure 2 demonstrates how the thigh placement regularly undercounted steps.

Figures 1 and 2 Scatterplots for mean difference (95% limits of agreement) for ankle and thigh accelerometer placement sites to go here

The median absolute percentage error (interquartile range) for quantification of step count for the ankle placement was 2.4%, (5.3, 0). The absolute percentage error (interquartile range) for the thigh placement was considerably higher at 42.4% (50, 27), with a much greater level of undercounting of steps compared to the ankle. The greatest absolute percentage error for the thigh placement was 54%, where a walk was performed with a wheeled walking frame. The smallest absolute percentage error was 0% for the thigh, where the accelerometer recorded an identical number of steps compared to observed step count. However, an

absolute percentage error of 42% was calculated for a second walk taken by the same participant, suggesting the thigh placement was not quantifying steps consistently.

Following removal of the accelerometers and skin examination there were no incidences of pallor, non-blanching redness or significant indentation attributable to wearing the accelerometers.

Discussion

This study determined that an ankle mounted Actigraph GT3X accelerometer, with the low frequency extension filter activated, was valid in step count quantification in hospitalised adults recovering from critical illness. When positioned on the thigh, the Actigraph GT3X underestimated steps on almost all walks. This finding concurs with other studies which have investigated the validity of a thigh mounted accelerometer (activPAL) in quantification of step count in critical care survivors, hospitalised older adults, patients with advanced cancer (in and outpatient) and outpatients with rheumatoid arthritis. (2,7,10,11) Absolute percentage error was reduced when the accelerometer was mounted on the non-affected limb in hospitalised acute stroke patients and community-based patients post hip fracture. (7)

The excellent results found for the ankle mounted GT3X concur with a study by Edbrooke et al. (2012), who investigated the validity of the ankle mounted AMP 331 accelerometer in hospitalised adults recovering from critical illness. (1) A mean difference (95% limits of agreement) of 0.92 (-3.27 to 5.11) steps was found when compared to observed step count. (1) This compares favourably with the results reported from this study, where a mean difference of - 0.84 (-3.88 to 2.2 steps) was calculated.

Furthermore, correlational analyses revealed identical results, with both studies reporting an intraclass correlation coefficient (95% confidence interval) of 0.99 (0.99-1.0) for the ankle. These findings suggest excellent intermethod reliability for this placement site which are not confined to one accelerometer model.

Similar results for an ankle placement have been reported for older hospitalised adults, using the GT3X+ accelerometer. (3) When the low frequency extension data filter was activated an intraclass correlation (95% confidence interval) of 0.94 (0.87-0.97) was determined. When the low frequency extension was deactivated, an intraclass correlation (95% confidence interval) of 0.68 (-0.21-0.9) was reported for the same placement site. (3) This finding supports activation of the low frequency extension data filter within Actigraph models to improve the accuracy of step count quantification within hospitalised populations who are likely to walk at slower speeds, due to its increased sensitivity to low intensity movement. (4)

The ankle mounted AMP 331 accelerometer was used to quantify physical activity levels in critical illness survivors. (12) The fair correlation between average number of steps recorded per day compared against self-report ($r = 0.33$, $p = 0.05$) may have been as a result of poor estimation of self-reported activity levels. (13) Critical illness survivors may experience persistent cognitive impairment, (14) which could adversely impact on the ability to recall all activity undertaken. The use of more objective methods of activity monitoring may provide a solution to accurately monitor activity levels. The setting of personalized, daily target step count goals may prove to be a motivator, exerting positive effects on activity levels during admission and following discharge from hospital.

This study has some limitations. Observation of steps counted by a single observer served as the criterion measure for which accelerometer step count was compared. Video recording was not used due to the risk of unintentionally capturing footage of participants or other patients within the hospital ward, posing ethical concerns. Whilst every effort was made to count every step taken by patients during walking episodes, it is possible that errors may have occurred. Walking episodes could not be revisited to clarify whether observed step count had been accurately recorded. The use of video recording would also have permitted a second observer to agree the number of steps taken by participants during each individual walk.

Participants self-selected the distances and speed that they walked. It was not possible to calculate walking speed to understand if there may have been a threshold walking speed which may have improved the ability of the thigh mounted Actigraph GT3X. Efforts were made to make the semi-structured movement protocol as naturalistic as possible. Introduction of pre-determined set distances to walk in order to assist in calculation of walking speed would possibly have made patients walk further than they felt they could physically achieve, which may have posed ethical concerns.

This study enrolled patients with no cognitive impairment. It remains unclear how acceptable an ankle placement would be with patients experiencing persistent cognitive impairment following critical illness. Another study conducted within a hospital inpatient population experiencing delirium, did not encounter incidences of premature removal by participants when multiple accelerometers were mounted on the lower limb. (15) Further research is encouraged to ascertain the acceptability of the ankle placement within those experiencing varying degrees of cognitive impairment following critical illness.

Accelerometer validity was investigated in a small sample size (n = 20), under limited conditions within a hospital ward setting. Walking was not undertaken on uneven ground or outside, which limits generalisability of the findings to all environments. Further research is encouraged within this patient group, enrolling much larger sample sizes, to continue validity investigation of accelerometers to quantify step count within the wider environment, incorporating outdoor and uneven surfaces. Placement sites other than the ankle should be explored, such as the wrist, increasing the options for placement should they demonstrate validity.

An implication of such investigations is that placement sites which have demonstrated validity could function as criterion measures during the development of bespoke smartphone applications which incorporate step count quantification, to provide feedback and monitor improvements in activity levels. Investigation into comfort should form part of these investigations to understand if wearing accelerometers for prolonged periods (i.e. during the entirety of waking hours) pose any tissue viability concerns or adversely affect compliance in wearing them.

Clinical Messages

- Step count quantified by an ankle mounted Actigraph GT3X accelerometer demonstrates concordance with observed step count within ward-based adults recovering from critical illness.
- Activation of the low frequency extension filter is recommended to increase sensitivity to low intensity movement and slow speed walking.

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Author contributions

Dr Anderson was responsible for the concept and production of the paper. Dr Green and Dr Yoward provided regular constructive feedback and assisted in revisions of important intellectual content following critical review.

Conflict of Interest Statement

The Authors declare that there is no conflict of interest.

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References

1. Edbrooke L, Lythgo N, Goldsworthy U, Denehy L. Can an accelerometer-based monitor be used to accurately assess physical activity in a population of survivors of critical illness? *Global Journal of Health Science* 2012;4(3):98-107.
2. Baldwin CE, Johnston KN, Rowlands AV, Williams MT. Physical activity of ICU survivors during acute admission: agreement of the activPAL with observation. *Physiother Can* 2018; 70(1): 57-63.
3. Webber SC, St John PD. Comparison of ActiGraph GT3X+ and StepWatch Step Count Accuracy in Geriatric Rehabilitation Patients. *Journal Of Aging And Physical Activity* 2016; 24(3):451-458.
4. Cain KL, Conway TL, Adams MA, Husak LE, Sallis JF. Comparison of older and newer generations of ActiGraph accelerometers with the normal filter and the low frequency extension. *International Journal of Behavioral Nutrition & Physical Activity* 2013;10(1):51 [Online]. Available from: https://ijbnpa.biomedcentral.com/track/pdf/10.1186/1479-5868-10-51 [Accessed 31st August 2018].
5. Hager ER, Treuth MS, Gormely C, Epps L, Snitker S, Black MM. Ankle Accelerometry for Assessing Physical Activity among Adolescent Girls: Threshold Determination, Validity, Reliability, and Feasibility. *Research Quarterly for Exercise and Sport* 2015;86(4):397-405.
6. Anderson JL, Green AJ, Yoward LS, Hall HK. Validity and reliability of accelerometry in identification of lying, sitting, standing or purposeful activity in adult hospital inpatients recovering from acute or critical illness: a systematic review. *Clin Rehabil* 2018;32(2):233-42.

7. Taraldsen K, Askim T, Sletvold O, Einarsen EK, BjÃ¥stad KG, Indredavik B, et al. Evaluation of a Body-Worn Sensor System to Measure Physical Activity in Older People With Impaired Function. *Phys Ther* 2011;91(2):277-85.
8. Giavarina D. Understanding Bland Altman analysis. *Biochemia Medica* 2015;25(2):141-51.
9. Bewick V, Cheek L, Ball J. Statistics review 7: Correlation and regression. *Critical Care* 2003;7(6):451-9.
10. Skipworth RJE, Stene GB, Dahele M, Hendry PO, Small AC, Blum D, et al. Patient-focussed endpoints in advanced cancer. Criterion-based validation of accelerometer-based activity monitoring. *Clinical Nutrition* 2011; 30 (6): 812-821.
11. Larkin L, Nordgren B, Purtill H, Brand C, Fraser A, Kennedy N. Criterion Validity of the activPAL Activity Monitor for Sedentary and Physical Activity Patterns in People Who Have Rheumatoid Arthritis. *Phys Ther* 2016;96(7):1093-1101.
12. Denehy L, Berney S, Whitburn L, Edbrooke L. Quantifying Physical Activity Levels of Survivors of Intensive Care: A Prospective Observational Study. *Phys Ther* 2012;92(12):1507-17.
13. Cheung VH, Gray L, Karunanithi M. Review article (meta-analysis): Review of Accelerometry for Determining Daily Activity Among Elderly Patients. *Arch Phys Med Rehabil* 2011;92:998-1014.
14. Pandharipande PP, Girard TD, Jackson JC, Morandi A, Thompson JL, Pun BT, et al. Long-term cognitive impairment after critical illness. *N Engl J Med* 2013;369(14):1306-1316.
15. Godfrey A, Conway R, Leonard M, Meagher D, Olaighin GM. Motion analysis in delirium: A discrete approach in determining physical activity for the purpose of delirium motoric subtyping. *Medical Engineering and Physics* 2010: 32 (2): 101-110

Table 1 Demographic data for the study population

Characteristic	**Mean ± SD (range), median (IQR) or *n* (%)**
Age (years)	62.3 ± 11.5 (39 - 82)
Male: Female	13 (65%): 7 (35%)
BMI	25.9 ± 6.1 (16.9 – 38.3)
Ventilation period (days)	15.0 (5.50, 36.0)
ICU LOS (days)	21.0 (8.25, 42.75)
Hospital LOS (days)	35 (17.25, 64.75)

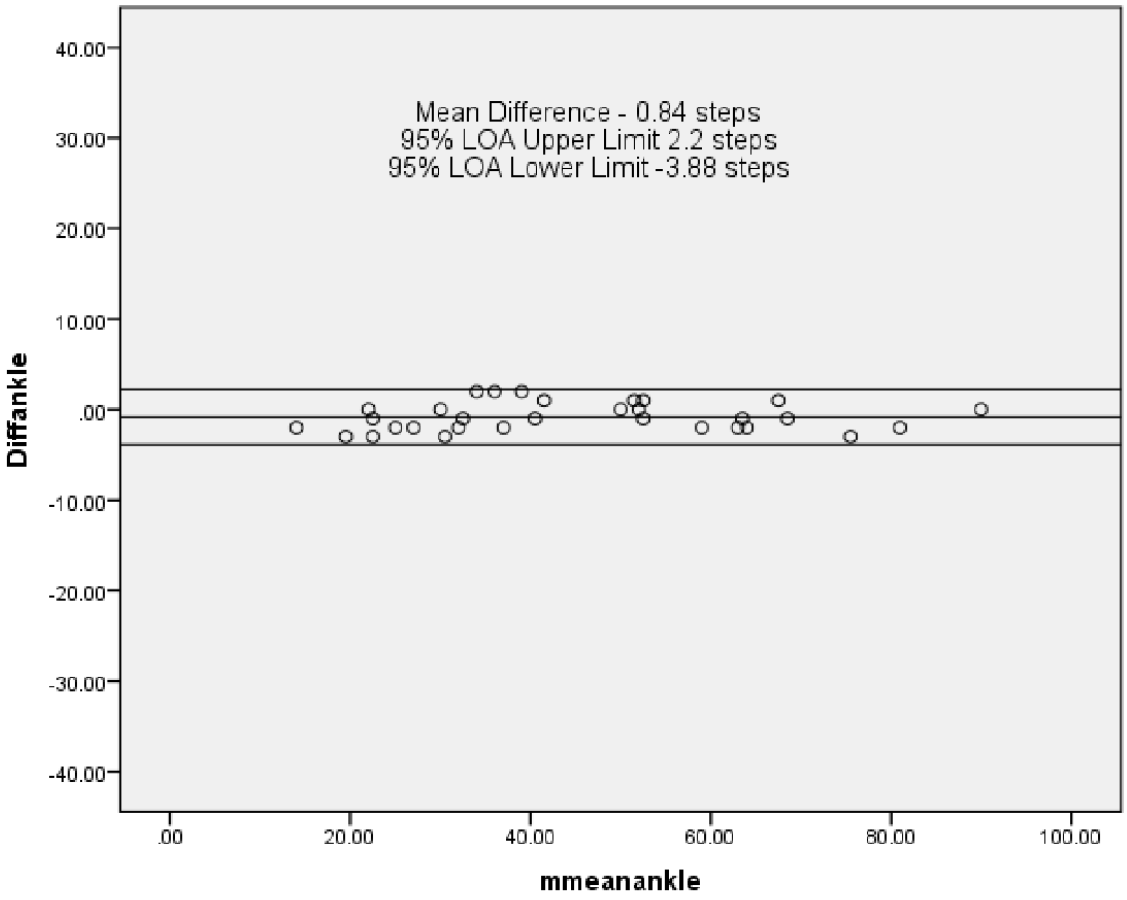
BMI, Body Mass Index SD, Standard deviation IQR, Interquartile range LOS, Length of stay

Table 2 Results of Bland Altman and correlational analysis for the ankle and thigh accelerometer when compared against observed step count

Placement site	Mean difference (95% limits of agreement)	ICC (95% CI)
Ankle	-0.84 steps (-3.88 to 2.2 steps)	0.99 (0.99 - 1.0)
Thigh	-17.7 steps (-40.63 to 5.23)	0.46 (-0.10 - 0.78).

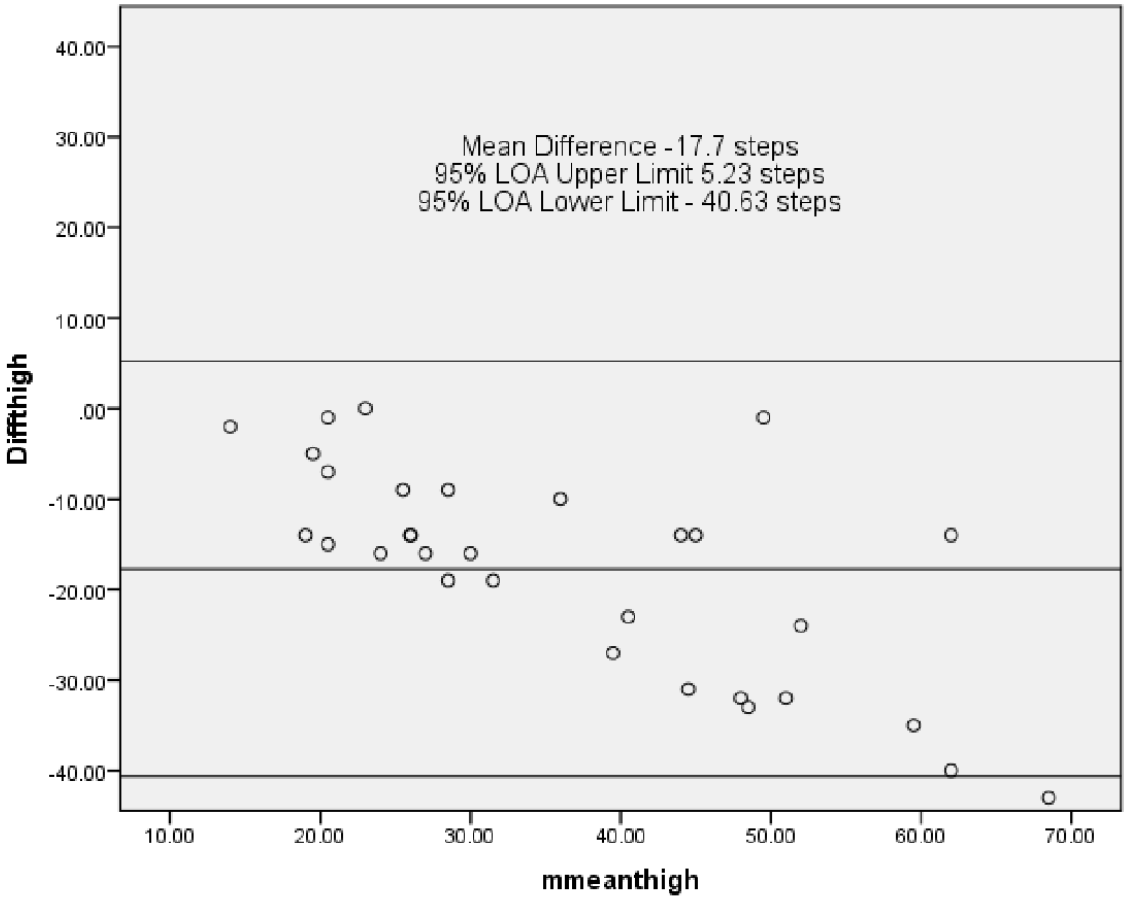
ICC, Intraclass correlation coefficient 95% CI, (95% confidence interval)

Figure 1 Scatterplot for ankle placement



LOA, limits of agreement

Figure 2 Scatterplot for thigh placement



LOA, limits of agreement