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The association of basic and challenging motor capacity with mobility performance and falls in young seniors

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ABSTRACT

Background: Understanding the association between motor capacity (MC) (what people can do in a standardized environment), mobility performance (MP) (what people actually do in real-life) and falls is important for early detection of and counteracting on functional decline, particularly in the rapidly growing population of young seniors. Therefore, this study aims to 1) explore the association between MC and MP, and between MC and falls, and 2) investigate whether challenging MC measures are better associated with MP and falls than basic MC measures.

Methods: Basic (habitual gait speed, Timed Up-and-Go) and challenging (fast gait speed, Community Balance & Mobility Scale) MC measures were performed in 169 young seniors (61–70 years). MP was assessed using one-week sensor-monitoring including time being sedentary, light active, and at least moderately active. Falls in the previous six months were reported. Associations and discriminative ability were calculated using correlation, regression and receiver operating curve analysis.

Results: Mean age was 66.4 (SD 2.4) years (50.6 % women). Small to moderate associations ($r = 0.06 - 0.31$; $p < .001$–.461) were found between MC, MP and falls. Challenging MC measures showed closer associations with MP and falls ($r = 0.10 - 0.31$; $p < .001$–.461) compared to basic ($r = 0.06 - 0.22$; $p = .012$–.181), remained significant in three out of four regression models explaining 2.5–8.6 % of the variance, and showed highest discriminative ability (area under the curve $= 0.59 - 0.70$) in all analyses.

Conclusions: Challenging MC measures are closer associated with mobility performance and falls as compared to basic MC measures in young seniors. This indicates the importance of applying challenging motor capacity assessments in young seniors. On the same note, small to moderate associations imply a need for an assessment of both MC and MP in order to capture the best possible MC and the actual daily-life MP in young seniors.

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1. Background

Understanding the association between what people are physically able to do during a specific assessment in a standardized environment and what people actually do in their daily life is important in order to develop specific mobility assessments and tailored interventions to prevent functional decline. The International Classification of Function, Disability, and Health (ICF) defines what a person can do in a standardized environment, e.g. in the lab, as 'motor capacity' (MC), and in contrast, what a person actually does in his or her current, everyday environment as 'mobility performance' (MP) (WHO, 2001). Mobility performance includes different activities such as different ways of locomotion (e.g. walking, running, hiking or climbing), transfers (e.g. lie-to-sit or sit-to-stand) or leisure activities (Lamb & Keene, 2017; WHO, 2001). If the two constructs were highly associated, MC measures could be used as predictors for MP. In addition, if a causal relationship exists, improving a person's MC would result in increased MP.

Previous studies have shown that basic MC measures such as the Timed Up-and-Go (TUG) or habitual gait speed are moderately correlated ($r = 0.42 - 0.50$) with objective MP measures such as the number of steps taken (Giannouli, Bock, Mellone, & Zijlstra, 2016) or the distance walked (Callisaya & Verghese, 2018) in real-life. A causal relationship has been reported showing that an increase in MC is related to increases in MP (Potter, Ellard, Rees, & Thorogood, 2011). Moreover, reduced MC is also linked to falls (Callisaya & Verghese, 2018; Tinetti, De Leon, Doucette, & Baker, 1994).

Current studies are restricted to older adults above the age of 70 years, often with functional limitations or chronic diseases (Callisaya & Verghese, 2018; Giannouli et al., 2016; Gijbels et al., 2010; Rapp et al., 2012; van Lummel et al., 2015). In contrast, studies exploring the relationship in relatively fit young seniors are lacking. However, understanding the relationship in young seniors becomes more and more important, as this population is growing rapidly (baby boomer generation). The proportion of people older than 60 in the world population is projected to rise from 12.3 % in 2015 to 21.5 % in 2050 (United Nations 2004). A detailed understanding of the capacity-performance relationship may allow the design of specific assessments for detecting early decline in MC and its impact on MP (and vice versa). This in turn may allow specific interventions to be developed for preventing early decline in capacity, performance and falls in young seniors.

However, in young seniors, other MC and MP parameters could be more distinctive as compared to in older seniors. From a capacity perspective, challenging capacities such as fast walking or dynamic stability may be more relevant, as these functions generally decline substantially in the 7th decade (Choy, Brauer, & Nitz, 2003; Era et al., 2006; Isles, Choy, Steer, & Nitz, 2004). In contrast, basic capacity such as normal walking speed may have limited relevance in young seniors (Schoene et al., 2013). Likewise, from a performance perspective, young seniors' everyday life is likely characterized by a larger amount of physically challenging, more vigorous daily activities such as gardening, outdoor hiking on uneven surfaces, leisure activities, running a short distance to catch a bus, or doing the housework such as carrying a laundry basket while climbing a flight of stairs (Hirvensalo & Lintunen, 2011). Executing such challenging daily activities requires advanced capacities such as fast walking, running, dynamic balance, etc. Challenging MC measures may therefore be closer associated with everyday MP in young seniors as compared to basic MC measures typically used in older adults and geriatric patients.

In this study, we systematically 1) explored the association between MC and MP, as well as between MC and falls, in young seniors, and 2) investigated whether challenging MC measures are better associated with MP and falls compared to basic MC measures in this target population.

2. Methods

2.1. Study design

This study was a cross-sectional analysis in a sample of community-dwelling young seniors aged 61–70 years (Coni et al., 2019; Gordt et al., 2018; Taraldsen et al., 2019; Weber et al., 2018). Participants were recruited as part of the EU project PreventIT in Germany (Robert-Bosch Hospital Stuttgart), the Netherlands (Vrije Universiteit Amsterdam), and Norway (Norwegian University of Science and Technology Trondheim). PreventIT was a three-year project aiming to develop and evaluate the feasibility of a new activity program for young seniors. Baseline data from the PreventIT feasibility RCT (collected from April 2017 - August 2017) were used in the current study. Participants were recruited via mail out after a random draw from local registry data. Inclusion criteria for the PreventIT feasibility RCT were being retired or not working more than 50 %, being able to walk 500 m without a walking aid, and no cognitive impairment (Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005) ≥24 points). Exclusion criteria were being too active (moderate-intensity physical activity ≥150 min/week in the previous three months), current participation in an organised exercise class (> once/week), and severe cardiovascular, pulmonary, neurological, or mental diseases. Further details are published elsewhere (Taraldsen et al., 2019). All participants provided written informed consent prior to participation. Ethical approval was obtained from the respective local institutional review board at each site and was in agreement with the Declaration of Helsinki.

2.2. Measures

Descriptive data including age, sex, body mass index (BMI), and cognitive status (Montreal Cognitive Assessment) were collected.

2.2.1. Motor capacity measures

For assessing MC, the focus was on two aspects of MC, mobility capacity in general and gait capacity in particular. MC measures were categorized as 'challenging' according to the two main pressure conditions for coordinative abilities, time and precision pressure (Neumaier, 1999). Time pressure is defined as executing the specific task as fast as possible, precision pressure as accurate as possible (Neumaier, 1999). Measures without time or precision pressure were classified as 'basic' MC measures.

2.2.1.1. Basic motor capacity measures. Basic gait capacity (habitual gait speed) was assessed according to the InChianti gait assessment guidelines (Rydwik, Bergland, Forsen, & Frandin, 2012). Time required to walk a distance of 7 m at habitual speed was recorded using a stopwatch (m/s).

Basic mobility capacity was assessed using the Timed Up-and-Go (TUG). The TUG assesses functional ability by asking the participant to stand up from a chair (height 45 cm), walk 3 m at a comfortable and safe pace, turn around, walk back to the chair, and sit down (Podsiadlo & Richardson, 1991). The time to complete the test was recorded with a stopwatch (s).

2.2.1.2. Challenging motor capacity measures. Challenging gait capacity (fast gait speed) was assessed using the same procedure as for assessing basic gait capacity (Rydwik et al., 2012). Time pressure was added by asking for the fastest possible execution, without running.

Challenging mobility capacity was assessed using the Community Balance & Mobility Scale (CBM), a performance-based measure including 13 challenging balance and mobility tasks related to daily activities, such as 'Hopping Forward', 'Crouch and Walk', 'Running with Controlled Stop', 'Forward to Backward Walking', 'Walk, Look & Carry', and 'Descending Stairs' (Gordt et al., 2018; Howe, Inness, Venturini, Williams, & Verrier, 2006; Weber et al., 2018). Both time and precision

Table 1
Descriptive characteristics of the study participants (n = 169).

	Mean/n	Standard Deviation/%	Minimum Score	Maximum Score
Age (years)	66.4	2.4	61	70
Sex (women; n, %)	90	50.6		
Body Mass Index (kg/m^2)	27.3	4.7	17.8	42.8
Montreal Cognitive Assessment (0 – 31)	27.1	1.9	24	31
Motor Capacity Measures				
Habitual gait speed (m/s)	1.48	0.23	0.70	2.42
Timed Up and Go Test (sec)	8.6	1.5	5.7	16.0
Fast gait speed (m/s)	1.97	0.43	0.79	3.25
Community Balance & Mobility Scale (0 – 96 points)	64.9	12.5	17	90
Mobility Performance Measures*				
% of sedentary time	46.0	6.5	23.8	66.1
% of light active time	16.2	4.5	4.1	27.2
% of at least moderate active time	5.7	2.6	0.5	12.5
Falls				
Faller (n, %)	27	14.5		

* 'Percentage' of lying time in order to add up to 100 %: mean: 37.9; standard deviation: 5.1; minimum: 22.8; maximum: 56.0.

pressure were exerted on the participants in all items, time pressure as the fastest possible execution, precision pressure as the most accurate execution, such as reaching a predefined line with each step. Each item can be scored from 0 to 5 (+ 1 point for descending stairs while carrying a basket) leading to a maximum of 96 points with higher scores indicating better performance. A full description of the CMB is reported in previous publications (Gordt et al., 2018; Howe et al., 2006; Weber et al., 2018).

2.2.2. Mobility performance measures

There are different methods for assessing everyday mobility performance (Lamb & Keene, 2017). In line with previous studies objectively assessing MP (Giannouli, Bock, & Zijlstra, 2018; Jansen et al., 2019), data were collected with a wearable sensor (Axivity devices) with a 3D accelerometer sampling at 100 Hz worn by the participants on the lower back for one week. Participants were instructed to wear the devices for seven days, during both day and night. An activity classification software was used to extract quantitative features of mobility performance from the raw data. The Metabolic Equivalents (METs) were estimated based on an algorithm described previously (Sasaki, John, & Freedson, 2011). The 'percentage (%) of sedentary time' (≤1.5 MET), '% of light active time' (1.5–3.0 MET), and '% of at least moderate active time' (> 3.0 MET) were analysed with respect to the total time recorded awake. If the MET was ≤1.5 MET and the angle between the vertical axis of the trunk and the horizontal plane was < 30°, the interval was labelled as 'percentage (%) of lying time' (Mansoubi et al., 2015). Using this approach, enables to capture a wide range of everyday mobility performance described by the WHO (2001) such as different transfers, walking or running, climbing stairs or leisure activities.

2.2.3. Falls

Falls were assessed using a standardized question whether the participant had fallen at least once in the past six months (yes/no). Falls were defined as an event which results in a person coming to rest unintentionally on the ground or other lower level (Tinetti, Speechley, & Ginter, 1988).

2.3. Statistical analysis

Participants' characteristics were summarized as mean and standard deviation (SD) for continuous measures and number and percentage for dichotomous measures.

To investigate the association between MC and MP and MC and falls, respectively, Spearman correlation coefficients were calculated between each MC measure and each MP measure, and point-biserial correlation coefficients between each MC measure and falls. Correlation coefficients of $r \leq 0.25$ were classified as small, 0.25–0.50 as moderate, 0.50 – 0.75 as good and ≥0.75 as excellent (Portney & Watkins, 2000)

Linear stepwise regressions adjusted for age, gender and BMI were performed to test the associations between all MC measures and each MP measure using an analytical approach applied previously (Sun, Shook, & Kay, 1996). Logistic backward regression adjusted for age, gender and BMI was performed to assess the association between all MC measures and previous falls using the likelihood ratio method (Field, 2013). Backward regression was applied in order to prevent suppressor effects which means that a predictor has a significant effect but only when another variable is held constant (Field, 2013). For all regression models, $p = 0.10$ was used as inclusion criterion.

The discriminative ability of the basic and challenging MC measures on each MP measure and falls was assessed using the area under the receiver operating characteristic curve (AUC) with 95 % confidence interval (CI). Median split was used to divide the participants into high- and low-performers based on each MP measure. Statistical significance was determined using an alpha level of 0.05. All statistics were performed using IBM SPSS Statistics (Version 24.0; IBM Inc., New York, USA).

3. Results

3.1. Descriptive results

Within the PreventIT cohort (Taraldsen et al., 2019), 169 participants (Amsterdam: n = 59, Stuttgart: n = 59, Trondheim: n = 51) performed all MC and MP measures included in this study. The mean age was 66.4 (SD 2.4) years of age and 90 (50.6 %) participants were female. Twenty-seven participants (14.55 %) reported experiencing at least one fall in the previous six months. TUG values ranged from 5.7 to 16.0 s indicating a heterogeneous sample of young seniors ranging from high functioning to functional impaired. Average habitual gait speed was above the norm values for this age group indicating that most participants in our study were high functioning (Beauchet et al., 2017). On average, participants spent 37.9 % lying, 46.0 % sedentarily, 16.2 % actively, and 5.7 % at least moderate actively. Descriptive results are shown in Table 1.

3.2. Correlations

Correlations between MC, MP and falls ranged from $r = 0.06 - 0.31$ ($p < .001$–.461) (Table 2), with generally stronger correlations found between the challenging MC measures and MP measures and falls ($r = 0.10 - 0.31$; $p < .001$–.461) compared to the basic MC measures and

Table 2
Correlations between motor capacity measures, mobility performance measures and falls (r: Spearman correlation coefficients; *p < 0.05; bold: strongest correlation for each mobility performance measure and falls).

	Motor Capacity Measures			
	Basic		Challenging	
	Gait Capacity	Mobility Capacity	Gait Capacity	Mobility Capacity
Mobility Performance Measures				
% of sedentary time	−0.11	0.11	−0.11	**−0.16***
% of light active time	0.12	−0.14	0.15*	**0.18***
% of at least moderately active time	0.23*	−0.13	**0.31***	0.21*
Falls				
Faller	−0.14	0.06	**−0.26***	−0.16*

MP measures and falls (r = 0.06 − 0.22; p = .012–.181).

3.3. Regression

Multivariate regression analyses confirmed our hypothesis that challenging MC measures were stronger associated with the MP measures and falls than basic MC measures. No basic MC measure remained significant in the regression models (Table 3). In three out of four regression models, the challenging MC measure, particularly the challenging gait capacity, remained significant explaining 2.5–8.6 % of the variance (Table 3). For the percentage of sedentary time, no MC measure remained significant in the final model.

3.4. ROC-analyses

The AUCs of the basic and challenging MC measures discriminating between high/low performers and faller/non-faller ranged between 0.39 and 0.70 (Table 4, Fig. 1). Descriptive results showed that higher AUCs were found for the challenging MC measures (AUC = 0.57 − 0.70) compared to the basic MC measures (AUC = 0.39 − 0.61). In all analyses, the highest AUCs (0.59 − 0.70) were found for a challenging MC measure.

Table 3
Multiple stepwise regression of the motor capacity measures on mobility performance and falls (adjusted for age, gender and body mass index).

	ΔR^2	B	SE_B	β	t	p
% of sedentary time						
(constant)		33.69	14.51		2.32	.021
age		.12	.20	.05	.59	.558
gender		−2.36	.98	−.18	−2.42	.017
BMI		.30	.11	.21	2.78	.006
total R^2 = .071 (N = 169; p = .002)						
% of light active time						
(constant)		26.18	9.45		2.77	.006
age		−.13	.13	−.07	−1.00	.321
gender		2.53	.64	.28	3.95	< .001
BMI		−.32	.07	−.33	−4.67	< .001
fast gait speed	.021	.02	.01	.17	2.33	.021
total R^2 = .223 (N = 169; p = .021)						
% of at least moderately active time						
(constant)		7.06	5.51		1.28	.202
age		−.05	.08	−.04	−.62	.538
gender		1.19	.37	.23	3.19	.002
BMI		−.14	.04	−.25	−3.38	.001
fast gait speed	.086	.02	.00	.31	4.25	< .001
total R^2 = .201 (N = 169; p < .001)						

	ΔR^2	B	SE_B	OR	95 % CI	p
Faller / Non-Faller						
age		−.05	.09	.96	.80; 1.14	.622
gender		.52	.48	1.69	.66; 4.34	.278
BMI		−.03	.05	.97	.88; 1.07	.503
fast gait speed	0.080	−.02	.01	.98	.97; 1.00	.006
total R^2 = .121 (N = 169; p < .001)						

Table 4
Area under the curve (AUC) for all motor capacity measures.

	Motor Capacity Measures			
	Basic		Challenging	
	Gait Capacity AUC (95 % CI)	Mobility Capacity AUC (95 % CI)	Gait Capacity AUC (95 % CI)	Mobility Capacity AUC (95 % CI)
Mobility Performance Measures				
% of sedentary time	0.58 (0.51; 0.68)	0.42 (0.33; 0.50)	**0.59** (0.51; 0.68)	0.57 (0.48; 0.65)
% of light active time	0.56 (0.47; 0.65)	0.43 (0.34; 0.52)	**0.60** (0.51; 0.68)	**0.60** (0.51; 0.68)
% of at least moderately active time	0.61 (0.53; 0.70)	0.39 (0.30; 0.47)	**0.66** (0.58; 0.75)	0.62 (0.53; 0.70)
Falls				
Faller / Non-Faller	0.61 (0.50; 0.73)	0.46 (0.34; 0.57)	**0.70** (0.60; 0.80)	0.63 (0.51; 0.74)

4. Discussion

Overall, we found small to moderate, but significant associations between capacity, performance and falls in young seniors, depending on the measures and outcomes used. The association found between MC measures and MP measures indicated that the MC measures obtained under laboratory conditions provides little information about everyday MP. This finding is in line with the studies in older adults, although the correlations found in our young senior sample were lower (r = 0.06 − 0.31) as compared to findings in older adults (r = 0.01 − 0.69) (Callisaya & Verghese, 2018; Giannouli et al., 2016; Spartano et al., 2019). We speculate that this is related to our population of young seniors, which was for the greater part high functioning as shown by an average habitual gait speed of 1.48 m/s. Previous studies found similar functional values in those 60 and 70 years of age (Schwenk et al., 2019).

Our subjects' MP may be influenced by many factors described in the literature such as individual factors (e.g. personality or attitudes) or external factors (e.g. social support or walkability of the neighborhood) (Benzinger et al., 2014; Carlson et al., 2012). All these factors explain parts of the variance of everyday mobility performance. However, in this study, we were not focusing on all of these factors, but on the specific factor 'motor capacity'.

The group of young seniors shows a diverse lifestyle leading to a wide range of factors accounting for MP and falls (Patterson & Pegg, 2009). This may be different in frail older adults who tend to have less interindividual differences and where existing impairments in capacity (e.g. walking deficits) directly affect MP (e.g. walking distance outside). This assumption is also supported by studies showing that young seniors need a lower relative effort compared to older to execute daily motor tasks (Suominen, 2011).

In line with this, our hypothesis was that the association between capacity and performance in young seniors would not be straightforward, but depend on the challenge of the capacity assessment. We specifically focused on the aspect of motor capacity influencing mobility performance which allowed us to answer our specific research question about the difference between basic and challenging MC measures. Indeed, our results support this assumption showing tendencies that the capacity-performance relationship is influenced by the MC measures applied. We found closer associations for the challenging MC

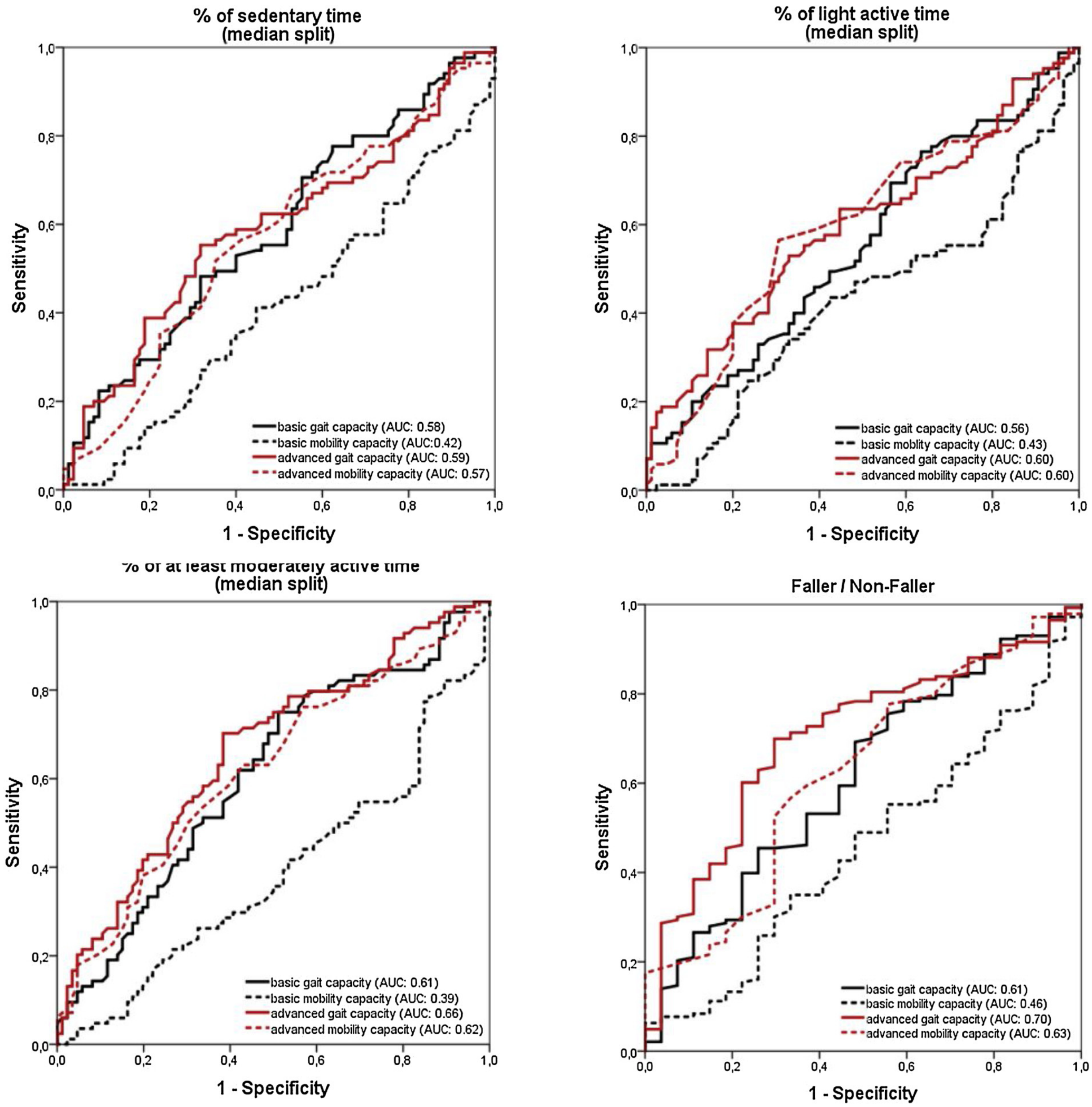

Fig. 1. Receiver operating curves for the discriminative ability of the motor capacity measures.

measures with MP measures and falls compared to the basic MC measures. Among all MC measures, fast gait speed showed the strongest associations and largest discriminative ability. Previous studies in older adults reported gait capacity as a consistent and strong predictor for MP and falls (Callisaya & Verghese, 2018; Van Kan et al., 2009). However, these studies used habitual gait speed, which showed only a weak association with MP and falls in young seniors (Van Ancum et al., 2019).

The strongest correlations were found between the challenging MC measures and the challenging MP measures. For the challenging performance, the relative effort needed is close to the maximal capacity tested in the challenging MC measures. For example, going hiking requires dynamic balance skills executed under precision pressure in order to avoid falling. The challenging MC measures applied in our study measure these skills, which may explain the closer associations found. Our findings suggest that it is important to apply challenging MC measures in order to test young seniors' limits in motor capacity executed under time or precision pressure. The testing the limits paradigm was originally developed in psychology (Kliegl, Smith, & Baltes, 1986). Only when subjects are challenged to their maximum for example by applying time and/or precision pressure, individual differences in performance emerge (Lindenberger & Baltes, 1995; van Lummel et al., 2015). Based on our study, this paradigm seems to be relevant in young seniors as using this approach may enable identification of early age-related decline in MC, which has limited impact on basic MP but may affect more challenging performances.

A major strength of this study is the systematic approach for classifying basic vs challenging measures. Similar to other studies we obtained only small to moderate associations between MC and MP (Callisaya & Verghese, 2018; Giannouli et al., 2016; Spartano et al., 2019). We acknowledge that the variance explained in the regression models was rather low, but comparable to other studies investigating this association (Callisaya & Verghese, 2018; Giannouli et al., 2016). In the present study, we specially focused on the factor motor capacity explaining this amount of variance. Our results underline that in addition to MC also other important internal and external factors play a role for MP explaining an additional proportion of the variance. However, importantly, despite the low variance, we could answer our research questions showing closer associations for the challenging MC with MP and falls compared to basic MC measures in this target population. A further strength is the objective assessment of mobility performance in contrast to studies using subjective methods such as questionnaires (Lamb & Keene, 2017).

Limitations are that our classification of challenging MC measures was restricted to the two main aspects of pressure conditions (time and precision pressure) while further aspects such as complexity pressure defined as simultaneous demands (e.g. dual-tasking) were not considered. This should be investigated in further studies. We are not able to draw conclusions on causes of falls as these were not assessed. Our sensor-based mobility performance assessment does not reveal information about indoor or outdoor mobility performance. This could be extended in future studies using GPS signals (Giannouli et al., 2016). Challenging measures may also be important for older seniors, but this cannot be addressed in this study. However, some challenging measures such as the CBM may show floor effects in older adults. Due to the cross-sectional design of the study, causal inferences cannot be evaluated, and further longitudinal studies are needed to show that changes in challenging MC measures are associated with changes in MP.

5. Conclusion

Our findings show closer associations of MC measures with MP measures and falls in young seniors if challenging MC measures were used. This underlines the need of challenging assessments in young seniors and is an important step towards tailored assessments for this target population. Assessment results could be the basis for tailored early intervention aiming to restore or improve relevant challenging capacities, in turn enabling young seniors to maintain healthy mobility performance patterns and an active lifestyle.

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Authors' contributions

KG conducted the statistical analyses and drafted the manuscript. MS contributed to the interpretation of data and drafting the manuscript. MP, ABM, JLH, BV, CB, KA and MS designed the PreventIT feasibility RCT. ASM, KT, RB, JMA, CN collected the data. API and SM analysed the wearable sensor data. All authors have critically reviewed, edited, and approved the final manuscript.

Declaration of Competing Interest

None.

References

Beauchet, O., Allali, G., Sekhon, H., Verghese, J., Guilain, S., Steinmetz, J. P., et al. (2017). Guidelines for assessment of gait and reference values for spatiotemporal gait parameters in older adults: The biomathics and Canadian gait consortiums initiative. *Frontiers in Human Neuroscience, 11*(353).

Benzinger, P., Iwarsson, S., Kroog, A., Beische, D., Lindemann, U., Klenk, J., et al. (2014). The association between the home environment and physical activity in community-dwelling older adults. *Aging Clinical and Experimental Research, 26*, 377–385.

Callisaya, M. L., & Verghese, J. (2018). The association of clinic-based mobility tasks and measures of community performance and risk. *PM & R: The Journal of Injury, Function, and Rehabilitation*.

Carlson, J. A., Sallis, J. F., Conway, T. L., Saelens, B. E., Frank, L. D., Kerr, J., et al. (2012). Interactions between psychosocial and built environment factors in explaining older adults' physical activity. *Preventive Medicine, 54*, 68–73.

Choy, N. L., Brauer, S., & Nitz, J. (2003). Changes in postural stability in women aged 20 to 80 years. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences, 58*, 525–530.

Coni, A., Ancum, J. M. V., Bergquist, R., Mikolaizak, A. S., Mellone, S., Chiari, L., et al. (2019). Comparison of standard clinical and instrumented physical performance tests in discriminating functional status of high-functioning people aged 61–70 years old. *Sensors, 19*(449).

Era, P., Sainio, P., Koskinen, S., Haavisto, P., Vaara, M., & Aromaa, A. (2006). Postural balance in a random sample of 7,979 subjects aged 30 years and over. *Gerontology, 52*, 204–213.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics.* Sage.

Giannouli, E., Bock, O., Mellone, S., & Zijlstra, W. (2016). Mobility in old age: Capacity is not performance. *BioMed Research International, 2016*.

Giannouli, E., Bock, O., & Zijlstra, W. (2018). Cognitive functioning is more closely related to real-life mobility than to laboratory-based mobility parameters. *European Journal of Ageing, 15*, 57–65.

Gijbels, D., Alders, G., Van Hoof, E., Charlier, C., Roelants, M., Broekmans, T., et al. (2010). Predicting habitual walking performance in multiple sclerosis: Relevance of capacity and self-report measures. *Multiple Sclerosis, 16*, 618–626.

Gordt, K., Mikolaizak, A. S., Nerz, C., Barz, C., Gerhardy, T., Weber, M., et al. (2018). German version of the community balance and mobility scale. *Zeitschrift für Gerontologie und Geriatrie*.

Hirvensalo, M., & Lintunen, T. (2011). Life-course perspective for physical activity and sports participation. *Review of Aging and Physical Activity, 8*, 13–22.

Howe, J. A., Inness, E. L., Venturini, A., Williams, J. I., & Verrier, M. C. (2006). The Community Balance and Mobility Scale–a balance measure for individuals with traumatic brain injury. *Clinical Rehabilitation, 20*, 885–895.

Isles, R. C., Choy, N. L., Steer, M., & Nitz, J. C. (2004). Normal values of balance tests in women aged 20–80. *Journal of the American Geriatrics Society, 52*, 1367–1372.

Jansen, C.-P., Toosizadeh, N., Mohler, M. J., Najafi, B., Wendel, C., & Schwenk, M. (2019). The association between motor capacity and mobility performance: Frailty as a moderator. *European Review of Aging and Physical Activity, 16*(16).

Kliegl, R., Smith, J., & Baltes, P. B. (1986). *Testing-the-limits, expertise, and memory in adulthood and old age*.

Lamb, S. E., & Keene, D. J. (2017). Measuring physical capacity and performance in older people. *Best Practice & Research Clinical Rheumatology, 31*, 243–254.

Lindenberger, U., & Baltes, P. B. (1995). Testing-the-limits and experimental simulation: Two methods to explicate the role of learning in development. *Human Development, 38*, 349–360.

Mansoubi, M., Pearson, N., Clemes, S. A., Biddle, S. J., Bodicoat, D. H., Tolfrey, K., et al. (2015). Energy expenditure during common sitting and standing tasks: Examining the 1.5 MET definition of sedentary behaviour. *BMC Public Health, 15*(516).

Nasreddine, Z. S., Phillips, N. A., Bedirian, V., Charbonneau, S., Whitehead, V., Collin, I., et al. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society, 53*, 695–699.

Neumaier, A. (1999). Koordinatives Anforderungsprofil Und Koordinationstraining. In H. Mechling, & A. Neumaier (Eds.). *Reihe Training derBewegungskoordination Köln*. Sport und BuchStrauss.

Patterson, I., & Pegg, S. (2009). Marketing the leisure experience to baby boomers and older tourists. *Journal of Hospitality Marketing & Management, 18*, 254–272.

Podsiadlo, D., & Richardson, S. (1991). The timed "Up & Go": A test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society, 39*, 142–148.

Portney, L. G., & Watkins, M. P. (2000). *Foundations of clinical research: Applications to practice.* Prentice Hall.

Potter, R., Ellard, D., Rees, K., & Thorogood, M. (2011). A systematic review of the effects of physical activity on physical functioning, quality of life and depression in older people with dementia. *International Journal of Geriatric Psychiatry, 26*, 1000–1011.

Rapp, K., Klenk, J., Benzinger, P., Franke, S., Denkinger, M. D., Peter, R., et al. (2012). Physical performance and daily walking duration: Associations in 1271 women and men aged 65–90 years. *Aging Clinical and Experimental Research, 24*, 455–460.

Rydwik, E., Bergland, A., Forsen, L., & Frandin, K. (2012). Investigation into the reliability and validity of the measurement of elderly people's clinical walking speed: A systematic review. *Physiotherapy Theory and Practice, 28*, 238–256.

Sasaki, J. E., John, D., & Freedson, P. S. (2011). Validation and comparison of ActiGraph activity monitors. *Journal of Science and Medicine in Sport, 14*, 411–416.

Schoene, D., Wu, S. M., Mikolaizak, A. S., Menant, J. C., Smith, S. T., Delbaere, K., et al. (2013). Discriminative ability and predictive validity of the timed up and go test in identifying older people who fall: Systematic review and meta-analysis. *Journal of the American Geriatrics Society, 61*, 202–208.

Schwenk, M., Bergquist, R., Boulton, E., Van Ancum, J. M., Nerz, C., Weber, M., et al. (2019). The adapted lifestyle-integrated functional exercise program for preventing functional decline in young seniors: Development and initial evaluation. *Gerontology, 65*, 362–374.

Spartano, N. L., Lyass, A., Larson, M. G., Tran, T., Andersson, C., Blease, S. J., et al. (2019). Objective physical activity and physical performance in middle-aged and older adults. *Experimental Gerontology, 119*, 203–211.

Sun, G.-W., Shook, T. L., & Kay, G. L. (1996). Inappropriate use of bivariable analysis to screen risk factors for use in multivariable analysis. *Journal of Clinical Epidemiology, 49*, 907–916.

Suominen, H. (2011). Ageing and maximal physical performance. *European Review of Aging and Physical Activity, 8*, 37–42.

Taraldsen, K., Mikolaizak, A. S., Maier, A. B., Boulton, E., Aminian, K., van Ancum, J., et al. (2019). Protocol for the PreventIT feasibility randomised controlled trial of a lifestyle-integrated exercise intervention in young older adults. *BMJ Open, 9*, e023526.

Tinetti, M. E., De Leon, C. F. M., Doucette, J. T., & Baker, D. I. (1994). Fear of falling and fall-related efficacy in relationship to functioning among community-living elders. *Journal of Gerontology, 49*, M140–M147.

Tinetti, M. E., Speechley, M., & Ginter, S. F. (1988). Risk factors for falls among elderly persons living in the community. *The New England Journal of Medicine, 319*, 1701–1707.

UnitedNations (2004). *World population to 2300: United Nations publications*.

Van Ancum, J. M., van Schooten, K. S., Jonkman, N. H., Huijben, B., van Lummel, R. C., Meskers, C. G. M., et al. (2019). Gait speed assessed by a 4-m walk test is not representative of daily-life gait speed in community-dwelling adults. *Maturitas, 121*, 28–34.

Van Kan, G. A., Rolland, Y., Andrieu, S., Bauer, J., Beauchet, O., Bonnefoy, M., et al. (2009). Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people an International Academy on Nutrition and Aging (IANA) Task Force. *The Journal of Nutrition, Health & Aging, 13*, 881–889.

van Lummel, R. C., Walgaard, S., Pijnappels, M., Elders, P. J., Garcia-Aymerich, J., van Dieen, J. H., et al. (2015). Physical performance and physical activity in older adults: Associated but separate domains of physical function in old age. *PloS One, 10*, e0144048.

Weber, M., Van Ancum, J., Bergquist, R., Taraldsen, K., Gordt, K., Mikolaizak, A. S., et al. (2018). Concurrent validity and reliability of the community balance and mobility scale in young-older adults. *BMC Geriatrics, 18*(156).

WHO (2001). *The international classification of functioning, disability and health (ICF)*. Geneva: WHO. http://www.who.int/classifications/icf/en/.