Physical activity and sedentary behavior 6 months after musculoskeletal trauma : What factors predict recovery?

Ekegren, Christina L., Climie, Rachel E., Simpson, Pamela M., Owen, Neville, Dunstan, David W., Veitch, William and Gabbe, Belinda J.

Ekegren, Christina L., Climie, Rachel E., Simpson, Pamela M., Owen, Neville, Dunstan, David W., Veitch, William and Gabbe, Belinda J. (2020). Physical activity and sedentary behavior 6 months after musculoskeletal trauma : What factors predict recovery? *Physical Therapy*, 100(2), pp. 332-345. https://doi.org/10.1093/ptj/pzz151

The version of record is available online at: https://academic.oup.com/ptj/article/100/2/332/5581641

TITLE: Physical Activity and Sedentary Behavior 6 Months After Musculoskeletal Trauma: What Factors Predict Recovery?

RUNNING HEAD: Physical Activity After Musculoskeletal Trauma

TOC CATEGORY: Prevention and Health Promotion

ARTICLE TYPE: Original Research

AUTHOR BYLINE: Christina L. Ekegren, Rachel E. Climie, Pamela M. Simpson, Neville Owen, David W. Dunstan, William Veitch, Belinda J. Gabbe

AUTHOR INFORMATION:

C.L. Ekegren, PT, PhD, Department of Epidemiology and Preventive Medicine, Monash University, 553 St Kilda Rd, Melbourne, Victoria 3004, Australia; Baker Heart and Diabetes Institute, Melbourne, Victoria, Australia; and The Alfred, Melbourne, Victoria, Australia. Address all correspondence to Dr Ekegren at: Christina.ekegren@monash.edu.

R.E. Climie, PhD, Baker Heart and Diabetes Institute; and Paris Centre de Recherche Cardiovasculaire, Paris, France.

P.M. Simpson, BSc (Hons), Grad Dip Biostats, Department of Epidemiology and Preventive Medicine, Monash University.

N. Owen, PhD, Baker Heart and Diabetes Institute; and Swinburne University of Technology, Melbourne, Victoria, Australia.

D.W. Dunstan, PhD, Baker Heart and Diabetes Institute; and Mary MacKillop Institute for Health Research, Australian Catholic University, Melbourne, Victoria, Australia.

W. Veitch, BBiomedSci (Hons), Department of Epidemiology and Preventive Medicine, Monash University.

B.J. Gabbe, PT, PhD, Department of Epidemiology and Preventive Medicine, Monash University; and Health Data Research UK, Swansea University, Swansea, United Kingdom.

KEYWORDS: Fractures, Orthopedics, Outcome Assessment, Health Care

ACCEPTED: June 27, 2019

SUBMITTED: January 3, 2019

Background. Physical activity is increasingly recognized as an important marker of functional recovery following fracture.

Objective. The objectives of this study were to measure sedentary behavior and physical activity 2 weeks and 6 months following fracture and to determine associated demographic and injury factors.

Design. This was an observational study.

Methods. Two weeks and 6 months following fracture, 83 adults who were 18 to 69 years old and had upper limb (UL) or lower limb (LL) fractures wore an accelerometer and an inclinometer for 10 days. We calculated sitting time, steps, moderate-intensity physical activity (MPA), and vigorous-intensity physical activity and conducted linear mixed-effects multivariable regression analyses to determine factors associated with temporal changes in activity.

Results. At 6 months versus 2 weeks after fracture, participants sat less, took more steps, and engaged in more MPA. Participants with LL fractures sat 2 hours more, took 66% fewer steps, and engaged in 77% less MPA than participants with UL fractures. Greater reductions in sitting time were observed for participants in the youngest age group and with LL fractures, participants with high preinjury activity, and participants who were overweight or obese. For steps, greater improvement was observed for participants in the youngest and middle-aged groups and those with LL fractures. For MPA, greater improvement was observed for middle-aged participants and those with LL fractures.

Limitations. Although this study was sufficiently powered for the analysis of major categories, a convenience sample that may not be representative of all people with musculoskeletal trauma was used.

Conclusions. Working-age adults with LL fractures had lower levels of physical activity 6 months after fracture than those with UL fractures. Older adults showed less improvement

over time, suggesting that they are an important target group for interventions aimed at regaining preinjury activity levels.

Fractures are the most common type of hospitalized injury, accounting for approximately 300,000 hospital admissions and 1 million bed days in Australia each year.[1,2] In the United States, the lifetime risk of sustaining a fracture requiring orthopedic referral has been estimated to be 39% for women and 42% for men up to the age of 65.[3] Many people do not fully recover from fractures and experience considerable long-term functional impairment and physical disability. Almost one-third of adults with a lower limb (LL) fracture fail to return to work 12 months after injury,[4] and at 2.5 years after injury, one-third of these patients still report some degree of disability.[5]

Activity levels are increasingly recognized as an important aspect of functional recovery in adults with fractures.[6–8] In the general population, the adverse effects of physical inactivity (ie, failure to meet physical activity guidelines[9]) and prolonged periods of time spent in sedentary behaviors (ie, waking behaviors characterized by low energy expenditure while sitting or reclining[10]) are now well-established. The short-term effects of prolonged sedentary behavior include impaired glucose control and fat metabolism, reduced bone density, and muscle wasting.[11-14]

In the long term, excessive sedentary behavior and physical inactivity have been associated with weight gain, diabetes, hypertension, certain types of cancer, cognitive decline, poorer mental health and all-cause mortality.[12,15,16]

Although some patients recover well from fracture and eventually resume their preinjury levels of activity, this is not universally the case. In this context, there is a need to identify the attributes of patients who are most at risk of poor activity recovery. Considering preinjury characteristics or the circumstances of injury, has the potential to greatly assist in determining which patients should be provided with enhanced rehabilitation initiatives aimed at regaining preinjury activity levels. Previous research examining activity recovery in patients with fractures has focused on older adults and adolescents, or has relied on self-reported measures of activity, which are susceptible to over-estimation.[6,17] To date, there is no research examining predictors of recovery using device-based activity measurement in the working-age musculoskeletal trauma population, a group with a high rate of fractures and high functional recovery demands.

The 2 aims of this study were to describe changes in time spent in physical activity and sedentary behavior from 2 weeks to 6 months following musculoskeletal trauma and to determine demographic and injury-related factors associated with changes in physical activity and sedentary behavior during recovery from musculoskeletal trauma.

[H1] Methods

This prospective cohort study follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist.[18]

[H2] Participants

All patients who were 18 to 69 years old and who were admitted to a major trauma center from February to September 2017 with a new isolated upper limb (UL) or LL) fracture (confirmed by radiography), including fractures/dislocations, a hospital length of stay of >24 hours, and home discharge, were eligible for inclusion (n = 445). Patients were excluded if they had pathologic fractures, cognitive deficits, or less than conversational English-language capabilities. Ethics approval was obtained from the Monash University and Alfred Hospital human research ethics committees. All participants were recruited during their inpatient hospital stay and provided written informed consent.

[H2] Procedures

Data collection was undertaken 2 weeks and 6 months after surgery (or after injury for those treated nonsurgically, n = 10). At both time points, the validated activPAL3 device[19] (PAL Technologies Ltd, Glasgow, United Kingdom) was used to measure sitting time, time spent in sitting bouts of >30 minutes, sit-to-stand transitions, and steps.[20–22] The ActiGraph GTX3+ triaxial accelerometer (ActiGraph LLC, Pensacola, FL, USA) was used to measure minutes of moderate-intensity physical activity (MPA) and vigorous-intensity physical activity (VPA).[23] Both devices were worn for 10 consecutive days. The activPAL was worn continuously (24-hour monitoring) on the anterior thigh (of the unaffected limb for LL fractures), and the ActiGraph was worn on the right hip during waking hours only. Participants completed a diary to record sleep/wake times and any periods of device removal of >15 minutes.

Additional details collected in-person via questionnaire at the 2-week time point included self-reported height and weight, self-reported physical activity for the week preceding injury (International Physical Activity Questionnaire, Short Form [IPAQ-SF][24]), and current weight-bearing status.

All participants were automatically included in the Victorian Orthopaedic Trauma Outcomes Registry (VOTOR). This registry collects administrative and follow-up data on all adult orthopedic admissions of >24 hours from 4 trauma centers across the state of Victoria, including the study recruitment site.[25,26] All registrants are followed up by telephone at 6 months after injury to collect a range of self-reported measures, including the preinjury measures included in this study. An opt-out consent process is used for the registry, with the current opt-out rate of <2%.[27] With participant consent, data from VOTOR were linked with data from this study and were available for 81 of 83 included participants. The registry has ethics approval from the Victorian Department of Health and Human Services and each participating hospital.

[H2] Data Processing

ActivPAL data were downloaded from devices using activPAL3 software. ActiGraph data were sampled at 30 Hz, and counts per minute were determined using ActiLife software (Version 6.13.3). All device data were processed in SAS 9.3 (SAS Institute Inc, Cary, NC, USA). To be included at each time point, participants were required to have recorded >4 valid days with >600 minutes of waking wear time per day.[28,29] To determine activPAL valid days, we removed sleep periods and then applied the algorithm outlined by Winkler et al.[30] Considering the potential for very low activity levels in our sample, we removed the condition that participants could not be engaged in “any one activity that accounts for >95% of waking wear time” and lowered the threshold for invalid days from 500 to 100 steps per day. ActiGraph valid days were determined using the Choi algorithm.[31] After applying this algorithm, heat maps of data (displaying activity counts for each day) were visually inspected for any potential classification errors (eg, sleep time as waking time). Finally, any potential errors were checked against the participants’ diaries, and the most plausible classification was chosen and applied.[32] Hours of sitting, sitting in bouts of >30 minutes, steps, MPA (1952–5724 counts per minute) and VPA (>5725 counts per minute) were standardized to a 16-hour day.[33] Sit-to-stand transitions were reported per hour of sitting per day.[34,35] Standardized values were totaled and then averaged across all valid days.

Data collected from VOTOR for this study included participant demographics (age, sex); level of education; principal diagnosis and cause of injury (coded using the International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification [ICD-10-AM][36]); date of surgery (when relevant); date of injury; preinjury work status ("yes" or "no" and occupation); preinjury health status (European Quality of Life Visual Analog Scale, scored from 0 to 100, with endpoints defined as "worst" and "best" imaginable health state[37]); preinjury level of disability (self-reported as none, mild, moderate, marked, or severe disability and categorized for analysis as "yes" or "no" for disability); and comorbidities (defined using the Charlson Comorbidity Index, mapped from ICD-10-AM codes, and categorized for analysis as "yes" or "no" for comorbidity[38].) Body mass index (BMI) was calculated as weight (kg) divided by height (m^2) and categorized according to accepted cutoff points.[39] Preinjury physical activity data was reported as low, moderate and high, in accordance with IPAQ-SF scoring protocols.[24]

[H2] Data Analysis

Summary statistics were used to describe demographic and injury characteristics of participants: frequencies and percentages for categorical variables and medians and interquartile ranges for skewed continuous variables. Associations between variables were assessed using chi-square tests for categorical variables and Wilcoxon rank sum tests for continuous variables. These tests were also used to compare characteristics between those with and those without 6-month data.

Outcomes at both time points were summarized using the mean and SD for normally distributed data (sitting) and median and interquartile range for skewed data (sitting bouts of

>30 minutes, sit-to-stand transitions, steps, MPA, and VPA). Scatterplots with an overlaid unadjusted line of best fit were created for each activity outcome to depict the change from 2 weeks to 6 months. These changes were assessed further via dependent *t* tests for sitting time and Wilcoxon matched-pairs signed rank tests for all other outcomes.

Predictors for the 3 main outcomes, sitting time, steps and MPA, were assessed using linear mixed models to account for the correlation between repeated measures from the same participant (random effects). As steps and MPA data were negatively skewed, a log transformation was applied prior to modelling. Based on previous literature, potential predictive variables included in the models were time (ie, 2 weeks versus 6 months), age, sex, fracture group (ie, UL versus LL fracture), cause of injury, BMI, preinjury physical activity, and highest level of education.[7,40,41] Owing to insufficient variability across response categories, preinjury work status, disability, health status, and the Charlson Comorbidity Index were not included. Variables showing a significant ($P < .25$) association on univariable analyses were entered into each multivariable model.[42] Nonsignificant variables were identified using Wald tests and were removed from the model individually in a backward stepwise approach ($P < .05$).[42] The reduced models were compared with the initial model using likelihood ratio tests and the remaining variable coefficients assessed to ensure that they had not substantially changed, indicating potential confounding. This process was repeated until a parsimonious final model was achieved. Variables excluded from the initial model were then included to ensure that important variables had not been missed. Residual plots were inspected to evaluate model assumptions (ie, normal distribution of residuals and equal variances).[43] The estimated models used 15 degrees of freedom. Thus, our final sample allowed for >5 participants per variable, exceeding the minimum number of participants per variable required for accurate estimation of regression coefficients, CIs, and adjusted R^2 values.[44]

Differences in magnitude of change in the outcome between participant subgroups (eg, men versus women) were explored using an interaction term between each variable and time (ie, 2 weeks and 6 months), with the adjusted mean change or ratio of geometric means (for log-transformed outcomes) representing the improvement in outcome in that group relative to the previous time point. All analyses were performed using Stata V.15 (StataCorp LLC, College Station, TX, USA).

[H2] Role of the Funding Source

This project was funded by a Monash University Faculty of Medicine Nursing and Health Sciences Strategic Grant. C.L. Ekegren was supported by a National Health and Medical Research Council of Australia (NHMRC) Early Career Fellowship (ref. no. 1106633). B.J. Gabbe was supported by an Australian Research Council Future Fellowship (ref. no. FT170100048). N. Owen was supported by an NHMRC Program Grant (ref. no. 569940), by a Senior Principal Research Fellowship (ref. no. 1003960), and by the Victorian Government's Operational Infrastructure Support Program. D.W. Dunstan was supported by an NHMRC Senior Research Fellowship (ref. no. 1078360) and by the Victorian Government's Operational Infrastructure Support Program. The funder had no involvement in the study design, data collection, analysis and interpretation of data, the writing of the report, or the decision to submit the article for publication.

[H1] Results

From the 445 eligible patients, 120 participants were recruited. At the 2-week time point, 83 participants returned valid activPAL data (n = 81) and/or valid ActiGraph data (n = 78). At the 6-month time point, 63 participants returned valid activPAL data (n = 59) and/or valid ActiGraph data (n = 60). Reasons for attrition at 6 months included loss of interest (n = 16) and insufficient/invalid data (n = 4). Participants lost to follow-up at 6 months were more commonly men (P = .03), and a higher proportion had only a high school level of education (P = .04) (Suppl. Material, available at https://academic.oup.com/ptj).

Characteristics of included participants are presented in Table 1. The majority were men, most had sustained LL fractures, and the mean age was 41 (SD = 14) years. The majority of participants were in paid employment prior to injury and were working in white collar professions, and approximately one-half were university educated. Approximately one-half of the participants had a BMI in the overweight or obese range, yet the majority scored zero on the Charlson Comorbidity Index. Participants reported mostly high levels of activity prior to injury, low levels of disability, and high self-rated health (European Quality of Life Visual Analog Scale). Approximately one-third of participants were injured via a low fall (<1 m). The most common LL fracture was an ankle fracture, and the most common UL fracture was a wrist/forearm fracture. Out of 83 participants, 6% (n = 5) had open fractures, 41% had intraarticular fractures, and 71% had comminuted fractures or fractures with multiple fragments. Ten of the 83 participants were treated nonsurgically. Of those treated surgically, 71 underwent internal fixation and 2 received external fixation. The median length of stay was 2.3 (interquartile range = 1.9–4.2) days. Approximately two-thirds of participants with LL fractures were non–weight bearing on the affected limb at the 2-week time point. For participants with valid 2-week data, there was an association between age and fracture group

(P = .04), with younger participants sustaining more LL fractures (Tab. 1). For participants with valid 6-month data, participants with an LL fracture reported lower health status than those with a UL fracture (P = .03), although the median difference was only 3.5%.

Time spent in sedentary behavior and physical activity at both time points are shown in the Figure and Table 2. Overall, participants spent less time sitting at 6 months than at 2 weeks (overall and in bouts of >30 minutes), had more sit-to-stand transitions, took more steps, and engaged in more MPA and VPA (P < .001). There were significant differences in outcomes by fracture group, with worse outcomes but greater improvement over time for participants with LL fractures than for those with UL fractures (Figure and Tab. 2). These differences were explored further via mixed linear multivariable models fitted for 3 main outcomes: sitting, steps, and MPA.

After adjusting for confounders, participants with LL fractures sat on average 2 hours more per day overall than participants with UL fractures (Tab. 3). All participants spent less time sitting at 6 months than at 2 weeks (adjusted mean difference = −2.72 [95% CI = −3.26 to −2.17]; P < .001). However, the magnitude of change from 2 weeks to 6 months differed by age, injury, preinjury physical activity level, and BMI (Tab. 3). The magnitude of change in sitting time was greater for participants in the youngest age group than for those in the oldest age group. The magnitude of change in sitting time was greater for participants with LL fractures than for those with UL fractures. The magnitude of change in sitting time was greater for participants with the highest level of preinjury physical activity than for those with the lowest level of physical activity. The magnitude of change in sitting time was greater for participants who were overweight or obese than for those who were of normal weight or underweight.

For steps, LL fractures were associated with 66% fewer steps per day than UL fractures (Tab. 4). Participants with an advanced diploma or certificate took 40% more steps per day than those who were university educated. Overall, participants took over 3 times more steps at 6 months than at 2 weeks (adjusted ratio of geometric means = 3.44 [95% CI = 2.69 to 4.39]; $P < .001$). However, this change over time differed by age and injury (Tab. 4). The magnitude of change in steps from 2 weeks to 6 months was lower for participants in the oldest age group than for all other participants. The magnitude of change in steps was greater for participants with LL fractures than for those with UL fractures.

For MPA, LL fractures were associated with 77% fewer minutes of MPA per day than UL fractures (Tab. 5). Participants in the middle-age and older age groups engaged in 47% and 51% less MPA, respectively, than those in the youngest age group. However, those who did not complete high school engaged in 68% less MPA than those who were university educated. Overall, participants performed more MPA at 6 months than at 2 weeks (adjusted ratio of geometric means = 5.37 [95% CI = 3.82 to 7.54]; $P < .001$). However, the magnitude of change differed by age and injury (Tab. 5). The magnitude of change in minutes of MPA was greater for participants who were 35 to 49 years old than for participants in the oldest and youngest age groups. The magnitude of change in minutes of MPA was greater for participants with LL fractures than for those with UL fractures.

[H1] Discussion

This study aimed to describe changes in time spent in physical activity and sedentary behavior from 2 weeks to 6 months following musculoskeletal trauma and determine demographic and injury-related factors associated with these changes. The 3 main findings were as follows. Physical activity levels and sedentary behavior were significantly improved at the 6-month time point. Participants with LL fractures had poorer outcomes for all measures at 6 months than those with UL fractures. Older participants had a lower magnitude of recovery than younger participants for sitting time, steps, and MPA.

Two weeks after fracture, all participants engaged in high amounts of sitting, took few steps, and had low physical activity levels. At 6 months, these outcomes had improved but were still lacking in some groups relative to normative values. The AusDiab study, one of the few population-based studies to use the gold standard device (activPAL[45]) to measure sitting time, reported a mean value of 8.8 (SD = 1.8) h/d in 678 Australian community-dwelling adults who were 36 to 80 years old.[46] Although these values were similar to daily sitting time at 6 months for our UL group, participants in the LL group recorded over 1 hour more of sitting time per day at 6 months. Over extended periods, 1 extra hour of sedentary time is associated with a higher odds of developing type 2 diabetes and metabolic syndrome[47] and, for those who sit >7 h/d, there is a 5% increased risk of all-cause mortality for each 1-hour increment in sitting time per day.[48] Furthermore, in this study, almost 60% of participants' sitting time was accumulated in bouts of 30 minutes or more at the 6-month time point, a pattern of behavior associated with higher BMI and waist circumference, less favorable high-density lipoprotein cholesterol and triglyceride levels, and a higher risk of all-cause mortality.[49–51]

There have been few large studies using the activPAL device to assess step counts. One study of 164 UK office workers who were healthy and had a comparable mean age of 39 (SD = 10.6) years reported a mean of 9737 (SD = 3517) steps per day, approximately double the steps measured in our study at the 6-month time point.[52] For MPA, our 6-month values compare well with population norms. The National Health and Nutrition Examination Survey

(NHANES), which has collected ActiGraph data from 6329 American adults, reports MPA of 12.3 to 41.3 min/d in those of a similar age, which is comparable to our 6-month values.[53] However, the majority of participants with LL fractures recorded no VPA whatsoever at the 6-month time point. These findings are important given that, over the long term, failure to meet physical activity guidelines (at least 150 minutes of MPA per week or 75 minutes of VPA per week or any equivalent combination of the 2) has been associated with numerous chronic health conditions and all-cause mortality.[15]

Further research is needed to determine whether the observed changes in physical activity patterns persist beyond the 6-month time point. In this study, many participants were injured during engagement in some form of physical activity, such as cycling. For these people in particular, fear of reinjury may play a strong role in preventing resumption of preinjury activity behavior.[54] There is evidence of this fear in people who have experienced hip fracture, with fear of falling cited as a reason for reduced functional mobility after fracture.[55] People who have experienced an anterior cruciate ligament rupture also cite fear of reinjury as a reason to avoid or delay returning to sport.[56] There is a need for further research to determine whether fear of reinjury, or post-traumatic stress, lead to physical activity restriction in working age adults following fracture. Considering the importance of habit in the maintenance of physical activity, loss of routine and loss of motivation may also contribute to long-term reductions in physical activity levels following musculoskeletal trauma.[57]

Participants with LL fractures demonstrated greater improvement in all activity outcomes over time than those with UL fractures, most likely because of their very low 2-week activity levels allowing greater room for improvement. A high proportion of participants with LL fractures were non–weight bearing on their fractured limb at the 2-week time point which may explain their low activity levels. Although our study was not powered for a subgroup analysis of this association in the LL fracture group, there is a need for a better understanding of the impact of weight-bearing restrictions in future research. Regardless, 6-month outcomes for those with LL fractures were still worse compared to UL fractures, which was unexpected given that bony consolidation and full weight bearing would be expected to have occurred by 6 months for most LL fractures.[58] These findings may relate to the increased severity of these injuries, with LL fractures leading to a greater loss of muscle mass and cardiovascular fitness, joint stiffness or pain, thereby increasing the challenge of resuming physical activity. A previous study using accelerometry to measure physical activity in adolescents aged 10 to 16 years found that participants with LL fractures engaged in 23% less MPA per day 6 months after surgery relative to their peers who were healthy.[40] This difference had worsened at the 18-month time point, indicating an enduring reduction of MPA following LL fracture.

By contrast, older participants (50–69 years old) had lower levels of activity and less improvement in activity over time than their younger and middle-aged counterparts, suggesting that older adults are more greatly affected by musculoskeletal trauma and find it more challenging to recover. Previous research demonstrated very low levels of physical activity and high amounts of sitting up to 6 months following hip fracture in older adults,[7,41,59] with results worsening with every year of increased age.[7,60] With greater comorbidity and reduced physical function, it is understandable that activity levels of older adults may be more greatly impaired by musculoskeletal trauma. In this study, it was notable that the impact of age on activity appeared to begin in those as young as 50 years.

Participants reporting higher levels of preinjury physical activity had greater improvements in sitting time at 6 months, suggesting an association between these 2 behaviors. More unexpected was our finding of greater improvements in sitting time for participants with a higher BMI. It is possible that having greater weight reserves may be beneficial in the fracture recovery process.[61] Consistent with our findings, previous research has shown better self-reported physical activity recovery 12 months after sports-related musculoskeletal trauma in those with a university degree compared to those without.[62] However, we also observed that those with a university education took fewer steps overall. One possible explanation for this is the tendency for university graduates to be employed in white-collar occupations (which are usually more sedentary[63]) but to also engage in more leisure-time physical activity.[64]

This study had a number of limitations. First, although sufficiently powered for our analyses, our convenience sample was relatively small and, given participants' high levels of preinjury physical activity, high health status, and high levels of educational attainment, the sample was likely not representative of all people with musculoskeletal trauma. Although this limits the generalizability of our findings, it suggests the possibility that activity recovery may be even worse in the wider musculoskeletal trauma population. Second, our use of activPAL rather than ActiGraph to measure steps was based on evidence of the higher accuracy of activPAL at slower walking speeds and when using gait aids.[22] However, further research is needed to validate measurement of physical activity via ActiGraph under these conditions. Third, there were types of physical activity that we were not able to measure in this study, including swimming and cycling, 2 activities that may be popular with people recovering from musculoskeletal trauma. Fourth, we did not collect data on pain as a potential correlate of physical activity and sitting time. Nor did we include data on fracture type and severity (eg, articular involvement, open/closed, degree of comminution) in our multivariable analyses. These factors may influence activity levels, particularly in the early stage of recovery, and therefore would be valuable to monitor in future research with larger samples. Furthermore, although understanding activity recovery requires accurate estimates of preinjury activity levels, currently the most feasible option for capturing these is via self-report, which has poor agreement with device-based measurement in people with fractures.[65] To reduce potential recall bias for preinjury physical activity levels collected 2 weeks after injury, we collected data via the IPAQ-SF, a widely used, validated measure of self-reported physical activity[66]; we reported IPAQ-SF categories of physical activity rather than IPAQ-SF–derived continuous physical activity data in Metabolic Equivalent of Task-minutes (providing better agreement with device-based measures[63]); and we collected preinjury physical activity data at a feasible, standardized time point following injury, allowing participants a reasonable period of recovery from their injuries.

This study has demonstrated excessive and prolonged bouts of sitting and low physical activity levels in people with musculoskeletal trauma, persisting up to 6 months following injury. Although pain medication effects and mobility deficits may impede walking and physical activity in the early stage of recovery, there are numerous potential health benefits from simply reducing and breaking up prolonged bouts of sitting.[32,46,67,68] This growing body of evidence supports the notion that advice commonly given to people with musculoskeletal trauma at hospital discharge about the need for rest could be supplemented with advice about the potential advantages of breaking up prolonged sitting with standing, stepping and light activity bouts, within their capacities and tolerability. Furthermore, interventions aimed at gradually increasing levels of MPA and VPA, targeted towards those at risk of poor activity recovery, should be an integral part of trauma rehabilitation, recognizing the fact that a lack of clinical deficits does not necessarily mark the endpoint of recovery. More research is still needed however, to determine which interventions are safe and effective in this population and whether these interventions result in long-term health benefits.

Author Contributions and Acknowledgments
Concept/idea/research design: C.L. Ekegren, R.E. Climie, N. Owen, D.W. Dunstan, B.J. Gabbe
Writing: C.L. Ekegren, R.E. Climie, N. Owen, D.W. Dunstan, B.J. Gabbe
Data collection: C.L. Ekegren, R.E. Climie, W. Veitch
Data analysis: C.L. Ekegren, P.M. Simpson
Project management: C.L. Ekegren
Fund procurement: C.L. Ekegren
Providing facilities/equipment: C.L. Ekegren, N. Owen, D.W. Dunstan, B.J. Gabbe
Providing institutional liaisons: C.L. Ekegren, R.E. Climie, N. Owen, D.W. Dunstan, B.J. Gabbe
Clerical/secretarial support: W. Veitch
Consultation (including review of manuscript before submitting): C.L. Ekegren, R.E. Climie, P.M. Simpson, N. Owen, D.W. Dunstan, W. Veitch, B.J. Gabbe

The authors thank Parneet Sethi, Jennifer Gong, and Dr Anthony Tsay for their assistance with this project and gratefully acknowledge the study participants for contributing their time and effort.

Ethics Approval

Ethics approval was obtained from the Monash University and Alfred Hospital human research ethics committees. All participants were recruited during their inpatient hospital stay and provided written informed consent.

Funding
This project was funded by a Monash University Faculty of Medicine Nursing and Health Sciences Strategic Grant. C.L. Ekegren was supported by a National Health and Medical Research Council of Australia (NHMRC) Early Career Fellowship (ref. no. 1106633). B.J. Gabbe was supported by an Australian Research Council Future Fellowship (ref. no. FT170100048). N. Owen was supported by an NHMRC Program

Grant (ref. no. 569940), by a Senior Principal Research Fellowship (ref. no. 1003960), and by the Victorian Government's Operational Infrastructure Support Program. D.W. Dunstan was supported by an NHMRC Senior Research Fellowship (ref. no. 1078360) and by the Victorian Government's Operational Infrastructure Support Program.

Disclosures

The authors completed the ICJME Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

References

1. Australian Institute of Health and Welfare. *Australia's Hospitals 2016-17 at a Glance.* Cat. no. HSE 204. Canberra, Australian Capital Territory, Australia: Australian Institute of Health and Welfare; 2018.
2. Bradley C, Harrison J. *Descriptive Epidemiology of Traumatic Fractures in Australia.* Cat. no. INJ 57. Adelaide, South Australia, Australia:Australian Institute of Health and Welfare; 2004.
3. Brinker MR, O'Connor DP. The incidence of fractures and dislocations referred for orthopaedic services in a capitated population. *J. Bone Joint Surg. Am.* 2004;86-a:290-297.
4. Faergemann C, Frandsen P, Rock N. Residual impairment after lower extremity fracture. *J Trauma Care Surg.* 1998;45:123-126.
5. Butcher JL, MacKenzie EJ, Cushing B, et al. Long-term outcomes after lower extremity trauma. *J Trauma.* 1996;41:4-9.
6. Ekegren CL, Beck B, Climie RE, Owen N, Dunstan DW, Gabbe BJ. Physical activity and sedentary behavior subsequent to serious orthopedic injury: a systematic review. *Arch Phys Med Rehabil.* 2018;99:164-177.
7. Fleig L, McAllister MM, Brasher P, et al. Sedentary behavior and physical activity patterns in older adults after hip fracture: a call to action. *J Aging Phys Act.* 2016;24:79-84.
8. Ekegren CL, Climie RE, Veitch WG. Sedentary behavior and physical activity patterns in adults with traumatic limb fracture. *AIMS Med Sci*. 2019;6:1-12.
9. Brown WJ, Bauman AE, Bull FC, Burton NW. *Development of Evidence-Based Physical Activity Recommendations for Adults (18-64 Years): Report Prepared for*

the Australian Government Department of Health, August 2012. Canberra, Australian Capital Territory, Australia: Commonwealth of Australia; 2013.

10. Sedentary Behaviour Research Network. Letter to the Editor: standardized use of the terms "sedentary" and "sedentary behaviours." *Appl Physiol Nutr Metab.* 2012;37:540-542.

11. Ferrando AA, Lane HW, Stuart CA, Davis-Street J, Wolfe RR. Prolonged bed rest decreases skeletal muscle and whole body protein synthesis. *Am J Physiol.* 1996;270:E627-E633.

12. Hamilton MT, Hamilton DG, Zderic TW. Role of low energy expenditure and sitting in obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes.* 2007;56:2655-2667.

13. Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: the population health science of sedentary behavior. *Exerc Sport Sci Rev.* 2010;38:105-113.

14. Van der Wiel HE, Lips P, Nauta J, Patka P, Haarman HJ, Teule GJ. Loss of bone in the proximal part of the femur following unstable fractures of the leg. *J Bone Joint Surg Am.* 1994;76:230-236.

15. 2018 Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Scientific Report.* Washington, DC: US Department of Health and Human Services; 2018.

16. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? *Lancet.* 2016;388:1302-1310.

17. Zusman EZ, Dawes MG, Edwards N, Ashe MC. A systematic review of evidence for older adults' sedentary behavior and physical activity after hip fracture. *Clin Rehabil.* 2018;32:679–691.

18. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol.* 2008;61:344-349.

19. Lyden K, Kozey Keadle SL, Staudenmayer JW, Freedson PS. Validity of two wearable monitors to estimate breaks from sedentary time. *Med Sci Sports Exerc.* 2012;44:2243-2252.

20. Harrington DM, Welk GJ, Donnelly AE. Validation of MET estimates and step measurement using the ActivPAL physical activity logger. *J Sports Sci.* 2011;29:627-633.

21. Ryan CG, Grant PM, Tigbe WW, Granat MH. The validity and reliability of a novel activity monitor as a measure of walking. *Br J Sports Med.* 2006;40:779-784.

22. Treacy D, Hassett L, Schurr K, Chagpar S, Paul SS, Sherrington C. Validity of different activity monitors to count steps in an inpatient rehabilitation setting. *Phys Ther.* 2017;97:581–588.

23. Sasaki JE, John D, Freedson PS. Validation and comparison of ActiGraph activity monitors. *J Sci Med Sport.* 2011;14:411-416.

24. The IPAQ Group. International Physical Activity Questionnaire. www.ipaq.ki.se. Accessed September 20, 2019.

25. Edwards E, Graves S, McNeil J, Williamson O, Urquhart D, Cicuttini F. Orthopaedic trauma: establishment of an outcomes registry to evaluate and monitor treatment effectiveness. *Injury.* 2006;37:95-96.

26. Ekegren CL, Edwards, ER, Oppy, A, et al. Twelve-month work–related outcomes following hip fracture in patients under 65 years of age. *Injury*. 2017;48:701-707.

27. Beck B, Devlin A, Hart M, Gabbe B. *Victorian Orthopaedic Trauma Outcomes Registry (VOTOR) Annual Report.* Melbourne, Victoria, Australia: Monash University; April 2018.

28. Matthews CE, Hagstromer M, Pober DM, Bowles HR. Best practices for using physical activity monitors in population-based research. *Med Sci Sports Exerc.* 2012;44(1 suppl 1):S68-S76.

29. Ward DS, Evenson KR, Vaughn A, Rodgers AB, Troiano RP. Accelerometer use in physical activity: best practices and research recommendations. *Med Sci Sports Exerc.* 2005;37(11 suppl):S582-S588.

30. Winkler EA, Bodicoat DH, Healy GN, et al. Identifying adults' valid waking wear time by automated estimation in activPAL data collected with a 24 h wear protocol. *Physiol Meas.* 2016;37:1653-1668.

31. Choi L, Liu Z, Matthews CE, Buchowski MS. Validation of accelerometer wear and nonwear time classification algorithm. *Med Sci Sports Exerc.* 2011;43:357-364.

32. Dunstan DW, Kingwell BA, Larsen R, et al. Breaking up prolonged sitting reduces postprandial glucose and insulin responses. *Diabetes Care.* 2012;35:976-983.

33. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc., accelerometer. *Med Sci Sports Exerc.* 1998;30:777-781.

34. Danquah IH, Kloster S, Holtermann A, et al. Take a Stand! A multi-component intervention aimed at reducing sitting time among office workers: a cluster randomized trial. *Int J Epidemiol.* 2017;46:128-140.

35. Healy GN, Eakin EG, LaMontagne AD, et al. Reducing sitting time in office workers: short-term efficacy of a multicomponent intervention. *Prev Med.* 2013;57:43-48.

36. National Centre for Classification in Health. *The Iternational Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification (ICD-10-AM).* Sydney, New South Wales, Australia: The University of Sydney; 2010.

37. Barton GR, Sach TH, Doherty M, Avery AJ, Jenkinson C, Muir KR. An assessment of the discriminative ability of the EQ-5Dindex, SF-6D, and EQ VAS, using sociodemographic factors and clinical conditions. *Eur J Health Econ.* 2008;9:237-249.

38. Charlson M, Pompei P, Ales K, MacKenzie C. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis.* 1987;40:373-383.

39. World Health Organization. *Physical Status: The Use and Interpretation of Anthropometry. Report of a WHO Expert Committee.* WHO Technical Report Series 854. Geneva, Switzerland: World Health Organization; 1995.

40. Ceroni D, Martin X, Lamah L, et al. Recovery of physical activity levels in adolescents after lower limb fractures: a longitudinal, accelerometry-based activity monitor study. *BMC Musculoskelet Disord.* 2012;13:131.

41. Resnick B, Orwig D, Hawkes W, et al. The relationship between psychosocial state and exercise Behavior of older women 2 months after hip fracture. *Rehabil Nurs.* 2007;32:139-149.

42. Hosmer DW Jr, Lemeshow S, Sturdivant RX. *Applied Logistic Regression.* 3rd ed. New York, NY: John Wiley & Sons, Inc; 2013:89-151.

43. Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice.* Vol 2. Upper Saddle River, NJ: Prentice Hall Health; 2000.

44. Austin PC, Steyerberg EW. The number of subjects per variable required in linear regression analyses. *J Clin Epidemiol.* 2015;68:627-636.

45. Edwardson CL, Winkler EAH, Bodicoat DH, et al. Considerations when using the activPAL monitor in field-based research with adult populations. *J Sport Health Sci.* 2017;6:162-178.

46. Healy GN, Winkler EAH, Owen N, Anuradha S, Dunstan DW. Replacing sitting time with standing or stepping: associations with cardio-metabolic risk biomarkers. *Eur Heart J.* 2015;36:2643-2649.

47. van der Berg JD, Stehouwer CD, Bosma H, et al. Associations of total amount and patterns of sedentary behavior with type 2 diabetes and the metabolic syndrome: The Maastricht Study. *Diabetologia.* 2016;59:709-718.

48. Chau JY, Grunseit AC, Chey T, et al. Daily sitting time and all-cause mortality: a meta-analysis. *PLoS One.* 2013;8:e80000.

49. Bellettiere J, Winkler EAH, Chastin SFM, et al. Associations of sitting accumulation patterns with cardio-metabolic risk biomarkers in Australian adults. *PLoS One.* 2017;12:e0180119.

50. Diaz KM, Howard VJ, Hutto B, et al. Patterns of sedentary behavior and mortality in U.S. middle-aged and older adults: a national cohort study. *Ann Intern Med.* 2017;167:465-475.

51. Evenson KR, Herring AH, Wen F. Accelerometry-assessed latent class patterns of physical activity and sedentary behavior with mortality. *Am J Prev Med.* 2017;52:135-143.

52. Smith L, Hamer M, Ucci M, et al. Weekday and weekend patterns of objectively measured sitting, standing, and stepping in a sample of office-based workers: the active buildings study. *BMC Public Health.* 2015;15:9.

53. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, Mcdowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc.* 2008;40:181-188.

54. van der Sluis C, Eisma W, Groothoff J, ten Duis H. Long-term physical, psychological and social consequences of a fracture of the ankle. *Injury.* 1998;29:277-280.

55. Bower ES, Wetherell JL, Petkus AJ, Rawson KS, Lenze EJ. Fear of falling after hip fracture: prevalence, course, and relationship with one-year functional recovery. *Am J Geriatr Psychiatry.* 2016;24:1228-1236.

56. Filbay SR, Crossley KM, Ackerman IN. Activity preferences, lifestyle modifications and re-injury fears influence longer-term quality of life in people with knee symptoms following anterior cruciate ligament reconstruction: a qualitative study. *J Physiother.* 2016;62:103-110.

57. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc.* 2002;34:1996-2001.

58. Parziale JR. Disability evaluation of extremity fractures. *Phys Med Rehabil Clin N Am.* 2001;12:647-657.

59. Magaziner J, Simonsick EM, Kashner TM, Hebel JR, Kenzora JE. Predictors of functional recovery one year following hospital discharge for hip fracture: a prospective study. *J. Gerontol.* 1990;45:M101-M107.

60. Resnick B, Galik E, Boltz M, et al. Physical activity in the post-hip-fracture period. *J Aging Phys Act.* 2011;19:373-387.

61. Krishnan M, Beck S, Havelock W, Eeles E, Hubbard RE, Johansen A. Predicting outcome after hip fracture: using a frailty index to integrate comprehensive geriatric assessment results. *Age Ageing.* 2014;43:122-126.

62. Andrew N, Gabbe BJ, Wolfe R, Cameron PA. The impact of serious sport and active recreation injuries on physical activity levels. *Br J Sports Med.* 2011;45:335-335.

63. Smith L, McCourt O, Sawyer A, et al. A review of occupational physical activity and sedentary behaviour correlates. *Occup Med (Lond).* 2016;66:185-192.

64. Droomers M, Schrijvers CTM, Mackenbach JP. Educational level and decreases in leisure time physical activity: predictors from the longitudinal GLOBE study. *J Epidemiol Community Health.* 2001;55:562-568.

65. Veitch W, Climie R, Gabbe BJ, Dunstan DW, Owen N, Ekegren CL. Validation of two physical activity and sedentary behavior questionnaires in orthopedic trauma patients. *Med Sci Sports Exerc.* 2018;50:711.

66. Craig CL, Marshall AL, Sjostrom M, et al. International Physical Activity Questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc.* 2003;35:1381-1395.

67. Climie RE, Wheeler MJ, Grace M, et al. Simple intermittent resistance activity mitigates the detrimental effect of prolonged unbroken sitting on arterial function in overweight and obese adults. *J Appl Physiol.* 2018 September 6 [Epub ahead of print]. doi: 10.1152/japplphysiol.00544.2018.

68. Dempsey PC, Larsen RN, Sethi P, et al. Benefits for type 2 diabetes of interrupting prolonged sitting with brief bouts of light walking or simple resistance activities. *Diabetes Care.* 2016;39:964-972.

Table 1.

Demographics and Injury Characteristics for Participants With Valid Data After Hospital Discharge by Fracture Site[a]

Characteristic	**2 wk**			**6 mo**		
	UL (n = 37)	**LL (n = 46)**	***P***	**UL (n = 26)**	**LL (n = 37)**	***P***
Sex			.59			.82
Men	22 (59.5)	30 (65.2)		14 (53.9)	21 (56.8)	
Women	15 (40.5)	16 (34.8)		12 (46.1)	16 (43.2)	
Age group (y)			**.04**			.10
18–34	13 (35.1)	23 (50.0)		9 (34.6)	16 (43.2)	
35–49	7 (18.9)	14 (30.4)		5 (19.2)	13 (35.2)	
50–69	17 (46.0)	9 (19.6)		12 (46.2)	8 (21.6)	
Education level[b]			.81			.74
University degree	17 (53.1)	21 (48.8)		13 (59.1)	16 (44.4)	
Advanced diploma, diploma, or certificate	8 (25.0)	15 (34.9)		7 (31.7)	15 (41.7)	
Completed high school	4 (12.5)	4 (9.3)		1 (4.6)	2 (5.6)	
Did not complete high school	3 (9.4)	3 (7.0)		1 (4.6)	3 (8.3)	
Worked prior to injury[b]			.42			.72
No	3 (9.4)	2 (4.7)		1 (4.5)	1 (2.8)	
Yes	29 (90.6)	41 (95.4)		21 (95.5)	35 (97.2)	
Occupation			.39			.42
Managers, administrators, and professionals	21 (72.3)	22 (53.7)		16 (76.1)	20 (57.1)	
Tradespersons	6 (20.7)	10 (24.3)		4 (19.1)	9 (25.7)	
Clerical, service, and sales workers	1 (3.5)	5 (12.2)		1 (4.8)	4 (11.5)	
Laborers and production and transport workers	1 (3.5)	2 (4.9)		0	0	
Students	0	2 (4.9)		0	2 (5.7)	
Body mass index category			.48			.34
Normal or underweight (<25 kg/m^2)	21 (56.8)	20 (43.5)		16 (61.5)	16 (43.3)	
Overweight (≥25–<30 kg/m^2)	12 (32.4)	19 (41.3)		6 (23.1)	14 (37.8)	
Obese (≥30 kg/m^2)	4 (10.8)	7 (15.2)		4 (15.4)	7 (18.9)	

Preinjury comorbidity (CCI score of ≥1)[c]			.45			.09
No	34 (97.1)	43 (93.5)		25 (100.0)	33 (89.2)	
Yes	1 (2.9)	3 (6.5)		0	4 (10.8)	
Preinjury physical activity (IPAQ-SF category)			.30			.32
Low	5 (13.5)	2 (4.4)		3 (11.5)	1 (2.7)	
Moderate	11 (29.7)	13 (28.3)		5 (19.2)	10 (27.0)	
High	21 (56.8)	31 (67.3)		18 (69.3)	26 (70.3)	
Preinjury disability[b]			.58			.57
No	26 (81.2)	37 (86.0)		17 (77.3)	30 (83.3)	
Yes	6 (18.8)	6 (14.0)		5 (22.7)	6 (16.7)	
Preinjury health status (EQ VAS) (0–100)[d]			.58			**.03**
Median (IQR)	90 (80–95)	90 (75–95)		93.5 (90–99)	90 (77.5–95)	
Range (minimum–maximum)	50–100	40–100		75–100	40–100	
Injury cause			.17			.49
Low fall	14 (37.8)	18 (39.1)		10 (38.5)	17 (50.0)	
High fall	6 (16.2)	6 (13.0)		3 (11.5)	5 (13.5)	
Motor vehicle/motor cyclist	5 (13.5)	7 (5.3)		4 (15.4)	5 (13.5)	
Pedal cyclist	9 (24.3)	4 (8.7)		7 (26.9)	4 (10.8)	
Other external cause	3 (8.2)	11 (23.9)		2 (7.7)	6 (16.2)	
Fracture type						
Foot		6 (7.2)			3 (4.8)	
Ankle		23 (27.7)			22 (34.9)	
Tibia/fibula		10 (12.1)			6 (9.5)	
Patella		4 (4.8)			3 (4.8)	
Hip		3 (3.6)			3 (4.8)	
Forearm/wrist	15 (18.1)			8 (12.7)		
Elbow	3 (3.6)			2 (3.2)		
Humerus	8 (9.6)			7 (11.1)		
AC/scapula/clavicle	11 (13.3)			9 (14.3)		
Weight-bearing status[e]	N/A			N/A		
Non–weight bearing		30 (65.2)			23 (62.2)	

Partial weight bearing/weight bearing as tolerated		16 (34.8)			14 (37.8)	
Days from surgery/injury to start of data collection			.26			.34
Median (IQR)	15 (14–18)	16 (14–19)		182 (179–185)	182 (178–183)	
Range (minimum–maximum)	8–29	2–27		170–218	164–201	

[a]*P* values in bold type are significant. AC = acromioclavicular joint; CCI = Charlson Comorbidity Index; EQ VAS = European Quality of Life Visual Analog Scale; IPAQ-SF = International Physical Activity Questionnaire–Short Form; IQR = interquartile range; LL = lower limb fractures; N/A = not applicable; UL = upper limb fractures.

[b]Missing data: for 2 wk, n = 8; for 6 mo, n = 5.

[c]Missing data: for 2 wk, n = 2; for 6 mo, n = 1.

[d]Missing data: for 2 wk, n = 11; for 6 mo, n = 7.

[e]Weight-bearing status at hospital discharge: non–weight bearing means that the person is not permitted to bear any weight on the affected limb (ie, must use crutches to hop on the unaffected limb); partial weight bearing means that the person is allowed to bear some weight on the affected limb (ie, must use crutches to walk); weight bearing as tolerated means that the person is allowed to bear as much weight on the limb as he or she can tolerate (ie, can walk with or without crutches).

Table 2.

Physical Activity and Sedentary Behavior Outcomes After Hospital Discharge in Participants With Fractures[a]

Activity or Behavior	Upper Limb Fracture		Lower Limb Fracture		Total		P^b
	2 wk (n = 37)	6 mo (n = 26)	2 wk (n = 46)	6 mo (n = 37)	2 wk (n = 83)	6 mo (n = 63)	
Sitting time (h/d)							<.001
Mean (SD)	10.6 (1.8)	9.1 (1.6)	13.6 (1.4)	9.9 (1.7)	12.2 (2.2)	9.6 (1.7)	
Range (minimum–maximum)	6.6–14.5	5.7–11.9	9.6–15.6	6.3–13.2	6.6–15.6	5.7–13.2	
Sitting bouts of ≥30 min (h/d)							<.001
Median (IQR)	5.7 (4.5–6.9)	4.6 (3.3–6.0)	10.6 (8.8–12.3)	5.8 (4.0–6.9)	8.6 (5.7–11.0)	5.1 (3.7–6.5)	
Range (minimum–maximum)	2.7–12.6	0.9–7.0	4.7–15.3)	1.6–10.4	2.7–15.3	0.9–10.4	
% of total sitting/d	54	51	78	59	71	53	
Sit-to-stand transitions/h of sitting (n)							<.001
Median (IQR)	5.0 (3.9–6.0)	5.8 (4.5–6.9)	2.5 (1.8–3.3)	4.9 (3.4–5.9)	3.5 (2.2–5.1)	5.1 (3.9–6.5)	
Range (minimum–maximum)	2.0–10.3	3.5–12.1	0.8–5.8	2.0–12.0	0.8–10.3)	2.0–12.1	
Steps/d (n)							<.001
Median (IQR)	4066 (2833–4668)	5441 (4637–6458)	779 (436–1243)	4318 (3600–5422)	1751 (705–3857)	4786 (3937–6269)	
Range (minimum–maximum)	969–8251	3964–9131	86–2370	1770–7959	86–8251	1770–9131	
MPA (min/d)							<.001
Median (IQR)	23.3 (10.5–51.7)	38.9 (28.0–49.8)	2.1 (0.7–5.5)	24.6 (14.9–44.5)	5.9 (1.5–26.2)	34.9 (21.8–49.3)	
Range (minimum–maximum)	0.4–76.7	5.7–87.0	0–41.5	0–114.7	0–76.7)	0–114.7	
VPA (min/d)							<.001
Median (IQR)	0 (0–0.6)	0.5 (0–7.2)	0 (0–0)	0 (0–0.54)	0 (0–0)	0.1 (0–1.3)	
Range (minimum–maximum)	0–14.8	0–31.7	0–1.8	0–4.0	0–14.8	0–31.7	

[a]IQR = interquartile range; MPA = moderate-intensity physical activity; VPA = vigorous-intensity physical activity.
[b]*P* value for the difference between 2-wk and 6-mo values for all participants (univariable analysis).

Table 3.

Predictors of Sitting Time and Change in Sitting Time From 2 Weeks to 6 Months, Determined by Linear Mixed-Effects Multivariable Regression Analysis[a]

Parameter	**Mean (SD) h/d for:**		**β (95% CI) for Adjusted Mean Difference in h/d Relative to Reference Group**	***P***	**β (95% CI) for Adjusted Mean Change in h/d From 2 wk to 6 mo**	***P*[b]**
	2 wk	**6 mo**				
Sex				.22		.29
Men	12.6 (1.9)	9.6 (1.5)	Reference		−2.98 (−3.64 to −2.31)	
Women	11.7 (2.6)	9.6 (1.9)	−0.41 (−1.08 to 0.25)		−2.39 (−3.26 to −1.51)	
Age group (y)				.42		**.03**
18–34	12.7 (2.0)	9.4 (1.7)	Reference		−3.41 (−4.14 to −2.68)	
35–49	12.4 (2.2)	9.7 (1.8)	−0.47 (−1.24 to 0.29)		−2.80 (−3.84 to −1.75)	
50–69	11.5 (2.3)	9.6 (1.6)	−0.39 (−1.14 to 0.36)		−1.86 (−2.76 to −0.96)	
Injury group				**<.001**		**<.001**
Upper limb	10.6 (1.8)	9.1 (1.6)	Reference		−1.48 (−2.17 to −0.79)	
Lower limb	13.6 (1.4)	9.9 (1.7)	2.02 (1.36 to 2.68)		−3.65 (−4.25 to −3.04)	
Preinjury physical activity				.29		**.03**
Low	10.5 (2.8)	9.7 (2.1)	Reference		−1.25 (−2.33 to −0.17)	
Moderate	12.4 (2.0)	10.0 (1.7)	−0.12 (−1.78 to 1.54)		−2.35 (−3.33 to −1.36)	
High	12.4 (2.1)	9.4 (1.7)	−0.69 (−2.33 to 0.94)		−2.97 (−3.64 to −2.30)	
Body mass index				.22		**.02**
Underweight/normal	11.7 (2.2)	9.6 (1.7)	Reference		−2.09 (−2.72 to −1.46)	
Overweight	12.9 (2.0)	9.3 (1.8)	0.43 (−0.28 to 1.13)		−3.73 (−4.73 to −2.73)	
Obese	12.5 (2.4)	9.9 (1.5)	0.82 (−0.16 to 1.81)		−2.55 (−3.83 to −1.27)	
Education level				.23		.05
University degree	12.6 (2.3)	9.8 (1.8)	Reference		−2.62 (−3.33 to −1.91)	
Diploma or advanced certificate	12.3 (2.0)	9.3 (1.7)	−0.63 (−1.32 to 0.07)		−2.99 (−4.03 to −1.95)	
Completed high school	11.2 (2.4)	10.3 (0.6)	−1.06 (−2.50 to 0.37)		−1.29 (−2.27 to −0.31)	
Did not complete high school	12.2 (0.9)	9.2 (1.6)	−0.56 (−1.92 to 0.80)		−3.16 (−4.56 to −1.75)	

[a] *P* values in bold type are significant.
[b] *P* value for the interaction of the variable with time.

Table 4.

Predictors of Steps and Change in Steps From 2 Weeks to 6 Months, Determined by Linear Mixed-Effects Multivariable Regression Analysis[a]

Parameter	**Median (IQR) Steps/d for:**		**RGM (95% CI)**	***P***	**RGM for 6 mo/2 wk (95% CI)**	***P*[b]**
	2 wk	**6 mo**				
Sex				.52		.99
Men	1626 (770–3213)	5268 (3897–6544)	Reference		3.43 (2.52 to 4.68)	
Women	2042 (660–4144)	4498 (3937–5629)	0.93 (0.76 to 1.15)		3.44 (2.35 to 5.03)	
Age group (y)				.97		**.03**
18–34	1508 (770–3213)	5413 (4451–6482)	Reference		4.03 (2.87 to 5.66)	
35–49	1200 (660–2642)	4736 (3830–5634)	0.97 (0.72 to 1.30)		4.26 (2.59 to 7.01)	
50–69	2833 (913–4187)	4486 (3848–5451)	0.97 (0.75 to 1.26)		2.34 (1.69 to 3.25)	
Injury group				**<.001**		**<.001**
Upper limb	4066 (2833–4668)	5441 (4637–6458)	Reference		1.56 (1.34 to 1.82)	
Lower limb	779 (436–1243)	4318 (3600–5422)	0.34 (0.27 to 0.43)		6.12 (4.76 to 7.86)	
Preinjury physical activity				.70		.14
Low	3346 (2892–4300)	4960 (3168–7380)	Reference		2.02 (1.19 to 3.44)	
Moderate	2132 (720–2773)	4565 (4182–6054)	1.20 (0.78 to 1.84)		3.19 (2.07 to 4.93)	
High	1358 (660–4072)	4895 (3830–6269)	1.17 (0.77 to 1.77)		3.69 (2.74 to 4.98)	
Body mass index				.45		.19
Underweight/normal	2151 (937–4072)	5404 (4318–6276)	Reference		2.87 (2.07 to 3.98)	
Overweight	1229 (660–2892)	4786 (3964–6482)	0.89 (0.69 to 1.13)		4.52 (3.09 to 6.60)	
Obese	1026 (487–3926)	3615 (3037–4906)	0.83 (0.61 to 1.14)		3.34 (1.76 to 6.35)	
Education level				**.03**		.37
University degree	1123 (389–4144)	4574 (3937–6458)	Reference		3.92 (2.61 to 5.87)	
Advanced diploma or certificate	1339 (879–3213)	4895 (4479–6413)	1.40 (1.13 to 1.77)		3.15 (2.30 to 4.32)	
Completed high school	2042 (1229–3680)	3038 (3037–5132)	1.32 (0.87 to 2.01)		2.33 (1.48 to 3.67)	
Did not complete high school	2066 (1026–2893)	4359 (3453–4789)	1.28 (0.95 to 1.73)		3.19 (1.80 to 5.66)	

[a] *P* values in bold type are significant. IQR = interquartile range; RGM = ratio of geometric means.

[b] *P* value for the interaction of the variable with time.

Table 5.

Predictors of MPA and Change in MPA From 2 Weeks to 6 Months, Determined by Linear Mixed-Effects Multivariable Regression Analysis[a]

Parameter	Median (IQR) min/d for:		RGM (95% CI)	*P*	RGM for 6 mo/2 wk (95% CI)	*P*[b]
	2 wk	6 mo				
Sex				0.17		.67
Men	6.5 (1.8–33.0)	38.9 (23.1–51.1)	Reference		5.03 (3.05 to 8.29)	
Women	4.7 (1.2–11.4)	26.1 (20.5–38.1)	0.76 (0.52 to 1.13)		5.88 (3.48 to 9.95)	
Age group (y)				**.01**		**.01**
18–34	13.7 (2.83–33.7)	49.3 (35.6–53.4)	Reference		5.01 (2.90 to 8.64)	
35–49	2.8 (0.7–7.9)	29.2 (20.5–40.9)	0.53 (0.29 to 0.95)		12.44 (5.94 to 26.05)	
50–69	5.9 (1.8–26.2)	24.0 (14.6–38.4)	0.49 (0.31 to 0.78)		2.85 (1.76 to 4.63)	
Injury group				**<.001**		**<.001**
Upper limb	23.3 (10.5–1.7)	38.9 (28.0–49.8)	Reference		1.95 (1.44 to 2.64)	
Lower limb	2.1 (0.7–5.5)	24.6 (14.9–44.5)	0.23 (0.14 to 0.40)		11.42 (7.21 to 18.10)	
Preinjury physical activity				.84		.58
Low	3.8 (1.5–7.9)	27.0 (8.8–63.1)	Reference		3.79 (2.07 to 6.95)	
Moderate	5.0 (1.2–26.2)	35.6 (11.8–44.5)	1.27 (0.41 to 3.94)		5.25 (2.98 to 9.22)	
High	6.3 (1.6–31.2)	34.3 (23.0–49.8)	1.36 (0.48 to 3.86)		5.62 (3.38 to 9.34)	
Body mass index				.65		.20
Underweight/normal	11.0 (1.4–40.5)	38.3 (23.1–49.4)	Reference		4.11 (2.51 to 6.71)	
Overweight	6.2 (1.5–26.2)	38.2 (22.4–62.1)	0.86 (0.53 to 1.39)		8.54 (4.46 to 16.37)	
Obese	2.7 (1.4–5.9)	24.7 (14.4–37.3)	1.09 (0.69 to 1.73)		4.96 (2.21 to 11.10)	
Education level				**.01**		.37
University degree	12.4 (2.5–37.6)	38.2 (24.6–45.9)	Reference		4.53 (2.60 to 7.88)	
Advanced diploma or certificate	5.0 (1.5–13.9)	25.1 (20.5–51.1)	0.86 (0.54 to 1.36)		7.18 (4.19 to 12.30)	
Completed high school	4.7 (0.8–12.5)	24.7 (0.0–52.6)	0.56 (0.28 to 1.13)		8.26 (2.36 to 28.91)	
Did not complete high school	2.0 (1.5–2.5)	2.5 (1.7–14.8)	0.32 (0.15 to 0.66)		2.86 (0.95 to 8.55)	

[a] *P* values in bold type are significant. MPA = moderate-intensity physical activity; RGM = ratio of geometric means.
[b] *P* value for the interaction of the variable with time.

Figure 1.
Time spent in sedentary behavior and physical activity at both time points.