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Predicting objective physical activity from a clinical performance-based test in patients with hip fracture

Graduate thesis in Medicine

Supervisor: Lars Gunnar Johnsen, Kristin Taraldsen

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Abstract

Background/aim: Older adults who sustain a hip fracture are at increased risk of becoming more inactive and reduce their mobility and independence in daily life. In this study we aimed to evaluate if a clinical performance-based test of lower extremity function, the Short Physical Performance Battery, could be used to predict patients' everyday physical activity, collected by use of accelerometer-based body-worn sensors in daily life.

Methods: We used data from the Eva-Hip Study, where community-dwelling persons at 70 years or older with a hip fracture were included if they were able to walk 10 meters prior to the fracture. Assessments were performed at 4, 6 and 12 months after the surgery. Lower limb physical function was assessed by use of the Short Physical Performance Battery (SPPB), ranging from 0-12, with 12 as the best score. Data on physical activity (time spent in upright position) was collected by accelerometer-based body-worn sensors over a period of minimum 4 days. We used the Spearman correlation method followed by linear mixed models to evaluate whether the SPPB could predict physical activity.

Results: In total, 143 participants were included (77% women, mean age 83.3 ± 6.1 yrs). Spearman correlation indicated that there was a statistically significant moderately positive association between the SPPB score and time spent upright at 4, 6 and 12 months. Results from our linear mixed model showed an increase of 13 minutes spent upright per incremental increase of SPPB, with a significant random intercept for subjects.

Conclusion: This study provided new knowledge about the relationship between physical function and physical activity, and the predictive value of the performance-based clinical test of SPPB on everyday physical activity in hip fracture patients. The relationship is moderate; hence our findings implies that physical activity might be inferred by SPPB to some degree, but the test does not serve as an absolute substitute.

Keywords: accelerometer; SPPB; aging; exercise; gait; hip fracture

Sammendrag

Bakgrunn/mål: Eldre hoftebruddpasienter har økt risiko for å bli mindre aktive, i tillegg til å oppleve redusert mobilitet og uavhengighet i det daglige liv. I denne studien tok vi sikte på å evaluere om en klinisk ytelsesbasert test av nedre ekstremitetsfunksjon, Short Physical Performance Battery, kan brukes til å forutsi pasienters daglige fysiske aktivitet, hvilket ble innsamlet ved bruk av akselerometerbaserte kroppsbårne sensorer i dagliglivet.

Metoder: Vi brukte data fra Eva-Hip-studien, der ikke-institusjonaliserte hoftebruddpasienter på 70 år eller eldre ble inkludert hvis de klarte å gå 10 meter før bruddet. Målingene ble utført 4, 6 og 12 måneder postoperativt. Fysisk funksjon ble evaluert ved bruk av Short Physical Performance Battery (SPPB), som går fra 0 til 12, der 12 er den beste poengsummen. Data om fysisk aktivitet (tidsbruk i oppreist stilling) ble samlet inn av akselerometerbaserte kroppsbårne sensorer over en periode på minimum 4 dager. Vi brukte Spearman-korrelasjonsmetode etterfulgt av lineære blandede effekt-modeller (linear mixed models) for å evaluere hvorvidt SPPB kunne predikere fysisk aktivitet.

Resultater: Totalt ble 143 deltagere inkludert (77% kvinner, gjennomsnittsalder 83,3 ± 6,1 år). Spearman-korrelasjon indikerte at det var en statistisk signifikant moderat positiv assosiasjon mellom SPPB-poengsum og tidsbruk i oppreist stilling etter 4, 6 og 12 måneder. Resultatene fra vår lineære blandede effekt-modell viste en økning på 13 minutter i oppreist stilling per trinnvise økning av SPPB, med et signifikant random skjæringspunkt for deltagere.

Konklusjon: Denne studien ga ny kunnskap om sammenhengen mellom fysisk funksjon og fysisk aktivitet, og den prediktive verdien av den ytelsesbaserte kliniske testen SPPB på daglig fysisk aktivitet hos hoftebruddpasienter. Assosiasjonen er moderat; dermed impliserer funnene våre at fysisk aktivitet kan deduseres av SPPB til en viss grad, dog fungerer ikke testen som en fullverdig erstatning.

Introduction

The inverting aging pyramid and the concomitant increase in life expectancy results in an increasing number of hip fractures worldwide[1,2]. From the total of 9-10.000 Norwegians who sustain a hip fracture each year, less than half of the patients regain the same level of physical function as before the fracture, defined as a loss in the ability to perform both basic and instrumental activities of daily living. Thus, the ability to live an active and independent life and maintain a home-living could be reduced, eventually putting a financial burden on society.

Recovery of physical function has been evaluated and studied from different angles[3], hence physical function has been conceptualized not only as activities of daily living (ADL) and muscle strength and grip, but also as clinical performance-based tests, on which a substantial component of knowledge about physical function following a hip fracture is based[4-10]. From these physical tests, the Short Physical Performance Battery (SPPB) is frequently used as an outcome measure for the effect of new treatment methods and interventions[11-14].

It is hypothesized that the performance-based outcomes are generalizable to other aspects of the patient's life, such as everyday physical activity. Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure[15]. As well as being a determinant for independence and thereby contributing to successful aging[16], a lack of physical activity has been identified as the fourth leading risk factor for global mortality[17]. In addition, physical activity seems to be one of the most important factors involved in rehabilitation or prevention of functional decline in older adults[18]. Optimizing physical activity as part of successful aging may be a part of the solution to the major challenges that population aging poses. Hence the facet of physical activity is useful to gain information about by utilization of reliable and available methods.

New technologies such as wearable digital sensors allow us to measure physical activity accurately in people’s everyday life. However, today the extent of performance-based tests surpasses the availability of advanced sensors able to measure physical activity throughout the day. Thus, evidence on the relationship between the results from clinical performance-based tests and the patient’s everyday physical activity measured by sensors might be of great interest and is yet to be clarified in the literature.

The SPPB is a commonly used performance-based test to evaluate physical function in older adults. The test originates from a major US study of elderly over the age of 65, the EPESE study, and has later been used in various disciplines. SPPB is widely used to identify the physical function of hip fracture patients[11,19-22]. In addition the test has been shown to have good predictability for death and admission to nursing home[23], future functional decline and increased need for help[24], hospitalization[25] and re-hospitalization[26]. Also it has proven to be suitable for use in hospitals for acutely ill elderly[27], as a screening test in primary health care[28] and for home-dwelling elderly[29]. Because of the wide use of SPPB in national and international studies, it may be of interest to gain knowledge of the relationship between SPPB and everyday physical activity measured by sensors. Accordingly, the overall aim of this study was to evaluate the relationship between physical function measured by SPPB and everyday physical activity measured by accelerometer-based body-worn sensors in hip fracture patients. We hypothesized that 1) SPPB would show a positive correlation with everyday physical activity as measured by the sensors and 2) that if a change in SPPB leads to a change in everyday activity, the effect will be the same over all measuring points. Thereby, we addressed the following research questions:

1. Is physical function measured by SPPB related to everyday physical activity in older adult hip-fracture patients, and what is the strength of this relationship?
2. Does SPPB have an effect on everyday physical activity in older adult hip-fracture patients, and what is the effect?
3. If there is an effect of SPPB on everyday physical activity, will it be consistent over all measuring points?

Methods

Design

The material for this study is extracted from the preceding Eva-Hip study. This study used a retrospective study design, primarily utilizing data of SPPB and physical activity measured by sensors continuously for four days.

Study setting

Patients in the preceding study were recruited between February 2011 and February 2013 at St. Olavs hospital, Trondheim University Hospital; followed by randomization and intervention completed in June 2013, and the last follow-up conducted in March 2014. Participants in the preceding study were 4 months postoperatively randomized to either a task-specific, home-based exercise program provided by physiotherapists or to standard training procedures.

Participants

We included 143 hip-fracture patients that were community-dwelling in Trondheim municipality prior to the fracture, 70 years or older, diagnosed and operated for intracapsular or extracapsular hip fractures (ICD-10 S72.0-S72.2), and identified by experienced physiotherapists by use of hospital admission lists. Exclusion criteria were pathological fracture, less than 3-months life expectancy, inability to walk 10 m (with or without walking aids) before the fracture, participation in conflicting research projects, or if the participant after a medical examination were shown to have contraindications for training (unstable medical condition) or were bedridden. Further, participants that did not have measurements for neither the SPPB test nor the sensors at one or more time points were not included in the analysis for that specific time points.

Assessments and Measures

During the follow-up period, assessments of physical function (SPPB) and sensor recordings of everyday physical activity were conducted at 4 months, 6 months and 1 year postoperatively. Basic and instrumental ADL (I-ADL) was assessed by the Barthel Index[30] and the Nottingham Extended I-ADL Scale[31]. Cognitive function was evaluated by the Mini-Mental State Examination[32] and the Clinical Dementia Rating (CDR) Scale[33], and depression by the Geriatric Depression Scale[34]. All assessments were conducted by two experienced physiotherapists.

Physical function. We used the SPPB[23] to assess lower-extremity physical function. The SPPB is a performance-based test that consists of three components: standing balance, gait speed and chair rise. The test has been found to be both valid and reliable for assessing physical function amongst older adults[35]. Testing begins with the balance component, which consists of three tasks of increasing difficulty i.e. side-by-side stand, semi-tandem stand, and tandem stand. Gait speed was calculated over a 4-m walkway and at the patient's usual pace. Finally, time to rise up and sit down on a chair 5 times was measured among those patients able to complete 1 chair rise without the use of hands. Each component is scored between 0 and 4, leaving a best score of 12.

Everyday physical activity. We used single-axis accelerometer-based sensors (activPAL, PAL Technologies Itd, Glasgow, UK) to measure physical activity continuously for four days. ActivPAL sensors were attached to the patients' non-affected thighs with waterproof plastics. It has previously been shown that the activPAL sensor system provides good validity for postures and transitions compared to video observations in older adults with impaired walking ability, including hip fracture patients[36]. The outcome measure we used was the mean time in upright (walking and standing) position, denoted as Uptime per day (24 hours).

Statistical analysis

Demographic data were summarized as mean and standard deviation (SD) for continuous data and counts and percentages for categorical data. First, scatter plots were used to assess ceiling/floor effects visually and to get an overall view of any possible associations. Secondly, we used the non-parametric Spearman correlation test to explore and assess the correlation between SPPB and time spent upright at the different time points. Finally, to assess the changes in time spent upright predicted by SPPB, we used linear mixed models (LMM) with time spent upright as a dependent variable. The reason for choosing LLM, was that we had data in a hierarchy of levels in terms of repeated, correlated measurements occurring among the lower level units for each upper level unit (participants). We designed the model to allow a random subject-specific intercept for participants (to account for between-subject differences that induce correlation among scores for repeated measures) and further added SPPB as a covariate and point of time for follow-up as a factor, both as fixed effects. As well as adding SPPB and time for follow-up as main effects in the model, we included an interaction term between the two latter. Model selection included checking for significant interaction among our fixed effects and checking the necessity of including the random intercept. Normality of residuals was assessed by visual inspection of Q-Q plots and adhering histogram to check for violations of the normality assumption. There was a slight deviation from normality, but after conducting an analogous model with a square-root transformation of time spent upright and checking normality tests, we considered our original model to be applicable on the basis of similar results. Two-tailed p-values less than 0.05 were considered statistically significant, and 95% confidence intervals (CI) are reported where relevant. Formal adjustment for multiple testing was included by Bonferroni correction. We used IBM Statistics SPSS 25.0 software to perform the analyses.

Results

Participants

We acutely screened 822 hip fracture patients, and from 223 potential participants, 44 died or declined further participation before baseline testing at 4 months. Another 36 were excluded or not included after testing at 4 months, see Flow chart (Figure 1) for details. One hundred and forty-three participants were included in the study. Participant characteristics and baseline variables are presented in Table 1.

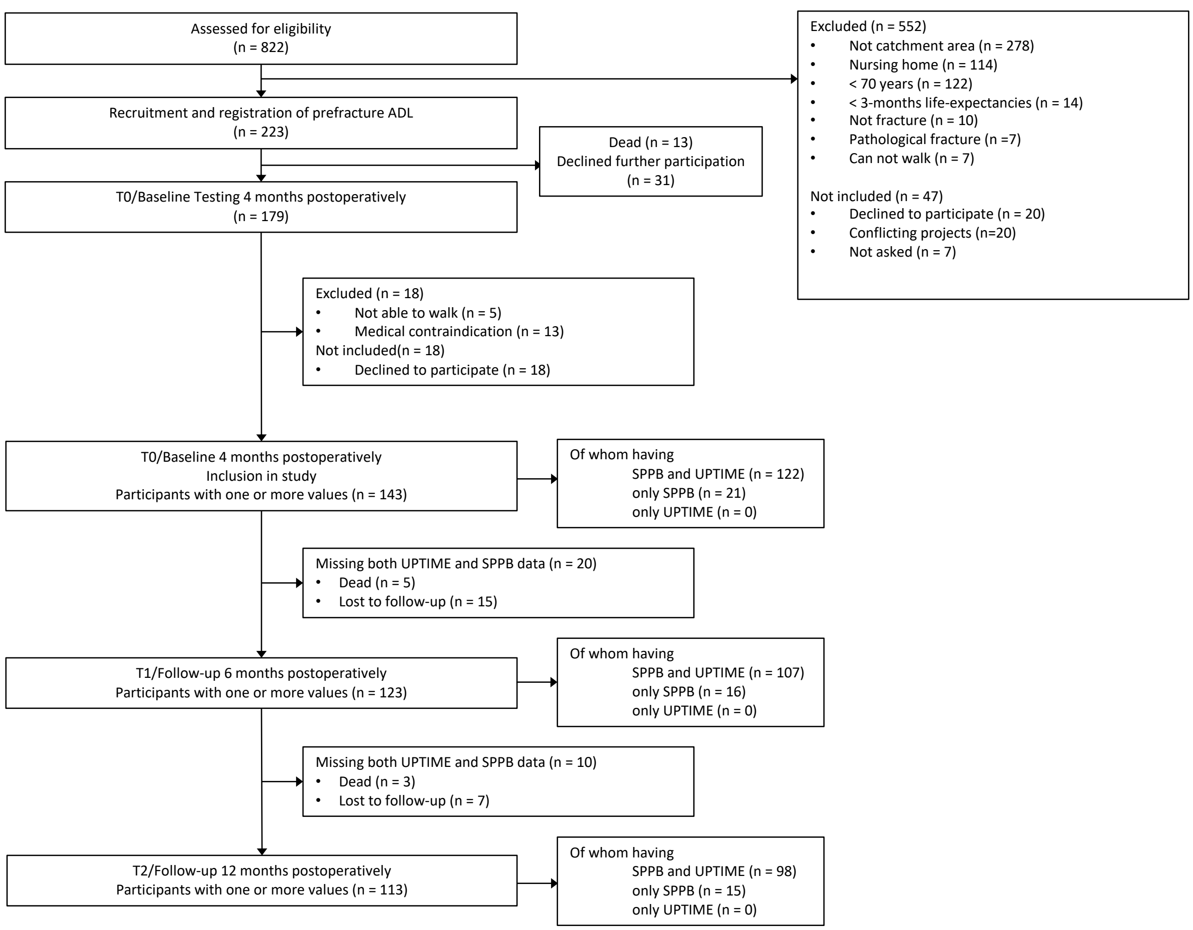

Figure 1 Flow chart

Table 1 Participant characteristics at 4 months after surgery (n = 143)

Age, mean (SD)	83.3 (6.1)	
Female sex, n (%)	99 (69%)	
Fracture (surgery)		
Intracapsular, n (%) (arthroplasty, n)	83 (58%) (67/83)	
Extracapsular, n (%)	60 (42%)	
Use of mobility aid or assistance for walking		
Use of rollator, n (%)	27 (19%)	
Baseline clinical characteristics	*n*	*Median (IQR)*
Performance based and self-reported scales		
Mini-Mental State Examination (0-30)	141	26 (7)
Clinical Dementia Rate (sum of boxes, 0-18)	140	0 (3)
Geriatric Depression Scale, (Short Form, 0-15)	136	3 (4)
Barthel Index (0-20)	135	18 (4)
Nottingham E-ADL (0-66)	143	37 (31)
Short Physical Performance Battery (SPPB, 0-12)	143	4 (4)
Baseline activity monitoring	*n*	*Median (IQR)*
Upright time (min/day)	122	218.5 (201.4)

Relationship between physical function and physical activity at 4, 6 and 12 months postoperatively.

From the Spearman correlation we found that there was a statistically significant, moderately positive association between SPPB and uptime at 4 months ($r_s(122) = .469$, $p < .001$), 6 months ($r_s(107) = .460$, $p < .001$) and 12 months ($r_s(98) = .405$, $p < .001$), with a few potential outliers in the data. Results at 4 months (bottom), 6 months (middle) and 12 months (top) are presented in Figure 2. Participants with higher values of SPPB tended to have higher values of uptime. Over the follow-up period, the sample size available for correlation tests decreased from 122 to 107 to 98 at respectively 4, 6 and 12 months due to missing values.

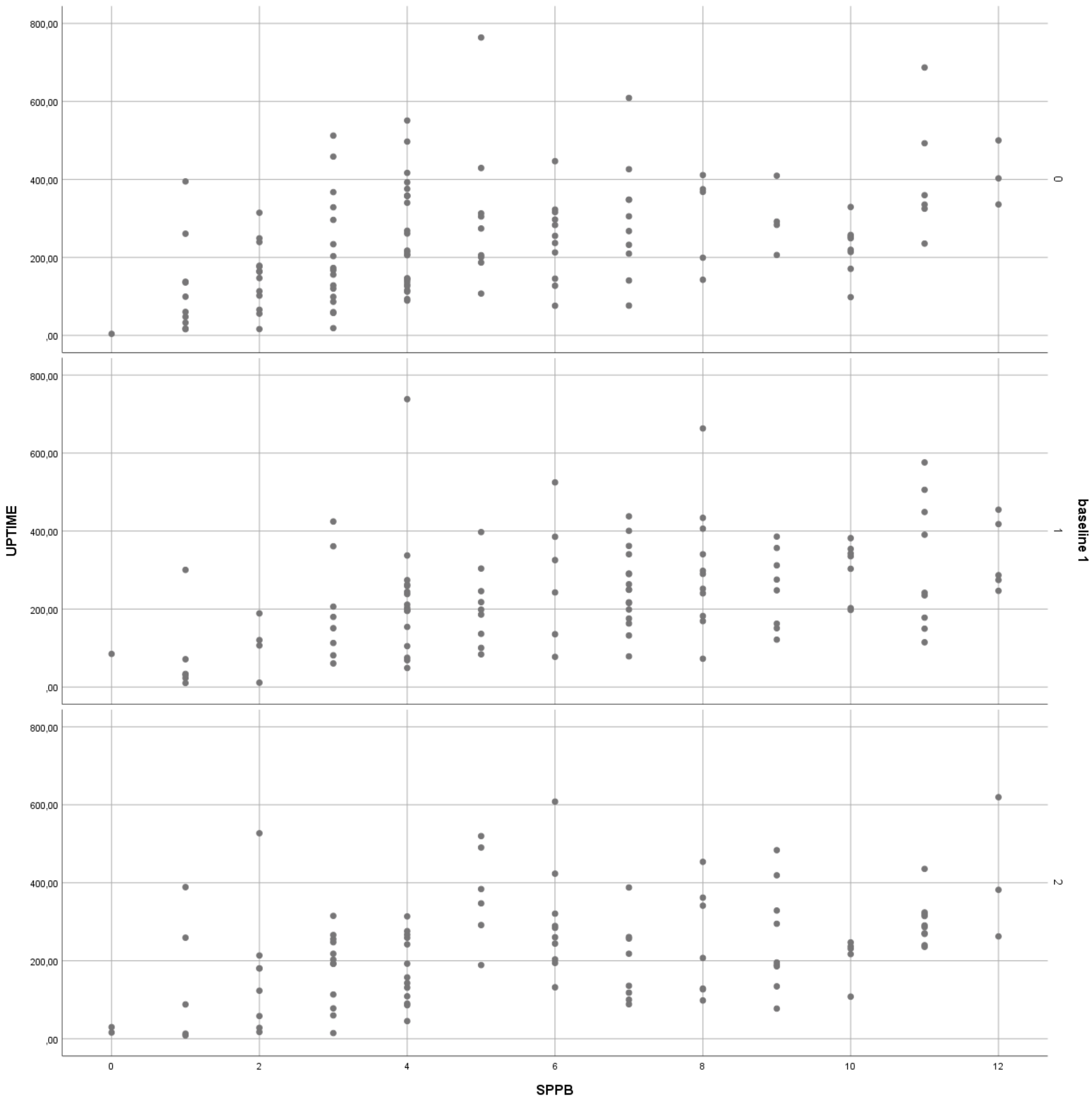

Figure 2 Scatter plot visualizing the relationship between SPPB and Uptime at 4, 6 and 12 months

The effect on physical activity by an incremental increase in SPPB.

For the LMM analysis, the interaction term between SPPB and time for follow-up was shown to be non-significant ($p = .829$), therefore we removed this explanatory variable from the analysis. Results from the final LMM analysis (Table 2) showed an increase of 13.1 units (i.e. minutes) uptime per point increase in SPPB score ($t = 6.27$, $p < .001$, 95% CI [8.96, 17.16]). Our random intercept had a value of 177.1 ($t = 11.45$, $p < 0.001$, 95% CI [146.69, 207.60]) at the baseline value of 4 months postoperatively. Time point affected SPPB, decreasing the intercept by respectively -15.9 (t = -2.32, p = .021, CI [-29.49, -2.41] and -26.0 (t = -3.77, p < 0.001, 95% CI [-39.54, -12.37]) for 6 and 12 months. The intraclass correlation coefficient (ICC) was .859. We also conducted an inverse LMM analysis with SPPB as a dependent variable (attachment).

Table 2 Estimates of fixed effects for the LMM regression with Uptime as a dependent variable

Parameter	Coefficient	95% CI	p-value
Intercept	177.14	146.69, 207.60	< 0.001
[Time_2=0] (12 months)	-25.95	-39.54, -12.39	< 0.001
[Time_2=1] (6 months)	-15.95	-29.49, -2.41	.021
[Time_2=2] (4 months)	0[a]	.	.
SPPB score	13.06	8.96, 17.16	< 0.001

a. This parameter is set as reference

Discussion

The aim of the present study was to assess the relationship between the SPPB test of physical function and the everyday physical activity data measured by accelerometer-based body-worn activPAL sensors in hip fracture patients aged 70 and older. Our results corroborate evidence of a relationship between the two methods of measuring physical function with a performance-based test and physical activity with accelerometer-based body-worn sensors, thus supporting our hypotheses. We found that there was a significant association between the SPPB score and time spent upright in our sample of older adults, although the strength of the correlation was moderate. This finding was as expected when considering other factors might affect physical activity than physical function and vice versa.

The statistically significant moderately positive correlation between SPPB and uptime was found at all time points, which supports our first hypothesis. Also, the strength of the correlation was mainly consistent over all time points. Furthermore, we also found evidence of an effect of SPPB on time spent upright, with a value of 13.1 minutes increase in time spent upright per point increase in SPPB. The interaction term was non-significant, which can be interpreted as there being no effect of the different time points on the association between our variables. This is consistent with our second hypothesis. Further, a high degree of reliability was found between SPPB and uptime measurements represented by the high ICC value, thus the actual measurements have a small degree of variance around the personal best-fit line for each subject.

As is the case with the correlation methods, the authors acknowledge that there are other variables, such as disease, disability and age, that also may affect engagement in physical activity and physical function of the participants, as well as the relationship between the two. Considering that the overlapping relationship between the two variables is valid, but not total, one might argue that one measure cannot substitute the other completely.

In our linear mixed model, we used uptime as a dependent variable. However, drawing a causal relationship between the clinical parameter and the sensor registrations is not straightforward. It is possible to reverse this relationship, considering physical function to be a consequence of daily habitual activity. We also conducted an inverse LMM analysis with SPPB as a dependent variable, which showed that time spent upright also could be used to predict physical function. Thus, it is important to keep this plausible bilateral relationship in mind when interpreting the results from the linear mixed model.

The part of the population aged 70 and older is rapidly growing and the information achieved through this study may be used for considering areas for future health funding aimed at augmenting the functional capacity in older adults. The findings in this study may also serve a part in future validations of SPPB as a tool of assessing physical activity in older adults.

Our study has some limitations. The sensors used in this study lack the ability to discriminate between active and passive mobilization, i.e. if participants are self-initializing movement or helped to move by another person. Secondly, our study sample is derived from the preceding Eva-hip study[10], in which participants were randomized to either a standard group with routine treatment and rehabilitation or an intervention group receiving additional exercise sessions. This could influence both length and frequency of mobilization, as a result of active mobilization naturally being more tiring for the participants. Still, mobilization was only performed 2 times per week in the first 10 weeks, and the overall amount of physiotherapy was relatively low throughout the year. Finally, although the Eva-hip study was designed to have high external validity, the high prevalence of frailty in this diverse population might differ from the representation in our sample, due to the exclusion criteria. It is a possibility that the participants in our sample had both a higher physical function and physical activity, since the preceding material only included community-dwelling older adults, excluding those living in institutions. In addition, there was some evidence that those who were lost to follow-up had lower gait speed at baseline than those not lost to follow-up[10]. Still, the preceding study offered a home-based program which allowed including vulnerable persons.

Strengths of our study include our method of measuring physical activity by validated objective sensors. Traditionally, physical activity has been assessed through questionnaires. By using activPAL sensors, we avoid the risk of recall bias that is associated with questionnaires, especially in some older subjects where recall may be generally poor[37]. In addition, we avert the problem of generic instruments assessing solely leisure time physical activity, not including activities performed as part of daily life activities[38-40]. Since a substantial part of physical activity in older persons may be performed as daily life activities, this facet is important to include. Further, activity assessed through objective measurement methods is neither age nor culture specific. The latter would have narrowed the generalizability across countries. Also, subjective measures of physical activity overestimate activity levels severely[38,40,41].

In addition to time spent upright measured by activPAL sensors, there is a rich variety in methods used for data collection and analysis as well as in reported variables, and different aspects of physical activity can be described[38]. Since the activPAL sensors shows no misclassification of activities in sedentary versus upright positions when compared to video observations[36], the measure of time spent upright can be considered accurately registered in this sample of hip fracture patients. Also, time in an upright position is likely to be a relevant measure of activity as older adults with impaired function spend most active periods performing indoor activities of daily living[36].

Lastly, SPPB is a common and well-established objective assessment tool for evaluating lower extremity function in older adults, and is previously tested for validity and reliability[42]. SPPB was measured by two experienced physiotherapists, which we believe ensured high inter-rater reliability and consistency of the measures.

Conclusion

We found a moderate relationship between measures of physical function by SPPB and everyday physical activity by accelerometer-based body-worn sensors, but not a complete overlap. This study examines the idea that a performance-based measure of physical function might be used to some degree as an outcome measure to infer knowledge about physical activity, but implies that it does not serve as an absolute substitute. Our findings may be used in future research examining these facets in older adults.

Abbreviations

CI: Confidence Interval; LMM: Linear Mixed Model; SD: Standard Deviation; ICC: Intraclass Correlation Coefficient; EPESE: Established Population for the Epidemiological Study of the Elderly; ICD: International Classification of Diseases; SPPB: Short Physical Performance Battery

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Availability of data and materials

Due to Norwegian regulations and conditions for informed consent, the dataset is not publicly available

Authors contributions

KT and LGJ planned the study. KT and her collaborators in the Eva-hip study recruited and tested the participants. KT, LGJ and HAR processed the data, performed the statistics by analyzing the data and interpreted the results. The manuscript was written by HAR and co-edited by KT and LGJ. All authors critically reviewed and approved the manuscript.

Authors' information

KT (PhD) works as a physiotherapist at Clinical Services, Trondheim University hospital and as a postdoctoral researcher in the Research Group on Geriatrics, Movement and Stroke (GeMS) at Department of Neuromedicine and Movement Science, NTNU. LGJ (PhD) works as an orthopaedic surgeon at Department of Orthopaedic Surgery and as a researcher at Department of Neuromedicine and Movement Science, NTNU.

Ethics approval and consent to participate

Approval of the study was obtained by the Central Regional Ethics Committee for Medical and Health Research Ethics (REK no. 2010/3265). The test battery consisted of well-known and commonly used assessment tools in older adult populations. Each session at the 4, 6 and 12-months follow up was closely supervised by two experienced physiotherapists, who also secured the participant with manual support if needed. Informed consent from participants were gathered in the preceding eva-hip study. For those not being able to provide informed consent, their next of kin was contacted and asked if they opposed participation. Conducting this study on already gathered data was not considered to potentially affect the participants.

Consent for publication

Not applicable.

Competing interests

On behalf of all authors, the corresponding author states that there is no conflict of interest. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article that could inappropriately influence (bias) the work.

Attachments

Results from the linear mixed model analysis with SPPB as a dependent variable:

Fixed Effects

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	235,162	88,768	,000
Time_2	2	201,395	16,295	,000
UPTIME	1	301,463	44,071	,000

a. Dependent Variable: SPPB.

Estimates of Fixed Effects[a]

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Intercept	3,066373	,404104	251,519	7,588	,000	2,270514	3,862232
[Time_2=0]	,747787	,184545	204,003	4,052	,000	,383927	1,111647
[Time_2=1]	,969033	,178113	200,221	5,441	,000	,617815	1,320250
[Time_2=2]	0[b]	0	.	.	.	.	.
UPTIME	,008575	,001292	301,463	6,639	,000	,006033	,011117

a. Dependent Variable: SPPB.

b. This parameter is set to zero because it is redundant.

Covariance Parameters

Estimates of Covariance Parameters[a]

Parameter	Estimate	Std. Error
Residual	1,651070	,167994
Intercept [subject = ID_EH] Variance	6,522986	,901247

a. Dependent Variable: SPPB.

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