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Quantifying physical functional trajectory in hospitalized older adults using body worn inertial sensors

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ABSTRACT

Acute medical illness requiring hospitalization usually is a critical event in the trajectory leading to disability in older adults. Functional decline frequently occurs during hospitalization, resulting in a loss of Independence in activities of daily living after discharge. The aim of the study was to assess the functional decline in different ADLs of hospitalized elderly patients in an Acute Care for Elderly (ACE) unit incorporating a body-worn inertial sensor and accompanying custom algorithms. 38 hospitalized older adults (age $\geq$ 75) were included. The patients completed different functional tasks, including a balance test, Gait Velocity Test (GVT), verbal and arithmetic dual-task gait, and a sit-to-stand ability test at admission and discharge. Movement-related parameters were acquired from a unique tri-axial inertial sensor unit. Maximal muscle strength and muscle power output endpoints were also assessed. The results indicated that significant improvements ($p < 0.05$) were found at discharge compared with the admission values for gait variability and spatiotemporal parameters in the 4- and 6-meter GVT. These significant gains were also obtained in the verbal GVT. In contrast, a significant reduction was found in the functional status measured with the Barthel Index scale. Regarding to the sit-to-stand ability, lower peak power was observed in the sit-to-stand phase of the task at discharge. In conclusion, inertial sensor unit and our custom, validated, algorithms represent a feasible tool for measuring and monitoring functional trajectory during hospitalization in older adults and they are sensitive to detect differences in movement pattern parameters in different ADLs such as walking and the ability to stand from a seated position.

1. Background

Hospitalization for an acute medical illness is frequently a critical event in the trajectory leading to disability in older people (Fimognari et al., 2017; Gill et al., 2015). Moreover, hospital stay has been shown to be associated with adverse outcomes including functional decline, rehospitalization, nursing home admission and mortality (Boyd et al., 2005; Covinsky et al., 2003; Gill et al., 2009; Laniece et al., 2008). Functional decline commonly occurs during the hospitalization period, leading to a poor health status and more severe disability after discharge (Covinsky et al., 2003). The loss of function cannot simply be attributed to the acute illness that caused the hospital admission but is also the result of extended bed rest, iatrogenic events, and the presence of invasive devices such as in-dwelling catheters, oxygen and intravenous lines during the hospitalization period (King, 2006). Although the patients profile has changed dramatically over the past century and is currently characterized by frailty, disability, multimorbidity and polypharmacy in chronic patients, the hospital care model is stuck in the previous century model, which increases the risk of patients developing avoidable potential adverse consequences associated with hospitalization, such as functional decline and disability (Martinez-Velilla et al., 2016). Therefore, health care should focus on not only the prevention and treatment of acute illness but also on identification functional status as a vital clinical sign in acutely hospitalized old patients.

Different screening tools are available to identify elderly patients at risk of functional decline during hospitalization and after discharge (Hoogerduijn et al., 2007). However, there is currently no "gold standard" for identifying older adults or measuring

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functional decline during hospitalization, so the predictive value of existing screening instruments and prediction models is limited (Lafont et al., 2011). Usually, preadmission and in-hospital functional status and functional trajectory are measured using a basic activities of daily living (ADL) scale and/or instrumental activities (IADL) scale (Hoogerduijn et al., 2007). Although ambulation impairment was recognized as functional complication of prolonged bed rest many years ago (Harper and Lyles, 1988), no study has objectively measured the functional impairments in ADLs including gait pattern or the ability to stand from a seated position associated with hospitalization.

Regarding physical functioning in older adults, gait is an essential component of a patienf́s ability to perform ADL (Berg and Norman, 1996). Yet, assessment of functional capacity during ADLs (e.g., the ability to rise from a chair) is currently limited to performance time measurements, potentially missing important information about the test subtasks. Modern body-fixed sensors based on accelerometers and gyroscopes are powerful tools for assessing functional capacity in clinical practice (Boonstra et al., 2006; Mayagoitia et al., 2002; Mancini et al., 2016). Typically, the spatiotemporal measurements have been performed in laboratories using expensive and complex instruments including accurate optoelectronic systems and force platforms. As a result, inertial sensor units have emerged as an innovative and useful tool for assessing more functional and unplanned human movements.

Thus, the main aim of this research was to examine the functional decline in different ADLs of hospitalized elderly patients in an Acute Care for Elderly (ACE) unit. To that end analysis was performed incorporating a body-worn inertial sensor and accompanying custom algorithms. The secondary aim of the study was to analyze changes in maximal muscle strength and muscle power output during hospital stay. We hypothesized that this new clinical tool could be a feasible instrument in clinical practice and provide meaningful information about the functional decline in ADLs associated with hospitalization in older adults.

2. Methods

2.1. Design

The study was conducted in the ACE of the Department of Geriatrics in a tertiary public hospital (*Complejo Hospitalario de Navarra, Spain*). This Department has 35 beds allocated and is staffed by 8 geriatricians (distributed in the ACU, orthogeriatrics and outpatient consultations). Admissions in the ACE derive mainly from the Accident and Emergency Department, with heart failure, pulmonary and infectious diseases being the main causes of admissions.

The study followed the principles of the Declaration of Helsinki and was approved by the Navarra Clinical Research Ethics Committee, Spain. All patients or their legal representatives provided written consent.

2.2. Participants

The participants were thirty-eight hospitalized older adults (range 76–94 years) recruited within the first 48 h of admission to the ACE by the geriatricians. Later, a trained research assistant conducted a screening interview to determine whether potentially eligible patients met the following inclusion criteria: age $\geq$ 75 years, Barthel index $\geq$60 points, being able to ambulate (with/without assistance), and to communicate and collaborate with the research team. Exclusion criteria included expected length of stay <6 days, very severe cognitive decline (i.e., Global Deterioration Scale score = 7), terminal illness, uncontrolled arrhythmias, acute pulmonary embolism and myocardial infarction, or extremity bone fracture in the past 3 months (Martínez-Velilla et al., 2015).

2.3. End points

2.3.1. Short physical performance battery (SPPB)

The SPPB includes usual walking speed over 4 m, a balance test, and the Five Times Sit to Stand Test (FTSST). The standing balance test required the participants to maintain stances with their feet placed in side-by-side, semi-tandem and full-tandem positions for 10 s each. In the FTSST, participants had to rise five times from a chair with their arms across their chest as quickly as possible. The scores assigned to the performance on each task ranged from 0 to 4 (maximum performance). Participants were classified as "unable to perform" if they were not able to complete the test and if the physician or the participant felt the test was unsafe. Scores of 1–4 points were assigned for each subtask based on timed quartiles that were established previously in a large population study (Guralnik et al., 1994). The sum of three individual categorical scores comprised the final SPPB score (range: 0–12), with higher scores indicating better lower extremity function and better functional capacity.

2.3.2. Six-meter gait velocity test (GVT) and dual-task gait

For the 6-meter GVT, patients were instructed to walk at their self-selected usual pace on a smooth, horizontal walkway. In addition to the habitual GVT, two different dual-task gait tests were performed, the arithmetic GVT and verbal GVT, in which gait velocity was measured while the participants counted backward aloud from 100 down to one or named animals aloud, respectively.

2.3.3. Other functional and muscle performance end points

The functional capacity of the patients was also measured using the Barthel Index score (ranges from 0 (severe functional dependence) to 100 (functional independence). The first 48 h of admission participants were asked about the functional status two weeks prior to admission. Furthermore, the maximal dynamic strength and muscle power output of the legs were assessed upon admission and discharge. Maximal dynamic strength was measured using the 1-repetition maximum test (1RM) on the bilateral leg press exercise (Exercycle S.L.; BHGroup, Vitoria, Spain). After 1RM values were determined, the participants performed ten repetitions at maximal velocity at intensities of 50% of 1RM to determine the maximum power (W). The power was recorded by connecting a velocity transducer to the force plates (T-Force System, Ergotech, Murcia, Spain).

2.4. Instrumentation

The GVT (including dual-tasks) and FTSST were performed wearing an inertial Orientation Tracker MTx (XSENS; Xsens Technologies B.V., Enschede, Netherlands) attached over the lumbar spine (L3) to record the acceleration data. The Orientation Tracker MTx provides drift-free 3-dimensional (3D) orientation and kinematic data: 3D acceleration, 3D rate of turn (rate gyro) and 3D earth magnetic field data. Before starting the measurement, the inertial sensor unit is calibrated and the sensor axes are aligned with anatomical directions. The acceleration signal consists of gravitational and inertial components. The inertial sensor unit registers gravity as a static vertical component, in addition to the dynamic acceleration caused by changes in velocity during locomotion. The gravity component must be subtracted to estimate the dynamic acceleration. The 3D orientation data provide the position of the inertial unit with respect to the gravitational vector, allowing the calculation of the inertial component for each axis.

The gravitational constant was estimated by leaving the inertial sensor unit still on a flat surface for two seconds. The sampling rate of these recorded data was 100 Hz.

2.4.1. Movement-related parameters

The gait pattern parameters measured during the 4-m walking test, the GVT and the dual-task gait, which are related to gait disorders in frail older adults (Martinez-Ramirez et al., 2015; Martinikorena et al., 2016), were as follows: step and stride regularity, gait symmetry, gait variability, the signal root mean square (RMS) value, and approximate entropy (ApEn). All these measurements were obtained for three directions: anterior-posterior (AP), medio-lateral (ML), and vertical (V). The validity of an evaluation index of the AP, ML, and V directions of trunk acceleration compared with traditional force platforms during walking has been previously investigated (Osaka et al., 2013).

Chair stand ability from a seated position was analyzed based on the methodological process described in previous studies (Millor et al., 2013a; Millor et al., 2014). The FTSST was divided into three different phases to assess the parameters of each sit-stand-sit cycle (i.e., impulse "Imp", sit-to-stand "SiSt", and stand-to-sit "StSi"). Once these three different phases were identified, the orientation range in the Imp phase, and the maximum linear acceleration, maximum linear velocity, peak of power and total impulse value of the SiSt and StSi phases were analyzed. Finally, the number of cycles completed during the task and the total duration were also recorded.

2.5. Statistical analysis

Means and standard error (SE) were reported for continuous measures and percentages were reported for categorical measures. The mean within-subject differences in each task during the hospitalization period were tested for statistical significance using two-sided paired t-tests and the Wilcoxon signed rank test for non-parametric statistics. A p value of < 0.05 was considered statistically significant. All data sets passed the Shapiro-Wilk normality test. MATLAB and Statistics Toolbox Release 2013b (Mathworks, Inc., Natick, MA) software was used for the data analysis and IBM-SPSS v20 software for the statistical analysis.

3. Results

Baseline demographic and clinical characteristics of the participants are presented in Table 1.

Table 1
Baseline characteristics of the participants.

	Hospitalized older adults (n = 38)
Age (years)	86 ± 4.9
Sex, men/women (n)	21/17
Height (cm)	155.6 ± 9.3
Body mass (kg)	66.7 ± 15.7
BMI (kg/m^2)	26.4 ± 6.8
Education, n (%)	
<12 years	5 (13)
≥12 years	33 (87)
Barthel Index score (points)	84.4 ± 16.4
Falls last year, n (%)	
0	18 (47)
1–2	13 (34)
>2	7 (19)
Cognition (MMSE score), n (%)	
30–27	6 (16)
26–24	13 (34)
<24	15 (39)
No data available	4 (11)
CIRS-G	12.8 ± 4.3
Admission reason, n (%)	
Cardiovascular	11 (29)
Pulmonary	11 (29)
Infectious	2 (5)
Neurological	2 (5)
Gastrointestinal	2 (5)
Other	10 (27)

Data are presented as mean ± standard deviation unless otherwise indicated. BMI, Body Mass Index; CIRS-G, Cumulative Illness Rating Scale for Geriatrics; GDS, Geriatric Depression Scale; MMSE, Mini Mental State Examination.

During the hospitalization period, there were no significant differences between the admission and discharge results for the SPPB total score (4.84 and 4.95, respectively; p = 0.727). Furthermore, no differences were found between the admission and discharge scores on the balance task (1.94 and 2.11, p = 0.362), 4-m walking test (1.53 and 1.61, p = 0.633) and FTSST (1.29 and 1.18, p = 0.488).

Several differences were found in the 4-m walking test between the two tests performed during the hospitalization period. Fig. 1 shows the gait parameters measured in the AP, ML, and V directions at admission and discharge. The older adults showed significant improvements at discharge compared with the admission results for step regularity in the AP (p < 0.01) and V (p < 0.01) directions, and significant increases were observed in stride regularity in the AP (p < 0.05) and V (p < 0.01) trunk accelerations. Moreover, significant improvements were found in symmetry in the AP (p < 0.05) direction and in the coefficient of variation (CoV) of step time (p < 0.05) at discharge.

For the FTSST, the hospitalized patients had a significantly lower peak of power in the SiSt phase of the task at discharge compared with the admission values (p < 0.05). No significant differences were found in the other temporal and kinematic parameters analyzed (Table 2).

The results obtained at admission and discharge for the GVT and dual-task gait are presented in the Table 3. As in the 4-m walking test, significant improvements were found at discharge on the habitual GVT for step and stride regularity in the AP (p < 0.05) direction and for the CoV of step time (p < 0.05). Furthermore, significant differences were observed for the ApEn in the ML (p < 0.05) and V (p < 0.05) directions at discharge compared with the admission baseline. Regarding the verbal GVT, the older adults had significant gains in step regularity in the V (p < 0.01) direction and in stride regularity in the AP (p < 0.05) and V (p < 0.05) directions at the end of hospitalization compared with the admission value. For the arithmetic GVT, no significant differences were observed during hospitalization.

Regarding functional capacity, the hospitalized patients had significantly lower scores on the Barthel Index at discharge compared with two weeks prior to admission (p < 0.01). No significant differences were found in the maximal muscle strength and muscle power output endpoints (Table 4).

4. Discussion

The main findings of this study indicate that acutely hospitalized older adults were able to maintain several outcomes related with lower limbs muscle strength, balance and gait velocity during hospitalization (measured with SPPB total score, balance tasks, FTSST, GVT and dual-task gait tests), and demonstrated improvements in the gait pattern on the last day of hospitalization compared with those recorded at admission. In contrast, lower functional capacity assessed with the Barthel Index was observed at discharge compared with two weeks prior to admission. To our knowledge, this is the first study in which an inertial sensor unit and accompanying custom algorithms were used to objectively assess the functional trajectory of older medical patients during hospitalization in ADLs such as walking and rising from a

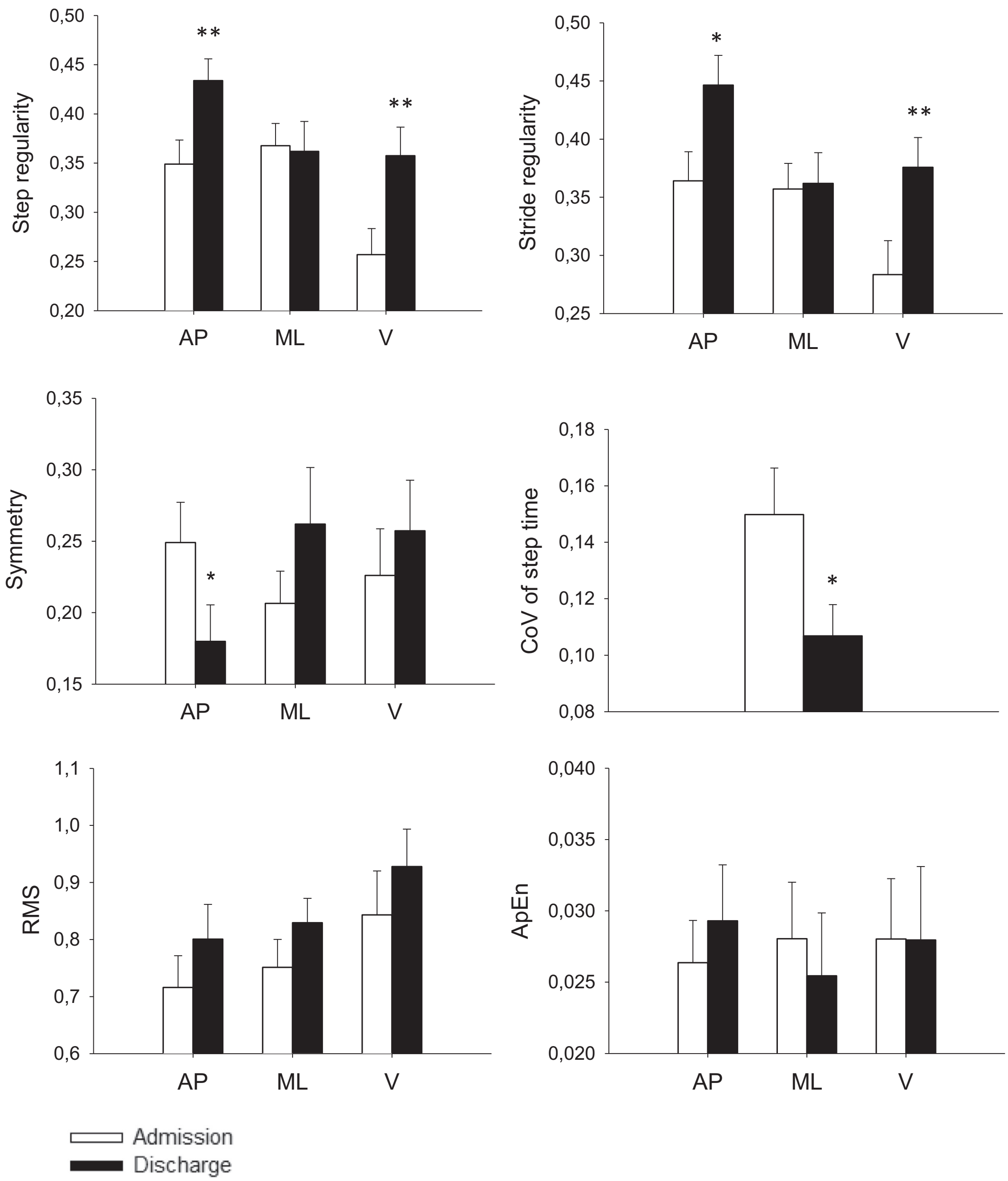

Fig. 1. Gait pattern parameters analyzed in the 4-meter walking test at admission and discharge for anterior-posterior (AP), medio-lateral (ML) and vertical (V) directions. $^{**}p < 0.01$ $^{*}p < 0.05$. Error bar represent standard error.

Table 2
Temporal and movement-related parameters measured in the Five Times Sit to Stand Test (FTSST) at admission and discharge in older adults.

	Nb. of cycles (n)	Time (s)	Imp. phase	SiSt phase				StSi phase			
			Orientation range (°)	Max. Acel. (m/s^2)	Max. Veloc. (m/s)	Peak Power (W/kg)	Imp. TOT. (Ns/Kg)	Max. Acel. (m/s^2)	Max. Veloc. (m/s)	Peak Power (W/kg)	Imp. TOT. (Ns/Kg)
Admission	3.82 ± 0.33	18.54 ± 1.90	17.21 ± 3.04	2.82 ± 0.34	0.42 ± 0.03	3.80 ± 0.39	0.99 ± 0.06	3.86 ± 0.50	0.47 ± 0.03	4.81 ± 0.54	0.95 ± 0.05
Discharge	3.58 ± 0.34	18.55 ± 2.06	13.64 ± 1.95	2.25 ± 0.20	0.40 ± 0.03	2.82 ± 0.52*	1.03 ± 0.09	3.41 ± 0.58	0.49 ± 0.03	3.92 ± 0.81	1.00 ± 0.08
Change	−0.24 ± 0.30	0.01 ± 1.46	−3.57 ± 3.18	−0.57 ± 0.26	−0.02 ± 0.04	−0.98 ± 0.46	0.04 ± 0.10	−0.45 ± 0.43	0.02 ± 0.02	0.89 ± 0.63	0.06 ± 0.07

Values are mean ± SE. $^{*}p < 0.05$. Imp, Impulse; Imp. TOT, Total impulse; Max. Acel, Maximum linear acceleration; Max. Veloc, Maximum linear velocity; Nb, Number; SiSt, Sit to Stand; StSi, Stand To Sit. Orientation range was measured in the anterior-posterior axis; other kinematic variables were obtained for vertical direction.

chair. In addition, a unique finding was that the inertial sensor unit and accompanying custom algorithms were a sensitive method for detecting significant differences between the physical performance of ADLs at admission and discharge.

Surprisingly, short-term hospitalization has no significant impact on function (i.e. SPPB score and GVT, including the dual-tasks) in frail older adults. Our results do not agree with many studies in which hospitalization and bed rest in the elderly were

Table 3
Cognitive score, gait velocity and gait pattern parameters during the habitual, verbal and arithmetic walking tests at admission and discharge in hospitalized elderly.

	GVTh				GVTv				GVTa			
	Admission	Discharge	Change	*p*	Admission	Discharge	Change	*p*	Admission	Discharge	Change	*p*
Cognitive Score					5 ± 0.45	6 ± 0.61	0.4 ± 0.46	0.652	11 ± 0.95	12 ± 1.16	1 ± 1.08	0.772
Gait velocity (m/s)	0.44 ± 0.04	0.45 ± 0.03	0.01 ± 0.02	0.219	0.36 ± 0.03	0.37 ± 0.03	0.01 ± 0.03	0.809	0.35 ± 0.03	0.36 ± 0.03	0.01 ± 0.02	0.493
Step regularity												
AP	0.29 ± 0.02	0.35 ± 0.02	0.06 ± 0.02	0.016	0.39 ± 0.03	0.43 ± 0.03	0.04 ± 0.04	0.397	0.30 ± 0.02	0.35 ± 0.02	0.05 ± 0.03	0.063
ML	0.27 ± 0.02	0.30 ± 0.03	0.03 ± 0.03	0.322	0.36 ± 0.03	0.38 ± 0.03	0.02 ± 0.04	0.652	0.34 ± 0.03	0.31 ± 0.03	−0.02 ± 0.03	0.339
V	0.25 ± 0.03	0.26 ± 0.02	0.01 ± 0.02	0.321	0.22 ± 0.03	0.29 ± 0.03	0.07 ± 0.03	0.008	0.23 ± 0.02	0.21 ± 0.02	−0.02 ± 0.02	0.417
Stride regularity												
AP	0.28 ± 0.02	0.33 ± 0.02	0.05 ± 0.02	0.048	0.35 ± 0.03	0.42 ± 0.03	0.07 ± 0.03	0.046	0.29 ± 0.02	0.32 ± 0.03	0.02 ± 0.03	0.405
ML	0.24 ± 0.02	0.27 ± 0.02	0.03 ± 0.02	0.130	0.34 ± 0.03	0.38 ± 0.03	0.04 ± 0.04	0.260	0.28 ± 0.02	0.29 ± 0.03	0.01 ± 0.03	0.861
V	0.23 ± 0.02	0.25 ± 0.02	0.02 ± 0.02	0.728	0.22 ± 0.03	0.29 ± 0.03	0.06 ± 0.03	0.031	0.20 ± 0.02	0.20 ± 0.02	0.00 ± 0.02	0.600
Symmetry												
AP	0.28 ± 0.03	0.28 ± 0.03	−0.01 ± 0.04	0.823	0.25 ± 0.04	0.24 ± 0.03	−0.01 ± 0.04	0.840	0.28 ± 0.04	0.32 ± 0.03	0.03 ± 0.05	0.518
ML	0.27 ± 0.03	0.27 ± 0.03	−0.01 ± 0.05	0.796	0.17 ± 0.03	0.19 ± 0.03	0.02 ± 0.04	0.666	0.23 ± 0.03	0.23 ± 0.03	0.01 ± 0.04	0.750
V	0.26 ± 0.03	0.28 ± 0.03	0.02 ± 0.04	0.632	0.26 ± 0.03	0.29 ± 0.04	0.03 ± 0.04	0.473	0.29 ± 0.03	0.27 ± 0.03	−0.02 ± 0.05	0.701
CoV step time	0.21 ± 0.02	0.18 ± 0.01	−0.03 ± 0.02	0.027	0.16 ± 0.02	0.15 ± 0.02	−0.01 ± 0.02	0.638	0.30 ± 0.09	0.22 ± 0.03	−0.08 ± 0.10	0.600
RMS												
AP	0.72 ± 0.06	0.79 ± 0.05	0.07 ± 0.04	0.172	0.67 ± 0.05	0.72 ± 0.05	0.05 ± 0.04	0.337	0.71 ± 0.06	0.72 ± 0.05	0.01 ± 0.04	0.813
ML	0.76 ± 0.05	0.84 ± 0.05	0.07 ± 0.04	0.183	0.73 ± 0.05	0.73 ± 0.04	0.00 ± 0.04	0.953	0.72 ± 0.06	0.72 ± 0.05	0.00 ± 0.04	0.360
V	0.89 ± 0.07	0.97 ± 0.08	0.08 ± 0.06	0.514	0.73 ± 0.07	0.75 ± 0.06	0.02 ± 0.06	0.922	0.77 ± 0.08	0.77 ± 0.07	0.00 ± 0.06	0.797
ApEn												
AP	0.04 ± 0.005	0.03 ± 0.004	−0.01 ± 0.01	0.064	0.03 ± 0.003	0.03 ± 0.003	−0.01 ± 0.01	0.646	0.05 ± 0.02	0.03 ± 0.004	−0.02 ± 0.02	0.861
ML	0.03 ± 0.004	0.02 ± 0.003	−0.01 ± 0.01	0.036	0.03 ± 0.004	0.03 ± 0.004	0.00 ± 0.01	0.583	0.03 ± 0.004	0.03 ± 0.004	0.00 ± 0.01	0.441
V	0.03 ± 0.005	0.02 ± 0.004	−0.01 ± 0.01	0.037	0.03 ± 0.005	0.03 ± 0.004	−0.01 ± 0.01	0.724	0.03 ± 0.005	0.03 ± 0.006	0.00 ± 0.01	0.781

Data are presented as mean ± SE. AP, anterior-posterior; ApEn, Approximate entropy; CoV, Coefficient of variability; GVTh, Gait velocity test habitual; GVTv, Gait velocity test verbal; GVTa, Gait velocity test arithmetic, HR, Harmonic ratio; ML, Medial-lateral; RMS, Root mean square; THD; Total harmonic distortion; V, Vertical.

Table 4
Functional, maximal muscle strength and muscle power output measured before and after the hospitalization in older adults.

	Hospitalization period			p value
	Admission	Discharge	Change	
Functional capacity				
Barthel Index (points)*	83.94 ± 2.85	78.33 ± 3.25	−5.61 ± 2.31	0.008
Leg strength and power				
Bilateral leg press 1RM (kg)	63.98 ± 7.73	63.64 ± 6.74	−0.34 ± 3.51	0.949
PW50 (W)	68.3 ± 10.29	69.89 ± 12.77	1.59 ± 4.77	0.820

Values are mean ± SE.
PW50, leg power at an intensity of 50% of 1RM test.
* Barthel Index admission score was obtained considering the functional capacity two weeks prior to admission.

associated with functional decline (Brown et al., 2004; Covinsky et al., 2003) and loss of muscle strength and aerobic capacity (Kortebein et al., 2008). However, recent evidence has demonstrated similar functional trajectories (De Buyser et al., 2014) and muscle strength characteristics (Bodilsen et al., 2013) in this population. Several factors could explain the results obtained in this study. First, no other studies have analyzed the functional impact of the hospitalization period on older adults using objective and high sensitive movement-related parameters of gait and sit-to-stand ability. Another possible explanation is the extremely poor health status of hospitalized elderly at admission because of acute medical illness. Consequently, patients could improve their functional capacity with better results in ADL with the correct management of their acute disease. In addition, only subjects with a preadmission Barthel Index score ≥60 points were included in this study. Thus, their functional trajectory during hospitalization could differ from that of older adults with worse functional capacity at baseline. The hospital stay for the older adults in our study was between 6 and 9 days. Other studies have also investigated the functional consequences of more prolonged hospitalization periods (Brown et al., 2004; Fimognari et al., 2017) which are associated with functional dependence in hospitalized elderly (Bo et al., 2016; Lafont et al., 2011; Martinez-Velilla et al., 2016). Finally, the older adults were admitted to an acute geriatric ward in which the functional recovery is the main objective to prevent iatrogenic disability (Lafont et al., 2011; Martinez-Velilla et al., 2016). Geriatric ACE have clearly shown better functional results in comparison with conventional care provided in other medical wards (Baztan et al., 2009). These features could explain the significant improvements observed in the gait pattern parameters at discharge compared with the admission values. Such positive findings were also found in the verbal dual-task gait at discharge. In contrast, our patients showed a significant reduction in the Barthel Index score at discharge compared two weeks prior to admission. Functional decline usually begins before admission (Fortinsky et al., 1999) due to acute illness. However, when scales based on subjective self-reports are used at admission, the potential for bias is likely to increase when retrospective information is recruited.

Regarding to the chair stand ability to stand from a seated position, lower peak power was observed in the SiSt phase of the FTSST at the end of hospitalization compared with admission. These findings are interesting, first because skeletal muscle power decreases earlier and faster than muscle strength with advancing age (Izquierdo et al., 1999) and second because muscle power output is more strongly associated than maximal muscle strength with performance on functional tasks in older adults (Cadore and Izquierdo, 2013; Casas-Herrero et al., 2013; Reid and Fielding, 2012).

The present study has some limitations. First, the sample size was small and only older adults with a Barthel Index Score ≥60 points at preadmission were included in the study. These two features made it difficult to generalize the results obtained to the entire hospitalized elderly population. Another possible limitation was that not all the patients were able to complete the study protocol at admission and discharge due to acute medical illness and poor health status. Regarding the gait pattern parameters obtained with the inertial sensor unit, spatial gait data, e.g., step and stride length and width, were not measured. Future studies should consider these data because these parameters are apparently affected by attention-demanding tasks (Grabiner and Troy, 2005).

5. Conclusion

The inertial sensor unit and accompanying custom algorithms seem to be a feasible tool for measuring and monitoring the functional trajectory of older adults during hospitalization. From a practical standpoint, the inertial sensor unit is sensitive to detect differences in functional tasks such as walking and the ability to stand from a seated position in clinical practice. We found that the hospitalized patients preserved their objectively measured functional capacity end points (i.e., SPPB, GVT, and dual-task gait) and maximal muscle strength during their hospital stays and even showed improved gait pattern parameters at discharge. Future research should analyze the functional trajectory in different ADLs adults after an exercise intervention in hospitalized old patients.

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Declaration of Competing Interest

All authors have nothing to declare.

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Ethics approval

This study was approved by the Navarra Clinical Research Ethics Committee, Spain (Pyto 23/2014). All participants read and signed an informed consent for participating in the study.

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