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ORIGINAL RESEARCH

Physical Performance and Cognition as Predictors of Instrumental Activities of Daily Living After Stroke: A Prospective Multicenter Cohort Study

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Abstract

Objective: To investigate whether cognition and physical performance, both separately and combined, 3 months post stroke predict change in instrumental activities of daily living (IADL) up to 18 months and whether different paths of IADL could be identified by different scenarios, defined by combinations of high and low scores on physical performance and cognition.

Design: The study is part of the Norwegian Cognitive Impairment After Stroke study, a prospective multicenter cohort study including patients with acute stroke.

Setting: Stroke outpatient clinics at 3 university hospitals and 2 local hospitals.

Participants: Adult survivors of stroke (N=544) were followed up at 3 and 18 months after stroke. Participants' mean ± SD age was 72.6± 11.8 years, and 235 (43.2 %) were female.

Interventions: Not applicable.

Main Outcome Measures: The primary outcome was IADL as measured by Nottingham Extended Activities of Daily Living. At 3 months, Short Physical Performance Battery (SPPB) and Montreal Cognitive Assessment (MoCA) were used to assess physical performance and cognition, respectively.

Results: Mixed-effects linear regression analyses showed that the regression coefficient (95% CI) for the interaction with time was significant for MoCA, 0.238 (CI, 0.030-0.445; *P*=.025) but not for SPPB. The model combining SPPB and MoCA was significantly better than separate models (likelihood ratio *P*<.001). Overall, there was no improvement in IADL over time. A combination of SPPB and MoCA score in the upper quartile at 3 months was associated with improved IADL of 1.396 (CI, 0.252-2.540; *P*=.017) over time.

Conclusions: Combining measures of cognition and physical performance gave the best prediction of change in IADL. Function at 3 months seems to be predictive for long-term IADL status, which highlights the importance of targeted rehabilitation in the early and subacute phases after stroke.

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Stroke is a leading cause of disability worldwide,[1] and 40% of survivors of stroke have functional dependency in instrumental activities of daily living (IADL) 3 years after stroke.[2] Furthermore, a significant proportion of survivors of stroke without functional dependency have been found to have problems with cognition and social participation up to 5 years post stroke.[3,4]

The European Stroke Organisation Conference is hosted by the European Stroke Organisation, and in 2021 the conference was organised as a virtual conference from September 1 to 3. The poster was presented at September 3.

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Maintaining independence in IADL is important for quality of life, reduces risk of depression and anxiety, and is associated with better health outcomes.[5,6] In the population with stroke, factors such as age, severity of stroke, and prestroke function are well-known predictors of poststroke functional decline.[7,8] Verstraeten et al reported that patients with stroke had reduced physical, cognitive, and IADL function 3 months after the event compared with controls without stroke.[9] Furthermore, a tendency toward performance-based tests being superior to rating scales in detection of poststroke impairments was found.[9]

Individuals with impairments in both physical performance and cognition have been described as having a phenotype with higher risk of morbidity and progression to dementia,[10] and a recent study reported that higher frequency of prestroke functional and cognitive impairments gave poorer prognosis post stroke.[10]

Poststroke cognitive impairment is increasingly recognized as a frequent condition, with reported prevalence ranging from 37%-67% for mild cognitive impairment and 21%-42% for dementia, depending on different populations, study design, and diagnostic criteria.[11,12] Cognitive dysfunction, especially within the domains of executive function, memory, and attention, have been reported to be associated with poorer IADL function after stroke.[13,14]

Reduced physical function is seen in almost 50% of stroke cases 3 months after stroke,[15] and assessment of physical performance is an established part of follow-up and integrated in stroke rehabilitation.[16] Regarding physical performance as a predictor of poststroke IADL function, evidence is diverging. Some studies have reported physical performance as a predictor of IADL function,[17,18] whereas others found no significant association between mobility in the acute phase and IADL 6 months later.[19] Thus, more research is needed to determine the effect of physical performance on the prediction of IADL after stroke.

Patients with stroke reach a plateau phase in functional recovery 3 months after a stroke.[8] However, studies have reported that recovery and transition between dependency and independency in activities of daily living (ADL) happen up to 12 months post stroke,[20,21] indicating substantial heterogeneity among patients. Thus, it would also be of great value to identify the recovery paths beyond 3 months for subgroups of survivors of stroke based on measures of cognition and physical performance.

The Norwegian Cognitive Impairment After Stroke (Nor-COAST) study previously reported that 103 (19%) of the participating survivors of stroke (n=553) had concomitant impairments in mobility (Short Physical Performance Battery [SPPB] <10 points) and global cognition (Montreal Cognitive Assessment [MoCA] <24 points) 3 months after stroke,[22] indicating that combining these measures might give a more precise prediction than applying 1 at a time.

The primary aim of this study was to investigate if measures of cognition and physical performance, separately or in combination, at 3 months after stroke can predict change in IADL function 15 months later. A secondary aim was to explore if different paths of IADL could be identified by different scenarios, defined by combinations of high and low scores on physical performance and cognition.

List of abbreviations:

ADL	**activities of daily living**
IADL	**instrumental activities of daily living**
MoCA	**Montreal Cognitive Assessment**
mRS	**modified Rankin scale**
NEADL	**Nottingham Extended Activities of Daily Living**
NIHSS	**National Institutes of Health Stroke Scale**
Nor-COAST	**Norwegian Cognitive Impairment After Stroke**
SPPB	**Short Physical Performance Battery**

Methods

Study design and participants

The present study is part of Nor-COAST, a large multicenter prospective cohort study including participants from 5 different hospitals in Norway between May 2015 and March 2017.[23] Patients were screened for inclusion during the index stay, with follow-up assessments at 3, 18, and 36 months. Inclusion criteria were diagnosed with stroke according to the World Health Organization criteria[24] or with findings on magnetic resonance imaging compatible with intracerebral hemorrhage or infarction, symptom onset within 1 week before admission, being older than 18 years, fluency in a Scandinavian language, and living in the catchment area of the participating hospitals. Patients with less than 3 months expected survival were excluded from the study. Further details were published in the protocol article for the Nor-COAST study.[23]

As indicated by the objective, the present study included data from the 3- and 18-month follow-up only. Hence, participants who completed Nottingham Extended Activities of Daily Living (NEADL), SPPB, and MoCA at 3-month follow-up were included (fig 1).

Assessments

Baseline characteristics

Age and sex were registered at hospital admission, and the Charlson Comorbidity Index[25] was retrieved from medical records. The National Institutes of Health Stroke Scale (NIHSS)[26] score at admission was used to measure stroke severity (range, 0-42), where higher score indicates more severe stroke. Functional dependency prior to the stroke was measured with modified Rankin scale (mRS) (range, 0-6),[27] where a higher score indicates a greater degree of dependency and 6 denotes death.

Dependent variable

IADL at 3- and 18-month follow-up were assessed with the NEADL scale, a 0-66-point scale where a higher score indicates greater independence.[28] The scale consists of 22 questions covering mobility, kitchen, domestic, and leisure activities.

Predictors

Global cognition was assessed with MoCA, a 10-item test covering 8 cognitive domains, with possible scores ranging from 0-30, including 1 additional point for education <12 years and higher scores indicating better cognition.[29] The SPPB is a measure of physical performance and consists of 3 tasks: 4-m preferred gait speed, balance, and sit-to-stand from chair 5 times, with 4-point scales for each task and a summary score ranging from 0-12, with higher scores indicating better physical function.[30,31]

Data collection

Baseline characteristics were retrieved from participants, proxies, and medical records during hospital stay. At 3- and 18-month follow-up participants were assessed at a hospital outpatient clinic.

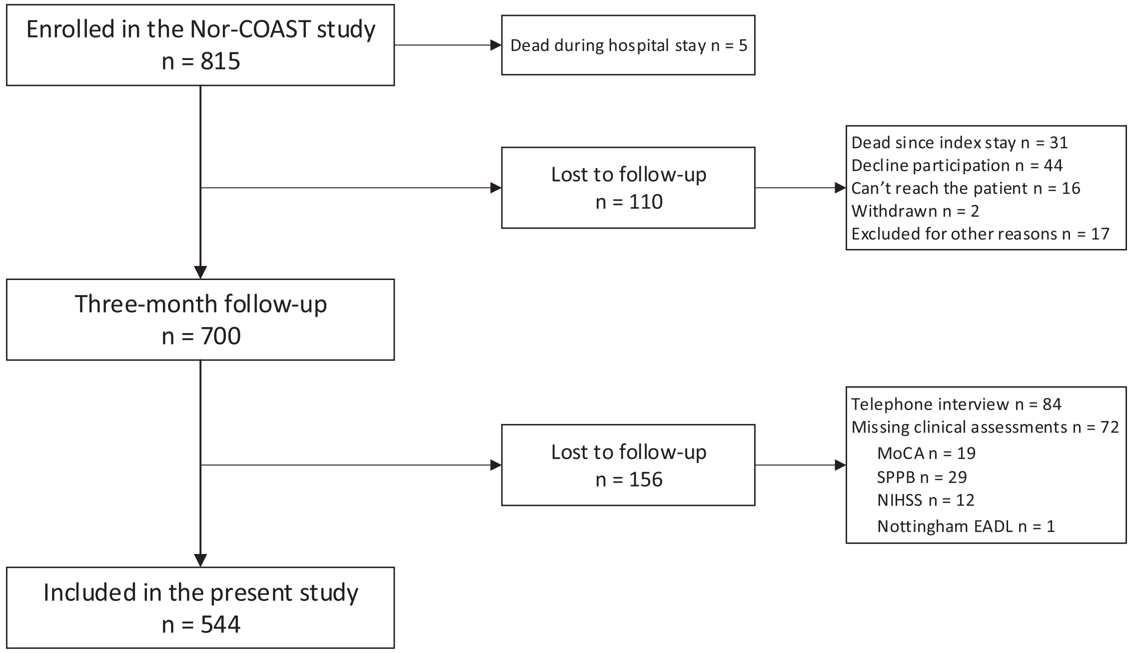

Fig 1 Flowchart on inclusion.

NEADL score was collected by an interview of the participant or proxy. Clinical assessments were performed by trained health care personnel according to a standardized manual.

Ethical considerations

The present study was carried out according to the Declaration of Helsinki. Participation was voluntary and based on written informed consent from the participant or, in cases where participants were not able to give consent, by their proxy. The study has been approved by the Regional Committee for Medical and Health Research Ethics (REC Central 194265) and registered in ClinicalTrials.gov (NCT02650531).

Statistical analyses

Demographic and clinical characteristics were summarized using means and SDs or frequencies and percentages. Single mean imputation was carried out in cases with single items missing on NEADL at 3 months (n=13) and 18 months (n=7), and MoCA (n=4). Cases with more than 50% of the items missing were excluded from the analyses. Missing scores on the SPPB were not imputed because of too few variables being part of the total score.

We used mixed-effects linear regression models with NEADL score as the dependent variable in 3 different models. All 3 regression models included the known risk factors age, sex, stroke severity (NIHSS), and prestroke functional dependency (prestroke mRS) as covariates and patient as random effect. Further, we included time point (ie, 18 months vs 3 months) and either MoCA (model A), SPPB (model B), or both in combination (model C) and their interactions with time. The interaction between time and MoCA and/or SPPB was examined to investigate the effect of the clinical measures on change over time. Normality of residuals was confirmed by visual inspection of quantile-quantile plots. Prestroke mRS was treated as a categorical variable in the mixed-models analyses because of its nonlinear association with NEADL score. Because of few participants with an mRS score of 4 or 5, participants with a score of 3 (n=27), 4 (n=1), or 5 (n=1) were collapsed into score 3-5 in the regression analyses. The model fit was compared between the models by likelihood ratio tests, with model C defined as the reference model.

To answer the secondary aim of the study we presented the estimated level of NEADL score over time for 4 scenarios based on the model with combined assessment, namely for SPPB scores of 8 and 12 as well as for MoCA scores of 22 and 28. These correspond to the lower and upper quartiles of SPPB and MoCA in our data set. These results were obtained by using the variables SPPB score minus 8, SPPB score minus 12, MoCA score minus 22, and MoCA score minus 28 in the analyses. The 4 scenarios were then defined by combining MoCA upper quartile with SPPB lower and upper quartile and MoCA lower quartile with SPPB upper and lower quartile in the linear mixed-effects model.

Statistical significance was defined as 2-sided $P<.05$. Data were analyzed using SPSS version 25.0[a] and STATA 16.[b]

Results

Participant characteristics

Of 815 participants included in the Nor-COAST study, 700 were assessed at 3 months. Because of missing data on MoCA, SPPB, NIHSS, and NEADL, 544 participants were included in the present study (see fig 1). Those lost to follow-up (n=271) were significantly older (mean ± SD age 77.9±10.3 years vs 71.4±11.8 years, $P<.001$) and had more severe strokes (NIHSS score, 6.8±7.8 vs 3.7±4.7, $P<.001$).

Of the participants, 235 (43.2%) were female, and 29 (5.3%) had a prestroke mRS score >2 (table 1). Three months post stroke mean ± SD SPPB score was 9.4±3.1 and mean MoCA score was 24.4±4.8 (table 2). Mean NEADL score at 3 months was 51.4±14.1, and at 18 months it was 52.3±14.8.

Table 1 Baseline characteristics

Characteristic	Total Sample n=544	Lost to Follow-up n=271
Demographics		
Age (y), mean ± SD	71.4±11.8	77.9±10.3
Female, n (%)	235 (43.2)	131 (48.3)
Living alone, n (%)	184 (34.4)	119 (46.9)
Education >9 y, n (%)	457 (84.0)	192 (70.9)
Stroke classification		
Infarction, n (%)	497 (91.4)	240 (88.6)
Hemorrhage, n (%)	47 (8.6)	47 (8.6)
Stroke severity		
NIHSS score at admission, mean ± SD	3.7±4.7	6.8±7.8
Charlson Comorbidity Index, mean ± SD	3.8±1.9	4.9±2.2
mRS score, prestroke, mean ± SD	0.7±0.9	1.6±1.4
mRS=0, n (%)	291 (53.5)	87 (32.6)
mRS=1, n (%)	147 (27.0)	47 (17.6)
mRS=2, n (%)	77 (14.2)	55 (20.6)
mRS=3, n (%)	27 (5.0)	51 (19.1)
mRS=4, n (%)	1 (0.2)	26 (9.7)
mRS=5, n (%)	1 (0.2)	1 (0.4)

Prediction of change in IADL function

In model A the interaction between MoCA and time was significant, with a coefficient of 0.268 (95% CI, 0.086-0.449; P=.004), indicating that MoCA had an effect on change in NEADL score from 3-18 months. In model B there was a significant interaction between SPPB and time (coefficient, 0.331; 95% CI, 0.042-0.619; P=.025). In model C the interaction between MoCA and time remained stable (coefficient, 0.238; 95% CI, 0.030-0.445, P=.025), whereas the interaction between SPPB and time was no longer significant (P=.431). Each model extension, that is, model C vs model A and model C vs model B, was a statistically significant improvement of the model (likelihood ratio test, all P<.001). All the results from the mixed-effects regression analyses are displayed in table 3.

Table 2 Clinical assessments at 3 and 18 months

Assessment	3 mo n=544	18 mo n=480
SPPB score (0-12), mean ± SD	9.4±3.1	NA
SPPB score <10 points, n (%)	198 (36.4)	NA
MoCA score (0-30), mean ± SD	24.4±4.8	NA
MoCA score <26 points, n (%)	275 (50.5)	NA
Nottingham EADL (0-66), mean ± SD	51.4±14.1	52.3±14.8
Mobility (0-18), mean ± SD	14.3±4.7	14.3±4.8
Kitchen (0-15), mean ± SD	13.5±3.2	13.5±3.3
Domestic activities (0-15), mean ± SD	10.7±4.4	10.9±4.3
Leisure activities (0-18), mean ± SD	12.9±4.2	13.6±4.6

Abbreviations: EADL, Extended Activities of Daily Living; NA, not applicable.

Table 3 Results from linear mixed-effects models with Nottingham EADL as dependent variable (N=544)

Model	Nottingham EADL		
	Coefficient	95% CI	P Value
Model A: Cognition			
MoCA	1.000	0.772−1.226	<.001
Time	−6.225	−10.772 to −1.678	.007
Time*MoCA	0.268	0.086 to 0.449	.004
Age	−0.206	−0.289 to −0.122	<.001
Female sex	−0.494	−2.196 to 1.208	.569
NIHSS	−0.334	−0.514 to 0.154	<.001
mRS prestroke, scores			
1	−3.482	5.504 to −1.460	.001
2	−5.712	−8.339 to −3.085	<.001
3-5	−16.375	−20.591 to −12.158	<.001
Model B: Physical performance			
SPPB	2.571	2.271 to 2.871	<.001
Time	−2.571	−5.798 to −0.005	.050
Time*SPPB	0.331	0.042 to 0.619	.025
Age	−0.164	−0.232 to −0.096	<.001
Female sex	−2.386	−3.834 to −0.938	.001
NIHSS	−0.209	−0.361 to −0.057	.007
mRS prestroke, scores			
1	−2.362	4.072 to −0.652	.007
2	−3.095	−5.337 to −0.854	.007
3-5	−11.042	−14.657 to −7.426	<.001
Model C: Combined assessment			
MoCA	0.570	0.369 to 0.770	<.001
SPPB	2.364	2.058 to 2.671	<.001
Time	−6.840	−11.394 to −2.285	.003
Time*MoCA	0.238	0.030 to 0.445	.025
Time*SPPB	0.132	−0.197 to 0.461	.431
Age	−0.085	−0.154 to −0.017	.015
Female sex	−2.220	−3.602 to −0.839	.002
NIHSS	−0.162	−0.307 to −0.016	.029
mRS prestroke, scores			
1	−2.230	−3.861 to −0.599	.007
2	−2.755	−4.894 to −0.615	.012
3-5	−7.972	−11.515 to −4.429	<.001

Abbreviation: EADL, Extended Activities of Daily Living

Change in IADL based on 3-month cognition and physical performance

Figure 2 illustrates the change in NEADL score over time for the 4 scenarios. Only the combination of MoCA and SPPB score in the upper quartile predicted a statistically significant improvement in NEADL score (coefficient, 1.396; 95% CI, 0.252-2.540; P=.017) (table 4).

Discussion

In this longitudinal observational study of survivors of stroke accessible for clinical assessments 3 months after stroke incident, we found that combining measures of physical performance and cognition was superior to only assessing 1 domain to predict change in IADL from 3-18 months post stroke. However, cognition appeared to be a stronger predictor than physical performance

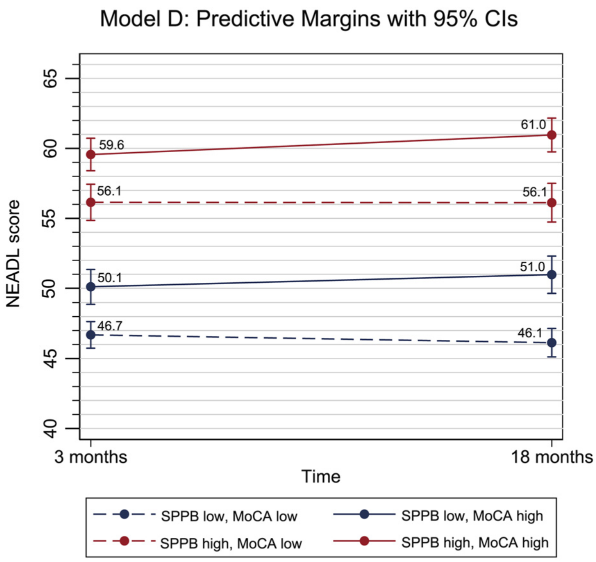

Fig 2 Predictive margins plot with 95% CI of model C with MoCA and SPPB centered on quartiles. SPPB low=8p; SPPB high=12p; MoCA low=22p; MoCA high=28p.

when applied in the same model (model C: Combined assessment). Overall, there was a stable IADL function from 3-18 months for all 4 predefined scenarios. High scores on both cognition and physical performance were associated with a statistically significant improvement in IADL over time. The results indicate that physical performance and cognitive status at 3 months post stroke is predictive of IADL function in the chronic phase after stroke.

Our main finding was that measures of physical performance and cognition in combination added value to the prediction of poststroke IADL function, even when adjusting for known risk factors of functional decline. This result highlights the need for clinical assessments of both cognition and global physical function in the subacute phase beyond application of traditional stroke severity scales and functional screening tools.[3,32,33]

MoCA was the strongest predictor of change in IADL function, a finding supported by previously published results, because even in a subgroup scoring 0 points on NIHSS, cognitive dysfunction correlated with a decline in poststroke IADL function.[13,19] Impairments in several cognitive domains after stroke, including global cognition, have been reported.[34] Executive function, memory, and attention, which are all incorporated domains in MoCA, are reported to be the most important for maintenance of IADL function in survivors of stroke.[14,29] MoCA is a sensitive screening tool for cognitive impairment in patients with stroke, in addition to being more feasible in a clinical setting than extensive neuropsychological testing.[35]

Singam et al reported that physical performance was predictive of IADL function 6 years after stroke.[18] This is in line with our results, which showed that physical performance may, when applied alone, be an important predictor of change in IADL function. However, the prediction was better in combination with measures of cognition. This is interesting because NEADL mainly includes tasks in which physical performance seems to be more important than cognition.[36] Many of the motor tasks in NEADL might in fact challenge the dual task capacity and the motor-cognitive interphase in addition to physical performance, which is thought to be closely linked to cognition and cognitive reserves.[37] Further, our results are in line with a recently published Delphi study regarding factors important for IADL function, where cognition was listed as the most important feature, while physical performance was also reported as an essential factor.[38]

We identified 4 distinct scenarios based on the model that included measures of both physical performance and cognition (model C: Combined assessment) where adjustments were made for other known risk factors. Functional dependency at 3 months post stroke, mainly reported as mRS, has been reported as a predictor of long-term function, in terms of ADL dependency, comorbidity, and death,[39] and the present study shows that applying clinical tests at 3 months adds value to the prediction in addition to known risk factors for functional decline.

Three of the 4 scenarios had stable, nonsignificant changes in IADL function from 3-18 months, indicating that the vast majority of the participants did not change in IADL function. This contrasts with the findings reported by Rejnö et al, who found that transition from ADL independency to dependency mainly happened during the first year after stroke.[40] Further, Buvarp et al found that patients with moderate stroke declined in functional mobility from 3-12 months post stroke, which is an argument for prolonged rehabilitation in a selected group of patients with stroke.[41] However, in the same study it was reported that patients with mild stroke had stable function,[41] and stroke recovery might take place up to 18 months post stroke, which could possibly explain our finding of stable function within this time frame.[8] The observed plateau in IADL function after 3 months might be explained by the fact that most functional recovery as well as rehabilitation takes place prior to this.[21,42] The statistically significant increase in NEADL score found in the best preforming scenario did not reach clinical significance on group level but may be an expression of continuous recovery in this subgroup.[43]

Time was a statistically significant predictor of change in the scenario representing survivors of stroke with the best scores on both physical performance and cognition. This scenario had an increase in NEADL score of 1.4, which is lower than the 6 points regarded as a clinically significant change.[43] However, approximately 15 points on the NEADL differed between this scenario and the one with scores on both MoCA and SPPB in the lower quartiles, which suggests that the level on performance-based tests at 3 months might predict the level of IADL function at which

Table 4 Coefficients of time in model C with MoCA and SPPB centered on quartiles

	MoCA Lower Quartile			MoCA Upper Quartile		
	Coefficient	95% CI	*P* Value	Coefficient	95% CI	*P* Value
SPPB lower quartile	−0.558	−1.561 to 0.446	0.276	0.867	−0.508 to 2.243	.216
SPPB upper quartile	−0.029	−1.462 to 1.404	0.968	1.396	0.252 to 2.540	.017

NOTE. SPPB: lower quartile=8p, upper quartile=12p; MoCA: lower quartile=22p, upper quartile=28p. Analyses are adjusted for age, sex, stroke severity, and prestroke function.

patients with stroke will stabilize in the long-term. This finding highlights the importance of high-quality acute treatment and early rehabilitation to achieve best possible cognition and physical function the first months post stroke.[42]

To our knowledge this is the first study to date addressing the role of physical performance and cognition in prediction of IADL function, which is an important outcome, after stroke. The large sample size and the longitudinal multicenter design should also be considered a significant strength. The repeated measures allow us to identify predictors of change in IADL function, and the mixed-model statistical analyses use data from all participants, including those with partially missing data, thus avoiding loss of statistical power. NEADL is shown to have few floor or ceiling effects,[44] making it applicable for a heterogeneous population with stroke, and MoCA and SPPB are widely used feasible clinical measures and therefore easily incorporated into clinical evaluations of patients with stroke.[45-49]

Study limitations

The cohort design of the study inhibits us concluding on causality, and there is a need for external validation to draw any conclusion on this prediction model outside of the present study sample. The Nor-COAST population is representative of the majority of the general population with stroke who experience mild to moderate strokes.[50] However, the present study sample was slightly younger and healthier than the original Nor-COAST cohort, and conclusions for individuals with severe stroke cannot be drawn. There are some sex biases in the application of NEADL in which several of the questions favor women, which is why sex was adjusted for in the analyses. Furthermore, NEADL includes more mobility than cognitive questions compared with other IADL tools, which might have led to an underestimation of associations with cognition.

Conclusions

Being able to predict change in IADL function after stroke is of great value to patients and health care providers. This is the first study to examine how the combination of cognition and physical performance in an early stage after a stroke predicts change in daily life activities over time. Combining measures of physical performance and cognition provided the best prediction of change in IADL over time. Cognitive and physical function at 3 months post stroke were predictive of IADL function over the next 15 months, and the observed effects of cognition over physical performance on IADL outcomes are arguments for increased attention on cognitive impairment in the acute phase.

Further research should target how measures of physical and cognitive performance in the early stage might be used to identify specific risk profiles and personalize long-term rehabilitation.

Suppliers

a. SPSS version 25; BMI.
b. STATA version 16; StataCorp.

Keywords

Activities of daily living; Cognition; Physical functional performance; Rehabilitation; Stroke

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