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9 10	Daily pain severity but not vertebral fractures is associated with lower physical activity in postmenopausal women with back pain
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1 Abstract (150 words)

- 2 Back pain lifetime incidence is 60-70%, whilst 12-20% of older women have vertebral fractures (VFs), often
- 3 with back pain. We aimed to provide objective evidence, currently lacking, regarding whether back pain and
- 4 VFs affect physical activity (PA).
- 5 We recruited 69 women with recent back pain (age 74.5 \pm 5.4y). Low (0.5 \leq g \leq 1.0), medium (1.0 \leq g \leq 1.5) and
- 6 high-impact ($g \ge 1.5$) PA and walking time were measured (100Hz for 7-days, hip-worn accelerometer). Linear
- 7 mixed-effects models assessed associations between self-reported pain and PA, and group differences (VFs
- 8 from spine radiographs/no-VF) in PA.
- 9 Higher daily pain was associated with reduced low (β =-0.12, 95%CI -0.22 to -0.03, p=0.013) and medium-
- 10 impact PA (β =-0.11, -0.21 to -0.01, p=0.041), but not high-impact PA or walking time (p>0.11). VFs were not
- 11 associated with PA (all p>0.2).
- 12 Higher daily pain levels but not VFs were associated with reduced low and medium-impact PA, which could
- 13 increase sarcopenia and falls risk in older women with back pain.
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1 Introduction

2 Low back pain is the leading cause of disability worldwide (Vos et al., 2012), with a lifetime prevalence of 60-3 70% in industrialised countries. It is widely known that low back pain can influence activities of daily living 4 (Grabovac & Dorner, 2019), and that a graded increase in pain is associated with greater restrictions on daily 5 life activities such as walking for individuals with a lumbar disc herniation (Kose, Tastan, Temiz, Sari, & Izci, 6 2019). Impaired mobility in individuals with low back pain appears multifactorial, with potential contributors 7 including impaired neuromuscular control, muscle weakness, altered posture and gait in addition to avoidance of 8 further pain (Hammill, Beazell, & Hart, 2008). Physical activity (PA) is important for many health outcomes 9 including all-cause mortality, physical function (Lee et al., 2012; Warburton & Bredin, 2019), mental health 10 (Rebar et al., 2015), sarcopenia (Meier & Lee, 2020; Steffl et al., 2017) and bone strength (Hannam et al., 2017; 11 Jain & Vokes, 2019; Johansson, Nordström, & Nordström, 2015). Results of objective measures of PA in 12 individuals with back pain are mixed and largely assessed in younger individuals, although deficits in PA appear 13 evident in those with a higher level of disability (Lin et al., 2011). Prevalence of low back pain is greater in 14 women than men (Cassidy, Carroll, & Côté, 1998), therefore associations between back pain and PA may 15 contribute to lower PA observed in older women (Caspersen, Pereira, & Curran, 2000). 16 Back pain can be caused by several problems including myofascial dysfunction or trauma, degeneration of the 17 intervertebral disc or facet joints, or by fractures within the vertebral body. Vertebral fractures (VFs) are present 18 in 12-20% of older women, and are the most common type of osteoporotic fracture within the older population

19 (O'Neill et al., 1996). Although VF incidence in men and women is similar in midlife, the age-related increase in

20 women is greater such that over the age of 70 VD incidence is around twice that in men (O'Neill et al., 1996).

21 Individuals with VFs are at one of the highest risks of future fracture (Ismail et al., 2001; Kaptoge et al., 2004),

22 and VFs are associated with increased mortality (Kado et al., 1999), morbidity (Hasserius, Karlsson, Jónsson,

23 Redlund-Johnell, & Johnell, 2005) and reduced quality of life (Adachi et al., 2002). Over 50% of individuals

24 with VFs have back pain (Society, 2014), which is qualitatively different to that in individuals with back pain

25 due to degenerative change (Clark, Gooberman-Hill, & Peters, 2016) being more commonly described as

- 26 crushing pain. In addition, back pain in individuals with VFs is more commonly relieved by lying down (Clark
- et al., 2016), which may lead to lower levels of PA. For these reasons, confounding effects of back pain reduce
- 28 our ability to assess the independent impact of VFs on health and function.

1	The structural changes associated with VF including reduced thoracic space (Silverman, 1992) likely limit the
2	ability of individuals to engage in PA, particularly vigorous activities known to be beneficial for bone strength
3	(Hannam et al., 2017). Alterations in spine biomechanics resulting from VFs may have other consequences
4	impacting on function, including impaired postural balance (Greig, Bennell, Briggs, Wark, & Hodges, 2007).
5	Identifying consequences of VF independent of back pain is essential in developing successful strategies for
6	improving functional outcomes in these individuals. However, whilst a number of studies using self-reported
7	questionnaires have identified difficulties in walking and lower PA in individuals with a VF (Al-Sari, Tobias, &
8	Clark, 2018), it is unclear whether this deficit is exaggerated compared with those with back pain due to other
9	causes. Moreover, self-reported PA measures have poor agreement and evidence of bias when compared to
10	objective accelerometry measures (Skender et al., 2016), which have not previously been applied to study PA in
11	individuals with VFs.
12	Therefore, we aimed to measure objectively and compare habitual PA levels in individuals with different levels
13	of back pain, and between those individuals with and without VF. We hypothesised that daily pain levels would
14	be negatively associated with PA. In addition, it was also hypothesised that PA would be lower in individuals
15	with VFs.
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1 Methods

2 Study design

3 The Physical Activity in Individuals with Back Pain and Vertebral Fractures (PAVE) study was a nested case 4 control study recruited from the Vfrac study (Khera et al., 2022), a cohort of older women from Bristol and 5 Stoke-on-Trent, UK. Inclusion study for Vfrac were women ≥ 65 years of age (65.4 to 96.8 years), with self-6 reported back pain in the preceding four months, recruited via general practices. Additional exclusion criteria 7 were having had a full spinal X-ray in the previous 4 months or being considered unsuitable for participation by 8 their general practitioner (GP) e.g due to being housebound, recent bereavement, cognitive impairment or being 9 near end of life. Invitation packs were sent by the participant's GP, and those willing to participate were asked 10 to complete a baseline questionnaire with information on demographics, socioeconomic status, traditional 11 osteoporosis risk factors, back pain, quality of life, medication use, healthcare utilisation and comorbidity, along 12 with a consent form and contact details which were sent to the study team. A study team member then checked 13 eligibility and if eligible, participants were booked in for a physical examination, and a spinal radiograph. Vfrac 14 participants provided written consent agreeing to be contacted about additional research studies and were 15 therefore invited to participate in the PAVE study. PA was recorded with a hip-worn Actigraph wGT3X-BT 16 accelerometer which was worn for 7 days, and self-reported pain measures were recorded for each day of PA 17 measurement.

Ethics approval was obtained for Vfrac from the West of Scotland REC 3 18/WS/0061, IRAS ID 239418 and
for PAVE from the Cambridgeshire and Hertfordshire REC, IRAS ID 257356.

20 Accelerometry

21 All participants were provided with an Actigraph wGT3X-BT accelerometer attached to an elasticated belt 22 (Actigraph, Pensacola, CA, USA). Participants were given written and verbal instructions (via telephone) to 23 wear the accelerometer over the right hip and to wear it for seven days during waking hours, except when 24 bathing/showering/swimming. A short self-completion questionnaire was given to all participants to record brief 25 daily details of their wear time and severity and causes of pain throughout the seven days of accelerometer wear. 26 After 7 days, the participants returned the accelerometer and questionnaire to the PAVE study team via post. 27 Accelerations were recorded at 100 Hz for 7 days. Raw vertical acceleration data were extracted using ActiLife 28 software (ActiLife 6 Data Analysis Software, Actigraph, Pensacola, CA, USA) and saved as CSV files. CSV

1 files were read into and processed using MATLAB software (MATLAB R2019a, Mathworks, Cambridge, UK). 2 Data analysis was conducted using previously published methods (Deere et al., 2016). Briefly, data were 3 visually inspected and cleaned for non-wear and artefacts. Periods of primarily inverted accelerations 4 highlighted instances where the monitor had been placed upside down, these were identified and corrected. Non-5 wear periods were identified as sustained periods of zero readings of > 20 minutes in duration, which were then 6 removed from the analysis. Data from 4 minutes at the start and end of each period of wear time were removed 7 to eliminate the acceleration artefacts from positioning the monitor and removing the monitor from the body. 8 Participants were required to have a minimum of 6 hours of wear time per day across 7 days. Individual isolated 9 instances of high acceleration >2 g during periods of low level activity were assumed to be artefacts as they 10 were not consistent with high impact activity with multiple high accelerations. These artefacts were removed 11 from the analysis.

12 Other established accelerometry assessments classify physical activity intensity using counts per minute 13 thresholds. However, these measures combine movement frequency and magnitude of acceleration such that a 14 small number of vigorous movements will be evaluated as equivalent to a large number of moderate 15 movements. Whilst this may be relevant for aspects of health such as energy expenditure, for others such as 16 muscle and particularly bone health effects of physical activity are intensity-specific (Hannam et al., 2017; 17 Hartley et al., 2018). Therefore we identified and grouped individual impacts according to their intensity, as we 18 have previously applied in a large group of older women (Deere et al., 2016; Hannam et al., 2016). Acceleration 19 peaks were identified and expressed in g, where g indicated units greater than 1 g, which was a constant due to 20 gravity. The number of acceleration peaks per week grouped into low $(0.5 \le 1.0)$, medium $(1.0 \le 1.5)$ and 21 high impact ($g \ge 1.5$) bands. Acceleration peaks below 0.5 g were categorised as sedentary activity and were not 22 used in the analysis. The acceleration bands were developed due to previous findings that showed that older 23 participants were unlikely to experience accelerations above 2.1 g (Deere et al., 2016; Tobias et al., 2014).

24 Development and application of a machine learning classifier for walking behaviour

A pre-trained binary machine learning k-Nearest Neighbours (k-NN) classifier was developed to predict when each participant was walking or stationary whilst wearing the accelerometer. The classifier was developed, tested, and trained using accelerometery data from eighty postmenopausal women who performed incremental shuttle tests, both on a treadmill and on a track. The testing of this classifier produced a leave-one-out validation accuracy of 99.61%. The cleaned accelerometery data were pre-processed by down-sampling to 50 Hz, filtered using a high pass filter and segmented into 2-second samples with 50% overlap. The samples were then
processed into 18 features and combined into a single feature set, which included features from simple statistics,
linear and non-linear digital signal processing. The resulting feature set was used as an input to the binary
machine learning classifier, a k-NN classification algorithm and Manhattan distance measure. The classifier
produced an output of either 'Walking' or 'Stationary' for every 1-second of the cleaned data. The percentage
walking time for each participant was then calculated for the entire 7-day wear time, resulting in a weekly
percentage walking time (Huggins et al., 2022).

8 Pain measurements

9 Sensory, affective and evaluative pain were assessed using a McGill questionnaire and each was calculated as a 10 McGill pain score (Melzack, 1975). Briefly, sensory pain was described as crushing, heavy, dull, aching, sharp, 11 gnawing, stinging, tingling and burning. Affective pain was described as tiring. Evaluative pain was described 12 as annoying, intense, unbearable and excruciating (Melzack, 1975). Pain location was also classified by the site 13 of back pain as thoracic, waist area, low back/buttock or multiple sites using a pain map (Clark et al., 2010). In 14 the Vfrac questionnaire (Khera et al., 2019), participants were asked: "How does your back pain change with 15 activity - generally my back is better with activity" and "How does your back pain change with activity -16 generally my back pain builds with activity". From their answers to these questions, participants were classified 17 as those whose back pain increased, decreased or remained unchanged with activity.

PAVE participants were given an additional short self-completion questionnaire to record brief details of their accelerometer wear time and the severity and causes of pain. They were asked to complete this daily throughout the seven days of accelerometer wear. Daily pain severity during the accelerometer wear period was recorded using a ten-point Likert scale. Average daily pain levels were calculated for each participant as an average of these daily pain recordings.

23 Radiographs

24 Participants were assessed for the presence of osteoporotic VFs on lateral thoracic and lateral lumbar

25 radiographs by EC utilising the Algorithm-Based Qualitative (ABQ) approach (Jiang, Eastell, Barrington, &

26 Ferrar, 2004; Khera et al., 2019). Radiographs were categorised into those with no fracture and those with

27 fracture. Number of fractures were also noted.

1 Sample size

Recruitment of 170 individuals (85 with VFs and 85 without) would provide 90% statistical power to detect a
0.5 SD group difference (two-tailed analysis) in PA at an alpha level of 0.05. We aimed to recruit 200
individuals (100 each group) to ensure sufficient study power allowing for a low rate of loss of complete data
(up to 17%) as found in previous cross-sectional studies in postmenopausal women (Hannam et al., 2017). This
cohort size would also give high power (>99%) to detect a moderate (r = 0.3) linear correlation between daily
pain and PA (two-tailed analysis) across the whole cohort.

8 Statistical analyses

9 Statistical analysis completed using R version 3.6.2. (R Foundation for Statistical Computing, v3.6.2, Vienna, 10 Austria) using packages nlme and emmeans. Differences in cohort characteristics between individuals with and 11 without VFs were assessed by Fisher's exact test, χ^2 tests and t-tests for binary, categorical and continuous 12 variables respectively, and Mann-Witney test where data were not normally distributed. Linear mixed effects 13 models were used to examine associations between average daily pain for each participant during accelerometer 14 wear (exposure) with weekly low, medium, and high impacts and percentage walking time (outcomes). In 15 addition, similar analyses were used to assess associations between the reported pain on any given day 16 (exposure) and daily low, medium, and high impacts (outcomes), for which participant ID was included as a 17 random effect. Associations between presence of VF as a binary exposure (yes/no) and weekly low, medium, 18 and high impacts and percentage walking time (outcomes) were also examined. Furthermore, weekly low, 19 medium, and high impacts and percentage walking time (outcomes) were compared between groups based on 20 site of back pain (thoracic, waist area, low back/buttock and multiple sites), for associations with different 21 dimensions of McGill pain scores (sensory, affective and evaluative) and for associations with perceived 22 changes in back pain due to activity. In all cases except percentage walking time, analyses were initially 23 adjusted for participant wear time (Model 1) and then in additional models for age (Model 2). Finally, to assess 24 the independence of associations between pain/VF and PA outcomes analyses for pain were further adjusted for 25 VF status and vice versa (Model 3). To meet assumptions of normality of residuals, PA data were root-26 transformed. The association between walking activity from the machine learning algorithm and low impact 27 activity were assessed using Pearson correlation.

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1 Results

Of the 466 invitations that were sent to potential participants (195 to individuals with VFs and 271 to those with no VFs), 99 were recruited whilst complete data from 69 participants were available to be used in the final analyses (Figure 1). Table 1 shows the characteristics of participants according to presence or absence of VF. There was no difference in age, height, weight or average daily pain, although directions of association were as expected.

The accelerometer impacts in low, medium and high impact bands for individuals with VFs and back pain
control participants are detailed in Table 2. There was no difference in time worn between the two groups.

9 Association between back pain and PA

10 For all participants in minimally-adjusted Model 1, higher average daily pain levels were associated with lower

11 low (standardised regression coefficient β – indicating change in outcome in SD per unit change in pain = -0.17,

12 95%CI -0.27 to -0.06, p = 0.013) and medium impact activity ($\beta = -0.14, 95\%$ CI -0.24 to -0.03, p = 0.011).

13 There was weaker evidence of a similar association with high impact activity ($\beta = -0.11$, 95%CI -0.22 to 0.00, p

14 = 0.058) but not with percentage walking time (β = -0.06, 95%CI -0.17 to 0.05, p = 0.272) (Table 3 and Figure

15 2). In a separate analysis, our novel method of identifying walking activity from accelerometry using machine

16 learning algorithms showed a moderate association with low impact activity (r = 0.35, 95%CI 0.07 to 0.51, p =

17 0.004) (Figure 3).

18 There was attenuation of associations after adjustment for age in Model 2; whilst associations with low and

19 medium impacts were still evident, there was little evidence for associations with high impact activity ($\beta = -$

20 0.08, 95%CI -0.19 to 0.02, p = 0.131). Further adjustment for presence of VF in Model 3 had no substantial

21 effect on associations.

22 Within-participant variation in pain was examined to assess whether individuals did less PA on days where they

had higher pain levels (Table 3). There was no association between daily pain level and low ($\beta = 0.02, 95\%$ CI -

24 0.03 to 0.06, p = 0.448), medium ($\beta = -0.00$, 95%CI -0.05 to 0.04, p = 0.922) or high impact PA ($\beta = 0.00$,

25 95%CI -0.06 to 0.06, p = 0.975).

26 Differences in PA between individuals with and without VFs were also examined (table 3). There was no

evidence of differences in PA in individuals with VF for low impacts ($\beta = -0.26, 95\%$ CI -0.75 to 0.22, p =

28 0.294), medium impacts ($\beta = -0.11$, 95%CI -0.60 to 0.38, p = 0.665), high impacts (($\beta = 0.15$, 95%CI -0.36 to

1	0.66, $p = 0.561$), or percentage walking time ($\beta = 0.27, 95\%$ CI -0.23 to 0.76, $p = 0.296$). This lack of
2	association was not substantially altered after adjustment for age or weekly pain level.
3	In additional analyses, associations between detailed features of pain and PA outcomes were examined. There
4	was little evidence of association between site at which participants reported experiencing pain (thoracic, waist
5	area, low back/buttock and multiple sites) and any PA outcome in any model (all $p > 0.2$, Table 3). Similarly,
6	there was little evidence of associations between participants' reported changes in pain due to PA and any PA
7	outcome (all $p > 0.2$, Table 3). Whilst McGill sensory pain score was positively associated with low impact PA
8	$(\beta = 0.26, 95\%$ CI 0.03 to 0.50, $p = 0.033)$ and weakly with % walking time in Model 1 ($\beta = 0.24, 95\%$ CI 0.00 to
9	0.48, $p = 0.056$), this was completely attenuated by adjustment for age (Table 3). The McGill affective pain
10	score was not associated with any PA outcome in any model (all $p > 0.1$). The McGill evaluative pain score had
11	similar inverse associations with percentage walking time in all models (Model 3 β = -0.27, 95%CI -0.53 to -
12	0.01, $p = 0.046$), but was not associated with other PA outcomes (all $p > 0.5$).
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1 Discussion

2 This study examined associations between back pain severity and PA, and between VF and PA in a small 3 sample of older women. We measured low-impact, medium-impact and high-impact PA using accelerometry 4 data and developed a novel machine learning classifier to estimate walking behaviour. Challenges caused by the 5 COVID-19 pandemic led to lower participant numbers and reduced study power to detect associations. Average 6 daily pain levels were associated with reduced low and medium impact activity, but not high impact activity or 7 walking time. There was no evidence for an association between reported pain on any given day and daily PA. 8 Objective walking, low, medium and high impact PA levels were similar in individuals with back pain and VF 9 compared to individuals with back pain without VF. In more detailed analysis of pain characteristics, higher 10 evaluative pain scores were associated with a lower percentage of time spent walking.

11 Comparison with previous findings

12 To the best of our knowledge, this is the first study to investigate associations between back pain and objective 13 measures of PA in older individuals. Examination of associations between detailed pain characteristics such as 14 pain location and type, and PA is also novel. These results are consistent with previous research showing 15 reductions in PA with higher levels of pain related disability in individuals with a mean age of 45-50 years (Lin 16 et al., 2011). In contrast, previous work found no evidence of an association between the level of back pain 17 experienced and both light and moderate to vigorous objective PA in younger males and females with low back 18 pain (Carvalho et al., 2017; Hendrick et al., 2011; Leininger et al., 2017). One previous accelerometer-based 19 study identified an average increase in PA (counts per day) in individuals with low back pain one year after the 20 development of symptoms coinciding with a reduced pain intensity (Bousema, Verbunt, Seelen, Vlaeyen, & 21 Knottnerus, 2007). In addition, severity of back pain time has shown no association with self-reported walking 22 in a number of previous studies (Fernando, Filho, & Barbosa, 2020) and our novel objective estimations of 23 walking time are in line with these findings. Whilst our walking time data were positively associated with low 24 impact activity, the effect size of the association was only moderate. This can be explained by other types of low 25 impact activity such as housework and stair negotiation which would not be characterised as walking. Interestingly, all participants displayed lower levels of low (-39% and -18%), medium (-32% and -15%) and 26 27 high impact activity (-29% and -24% for VF and back pain vs back pain only groups respectively) when 28 compared to a similar cohort of postmenopausal women (mean age 76.8 years vs 74.5 years in the current study, 29 median height 1.59 m vs 1.61 m in the current study, median weight 67 kg vs 67 kg in the current study) without any back pain symptoms with the same methods of assessment (Hannam et al., 2017). This might suggest that
 back pain of any aetiology could be associated with reduced PA.

3 Our findings show similar PA levels in individuals with and without fractures, and are in agreement with 4 previous literature based on self-reported data (Mikkilä, Calogiuri, Emaus, & Morseth, 2019). People with VFs 5 have reported lower physical performance (self-reported mobility and activities of daily living) when compared 6 to control participants (Al-Sari et al., 2018). The presence of a VF has been associated with further functional 7 limitations than the effect of either back pain or VF alone (Edmond, Kiel, Samelson, Kelly-Hayes, & Felson, 8 2005). When considering that individuals with VF reported a 27% increase in difficulty in undertaking 9 ambulatory activities, it might be expected that this could influence walking and low impact PA. Research has 10 also highlighted that often, measures of pain are not included and that higher levels of pain could substantially 11 influence PA levels (Al-Sari et al., 2018). The presence of a single vertebral deformity has also shown no 12 association with physical function (Jinbayashi et al., 2002) and activities of daily living when controlled for 13 back pain (Huang, Ross, & Wasnich, 1996), which could both influence PA levels. Multiple vertebral 14 deformities are associated with decreased physical function, even when controlled for back pain symptoms 15 (Jinbayashi et al., 2002). Therefore, it is plausible that effects of VF on physical activity may be more 16 pronounced in individuals with multiple VFs. The current study only had two participants with multiple VFs, 17 which may help to explain the lack of observed associations between VF and PA. Larger studies assessing PA 18 and VF should also consider assessment of the contribution of pain to any observed associations, in addition to 19 the effects of multiple VFs on PA.

20 Explanation of findings

Pain has been reported to be the main barrier to PA in people with back pain (Boutevillain, Dupeyron, Rouch, Richard, & Coudeyre, 2017). This may help to explain why higher levels of pain were linked to reduced low and moderate PA levels in our results. In addition, greater sedentary behaviour is a known risk factor for lower back pain (Citko, Górski, Marcinowicz, & Górska, 2018). Individuals with greater sedentary behaviour also experience increased muscular atrophy and lower levels of muscle strength, these could adversely affect the stability of the spine and exacerbate existing lower back pain issues (Alsufiany et al., 2020). These issues in turn could also further reduce PA levels.

Certain types of back pain are known to cause avoidance of PA due to fear of pain (Keen et al., 1999; Marshall,
Schabrun, & Knox, 2017; Schaller, Exner, Schroeer, Kleineke, & Sauzet, 2017), and have been linked with a

1 sedentary lifestyle (Sribastav et al., 2018). We observed associations between evaluative pain and walking time 2 but not low impact activity. This could indicate avoidance of more voluntary PA such as recreational walking 3 or commuting by walking, whereas other daily activity is maintained. Whilst there is limited information on 4 associations between pain type and function in individuals with back pain, evaluative pain in post hip-fracture patients is associated with impaired ability to complete activities of daily living (Campos, Liebano, Lima, & 5 6 Perracini, 2020). However, previous work has identified other activities such as gardening being perceived as 7 potentially harmful activities in individuals with back pain whereas walking activities are perceived as low risk of harm (Leeuw, Goossens, van Breukelen, Boersma, & Vlaeyen, 2007). Therefore, the relationship between 8 9 evaluative pain and walking activities requires further investigation. Our data show that some individuals 10 presented relatively low pain levels despite the presence of a VF. As pain due to VF may be shorter in duration 11 and is less likely to radiate to the legs, this may have less of an effect on overall PA than lower back pain from 12 degeneration (Clark et al., 2016).

13 Implications of findings

14 Back pain is the highest contributor to global disability (Hoy et al., 2014), and older women with back pain have 15 greater risk of all-cause mortality, cardiovascular mortality and cancer mortality (Roseen et al., 2019), as well as 16 obesity (Nieminen, Pyysalo, & Kankaanpää, 2021) and sarcopenia (Tanishima, Hagino, Matsumoto, Tanimura, 17 & Nagashima, 2017). Therefore, reduced PA in older women with back pain may contribute to these health 18 impairments. Additionally, the median number of high impacts were 29% (VF and back pain) and 24% (back 19 pain only) lower than reported in a similar aged female population (Hannam et al., 2017). This may also infer a 20 greater risk of reduced lower limb bone strength for both individuals with VF and those with back pain only, 21 although this would need further investigation.

22 It must be acknowledged that back pain from VFs and back pain from degenerative changes are fundamentally 23 different, with VF related back pain easing when lying down, for example (Clark et al., 2016). However, higher 24 average daily pain appears to be associated with reduced low and medium PA irrespective of the presence of a 25 VF. This has key implications for the management of pain symptoms when it comes to the promotion of a 26 physically active lifestyle with these populations. Pharmacological interventions have had mixed results in the 27 management of back pain symptoms (Maher, Underwood, & Buchbinder, 2017), whereas targeted exercise 28 therapies such as stretching or muscle strengthening activities are an effective treatment for low back pain 29 symptoms and have been reported to decrease pain and improve physical function (Hayden, van Tulder,

1 Malmivaara, & Koes, 2005). This may require extra support in helping individuals circumvent barriers that

2 prevent them from PA (Marshall et al., 2017; Schaller et al., 2017). In addition, cognitive behaviour therapy can

3 be used in individuals with chronic pain in order to target effects of evaluative pain on function (Makris,

4 Abrams, Gurland, & Reid, 2014).

5 Strengths and limitations of study

6 This is the first study to assess objective PA data with a population of older women with back pain, some of 7 whom had VFs. In addition, application of a classifier developed to identify walking behaviour from 8 accelerometer data is also novel. Despite our small sample size, we confirmed that back pain is associated with 9 reduced PA. A primary aim of our study was to examine associations between VFs and PA, but effects of the 10 Covid-19 pandemic meant that we only recruited 24 participants with VFs. This was exacerbated by the age of 11 our population, as the vast majority were over 70 and considered 'clinically vulnerable' by UK government 12 guidance. This meant that our study only achieved sufficient power to detect large effects (88% power to detect 13 0.8 SD group difference). The dropout rate due to incomplete data was much higher than our previous studies, 14 which might relate to the remote nature of the data collection. In addition, non-random dropout may have 15 introduced bias into our sample limiting generalisability of the results. The small sample size also did not allow 16 us to explore the role of potential mediating factors such as body size. The accelerometry data collected provide 17 reliable, detailed information of different intensities of PA during daily living. However, some popular activities 18 such as cycling and swimming would have not been captured due to participants having to remove the 19 accelerometer or the lack of impact activity. In addition, the act of wearing an accelerometer may influence an 20 individual's engagement in PA whether consciously or subconsciously. The inclusion of a group without back 21 pain would have allowed us to assess the extent of PA deficits attributable to increased back pain in relation to 22 typical activity levels. Whilst overall pain levels were assessed during the period of accelerometer data 23 collection, questionnaire-based data on pain characteristics such location and type were collected on average 24 several weeks beforehand in tandem with scanning sessions. Therefore, given weekly variability in reported 25 pain in our study participants with back pain (Jamison, Raymond, Slawsby, McHugo, & Baird, 2006), future studies should ensure to collect all pain-related data concurrently with outcome assessments. 26

27 Conclusions

28 Greater average daily pain was associated with lower levels of low and medium PA but not high impact activity 29 or walking time in older women with back pain. In exploratory assessments of associations between detailed

1	characterisation of pain and PA, we observed lower levels of walking in individuals with higher evaluative pain.
2	Lower levels of PA in older women with higher average daily pain may contribute to their increased risk of all-
3	cause mortality, sarcopenia and future fractures. These results support the need for approaches aiming to
4	increase PA in older women with back pain, such as targeted exercises.
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1	Table 1. Participant characteristics presented as means and SD)
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	Back pain and vertebral fracture $(n = 24)$	Back pain and no vertebral fracture (n = 45)	<i>p</i> value
Age (years)	75.9 (6.0)	73.7 (5.0)	0.139
Height (m)	1.57 (0.08)	1.60 (0.05)	0.064
Weight (kg)	67.6 (15.4)	73.7 (18.6)	0.159
Average daily pain	4.1 (2.5)	3.7 (2.0)	0.463
Pain Site (n)		()	0.515
Thoracic	3	1	
Waist area	4	7	
Low back/buttock	3	7	
Multiple	14	29	
McGill Pain Score			
Sensory Pain	2.3 (1.0)	2.3 (1.0)	0.857
Affective Pain	0.6 (0.5)	0.4 (0.5)	0.132
Evaluative Pain	0.7 (0.9)	0.8 (0.9)	0.618
Back pain due to			0.615
activity (n)			
Better	6	16	
No change	4	7	
Worse	14	21	

Non vertebral fracture back pain (n = 44) for pain site, McGill pain score and back pain due to activity. p values are presented for group differences.

Table 2. Accelerometer impacts across acceleration bands and average daily pain for vertebral fracture and control back pain participants

			Number of Vertical Impacts	per of Vertical Impacts							
	Back pair	n and vertebral fr	acture (n = 24)	Back pain an	Back pain and no vertebral fracture (n = 45)						
Impact Band	Median	25th	75th	Median	25th	75th					
Low (0.5 <g<1.0)< td=""><td>5385</td><td>1513</td><td>15576.2</td><td>7267</td><td>3619</td><td>13869</td></g<1.0)<>	5385	1513	15576.2	7267	3619	13869					
Medium (1.0≤ g<1.5)	233.5	55	691	292	109.2	769.5					
High (≥1.5 g)	30	14.25	67.75	32	12	123					
Weekly walking time (%)	14.2	8.4	19.8	12.2	7.8	16.8					
Weekly wear time (mins)	5525	5089	5839	5171	4738	5629					

Table 3. Associations between pain and vertebral fracture (VF) exposures and PA outcomes. SRC –standardised regression coefficient. Model Adjustments - Model 1: participant wear time (except for % walking time, which was unadjusted, Model 2: Model 1 + age, Model 3: Model 3 + VF (for pain exposures) or weekly pain (for VF).

Exposure		Outcomo	Model 1				Model 2				Model 3			
		Outcome	SRC	95%	6 CI	р	SRC	95%	6 CI	р	SRC	95%	6 CI	р
	ily Pain	Low Impacts	0.01	-0.01	0.03	0.484	0.01	-0.01	0.03	0.478	0.01	-0.01	0.03	0.386
Dai		Medium Impacts	0.00	-0.02	0.02	0.885	0.00	-0.02	0.02	0.892	0.00	-0.02	0.02	0.887
		High Impacts	0.00	-0.02	0.02	0.895	0.00	-0.02	0.02	0.888	0.00	-0.02	0.02	0.824
		Low Impacts	-0.27	-0.76	0.23	0.294	-0.07	-0.51	0.37	0.751	-0.03	-0.45	0.39	0.889
	VE	Medium Impacts	-0.11	-0.61	0.39	0.665	0.06	-0.40	0.52	0.803	0.09	-0.36	0.54	0.682
	V I	High Impacts	0.15	-0.34	0.63	0.561	0.27	-0.20	0.75	0.257	0.30	-0.16	0.77	0.208
		% Walking Time	0.26	-0.23	0.76	0.296	0.38	-0.09	0.86	0.121	0.41	-0.07	0.88	0.102
		Low Impacts				0.591				0.431				0.406
Do	in Sita	Medium Impacts				0.324				0.214				0.201
га.	III Site	High Impacts				0.593				0.550				0.544
		% Walking Time				0.533				0.492				0.498
		Low Impacts	0.13	-0.14	0.39	0.355	0.10	-0.13	0.32	0.412	0.03	-0.20	0.26	0.797
Dain	Activity	Medium Impacts	0.01	-0.26	0.28	0.947	-0.02	-0.26	0.22	0.888	-0.08	-0.32	0.16	0.522
Falli	Activity	High Impacts	-0.08	-0.34	0.19	0.577	-0.09	-0.34	0.16	0.466	-0.15	-0.40	0.11	0.263
		% Walking Time	-0.05	-0.32	0.22	0.712	-0.07	-0.33	0.19	0.606	-0.10	-0.36	0.17	0.482
		Low Impacts	0.27	0.03	0.50	0.033	0.13	-0.09	0.35	0.249	0.13	-0.09	0.35	0.250
	Sancorr	Medium Impacts	0.19	-0.06	0.43	0.137	0.07	-0.16	0.30	0.572	0.06	-0.17	0.30	0.584
	Sensory	High Impacts	0.16	-0.08	0.40	0.195	0.08	-0.16	0.32	0.519	0.07	-0.17	0.32	0.544
		% Walking Time	0.24	0.00	0.48	0.056	0.17	-0.07	0.41	0.177	0.16	-0.08	0.41	0.197
McGill		Low Impacts	0.04	-0.44	0.52	0.882	0.06	-0.34	0.47	0.758	0.07	-0.35	0.49	0.732
Pain	Affective	Medium Impacts	0.26	-0.21	0.73	0.285	0.29	-0.14	0.71	0.192	0.28	-0.16	0.71	0.216
Score	Allective	High Impacts	0.34	-0.12	0.81	0.153	0.36	-0.08	0.80	0.116	0.32	-0.13	0.77	0.168
Score		% Walking Time	-0.16	-0.64	0.32	0.511	-0.22	-0.68	0.24	0.351	-0.22	-0.68	0.24	0.351
		Low Impacts	0.05	-0.23	0.33	0.742	0.01	-0.23	0.25	0.912	0.01	-0.23	0.25	0.920
	Evaluative	Medium Impacts	0.09	-0.19	0.37	0.546	0.06	-0.19	0.31	0.654	0.06	-0.19	0.31	0.638
		High Impacts	0.07	-0.21	0.35	0.625	0.05	-0.21	0.31	0.716	0.06	-0.21	0.32	0.665
		% Walking Time	-0.26	-0.54	0.01	0.064	-0.28	-0.54	-0.02	0.040	-0.27	-0.53	-0.01	0.046

Figure 1

Flow diagram of participant recruitment



Figure 2.

Associations between average daily pain and PA outcomes, shown as standardised regression coefficients (indicating change in outcome in SD per one unit increment in average pain score) and 95% confidence intervals. Model 1 adjustments: wear time (except for walking time%, which is unadjusted), Model 2: Model 1 + age, Model 3: Model 2 + vertebral fracture.



Figure 3.

The relationship between number of weekly low impacts and percentage walking time in all individuals, shown as Pearson correlation coefficient. Shaded area shows 95% confidence intervals.

