Retrospective Data Analysis

UKLFR dataset analysis

Datasets description:

UKLFR dataset features
Disease diagnosis
Tandem walking (heel-to-toe)
Tinnetti assessment total score
Timed Up-and-Go (TUG)
Five Times Sit to Stand (5xSTS)
Timed 15-meter walk time (G15)
Barthel Index total score
Lawton-Brody Instrumental Activities of Daily Living (IADL) total score
Mini-Mental State Examination (MMSE) total score
Martin Vigorimeter (hand grip) force
Geriatric Depression Scale (GDS) total score

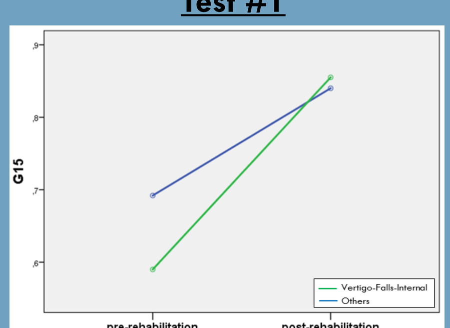
- 377 patients with multi-casual mobility problems (mean 78.4 years, 171 males).
- Patient diagnosis included:
  - stroke
  - Parkinson's disease
  - peripheral/other neurological disorder
  - vertigo
  - internal (unspecified)
  - orthopedic disorders
  - falls
- Focus on vertigo, fallers and internal as more relevant to HOLOBALANCE:
  - Vertigo-Falls-Internal vs Others
  - Effect of baseline symptomatology
  - Dependencies between scales

Methodology:

- Mixed ANOVA analysis with repeated measures to investigate the dependencies of **disease diagnosis** (between subjects factor) on rehabilitation outcomes (within-subjects factor):
  - **Test #1** groups: Vertigo-Falls-Internal vs Others
- Mixed ANOVA analysis with repeated measures to investigate the dependencies of **baseline symptom** phenotype (between subjects factor) on rehabilitation outcomes (within-subjects factor):
  - **Test #2** groups: Independent (BI score ≥80) vs Dependent (at any degree, BI score <80),
  - **Test #3** groups: High risk of fall (TUG time ≥14 sec) vs Low risk of fall (TUG time <14 sec)
- Spearman correlation tests to investigate whether the measured improvements different evaluation scales/tests depend on each other.

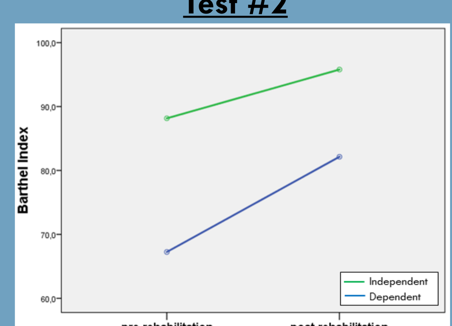
Results:

Test #1



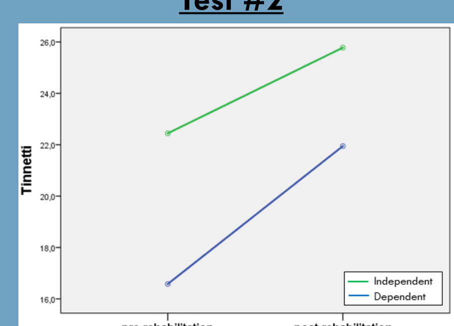
F(1, 43)=10.42, p=.002

Test #2



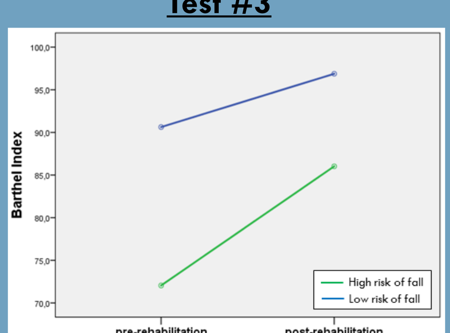
F(1, 66)=13.467, p<.0005

Test #2



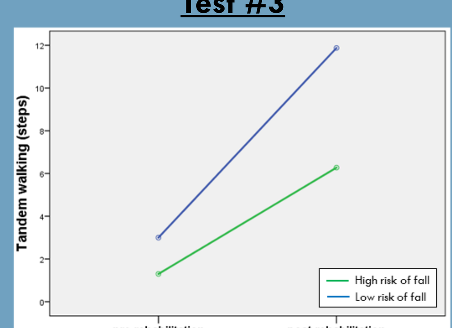
F(1, 26)=4.554, p=.042

Test #3



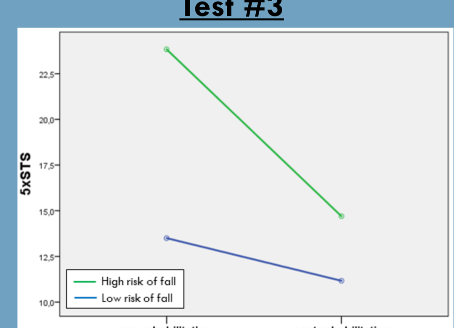
F(1, 50)=6.930, p=.011

Test #3



F(1, 46)=9.198, p=.004

Test #3



F(1, 34)=5.448, p=.026

Spearman correlations between measured improvements.

	BI	IADL	Tinnetti	Tandem	TUG	5xSTS	MMSE	GDS	G15	Vigorimeter
BI	1.00	**0.337****	0.166	0.113	**0.206****	0.005	0.140	-0.197	**0.450****	0.162
IADL		1.00	**0.204***	0.055	0.123	0.142	0.187	-0.116	**0.337***	**0.261***
Tinnetti			1.00	0.135	0.168	0.214	0.019	-0.040	**0.396***	-0.167
Tandem				1.00	0.063	0.154	0.003	-0.233	0.387	0.108
TUG					1.00	**0.458****	-0.034	-0.235	**0.447****	**0.251***
5xSTS						1.00	-0.011	-0.059	**0.392****	**0.241***
MMSE							1.00	-0.297	-0.177	0.152
GDS								1.00	-0.076	**-0.634****
G15									1.00	0.183
Vigorimeter										1.00

* p<.05, ** p<.01; level of significance.

Conclusions:

- The intervention effect analysis shows the potential of an individualised intense training for mobility [1, 2], with activities of daily living showing clearly profit from mobility training [3].
- Correlations between different evaluations suggest a potential for a reduction of the number of assessments needed to monitor patients' mobility state.

References:

[1] Wada T. *et al.*, Customized exercise programs implemented by physical therapists improve exercise-related self-efficacy and promote behavioral changes in elderly individuals without regular exercise: a randomized controlled trial, BMC Public Health;19(1):917, 2019.
[2] Guirguis-Blake J.M. *et al.*, Interventions to Prevent Falls in Older Adults: Updated Evidence Report and Systematic Review for the US Preventive Services Task Force, JAMA; 319(16):1705-1716, 2018.
[3] Forster A. *et al.*, Medical day hospital care for the elderly versus alternative forms of care, Cochrane Database Syst. Rev.; (4):CD001730, 2008.

KCL dataset analysis

Datasets description:

KCL dataset #1 features
Patient demographics
FGA score
ABC scale
FES score
EAMQ
EQ-5D self-report questionnaire
VSS scale
Dual Task TUG test
HADD and HADA scores
CANTAB (including RTI, RVPA, DM, PAL, SWM tests)

- Older subjects (≥65 years) with history of falls or at high risk of falling (TUG >15 sec) referred to falls rehabilitation.
- Randomised to two interventions:
  - modified FaME group
  - multisensory group
- 91 elders are used split in fallers and non fallers, using FGA<23 as threshold:
  - 51 participants "non fallers"
  - 40 participants "fallers"

KCL dataset #2 features
Patient demographics
FGA score
ABC scale
DHI score
SCQ
VSS scale
HADD and HADA scores
CANTAB (including RTI, RVPA, DM, PAL, SWM tests)

- 104 subjects (64 healthy-40 vestibular patients, age-matched) assessing:
  - effect of dual-task and/or cognitive task on FGA performance, gait speed and task prioritization.
  - correlations between self-reported evaluations and ability to perform complex gait test.
- Subjects are split as:
  - 64 healthy
  - 40 vestibular patients

Methodology:

Data pre-processing

- One Hot encoding of categorical features.
- Scale numerical features in [0,1].
- Impute missing values (<20%) based on k-nearest neighbours or the most-frequent value.

Feature Ranking

- Produce a ranked list of features by applying the Random Forest algorithm.

Model Selection and Identification

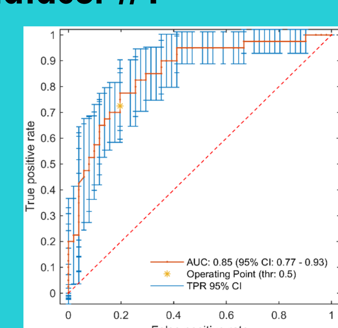
- Optimize model's hyper-parameters minimizing the 5-fold cross-validation negative logarithmic loss.
- Compute model's parameters based on the gradient tree boosting algorithm.
- Class imbalance handling (if needed) based on repeated random undersampling to negate the effects in classification performance.

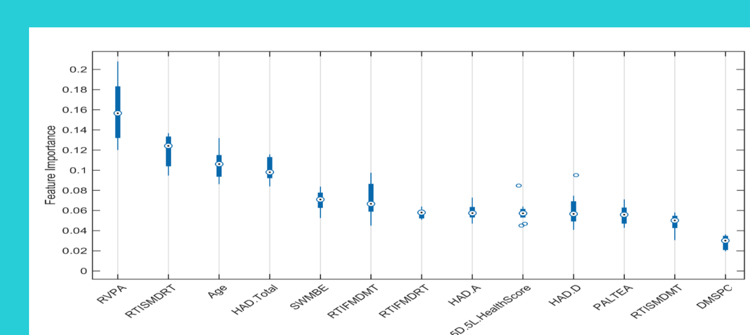
Model Evaluation

- Evaluate model's performance (e.g. sensitivity, specificity) over 10-fold cross-validation.

Results:

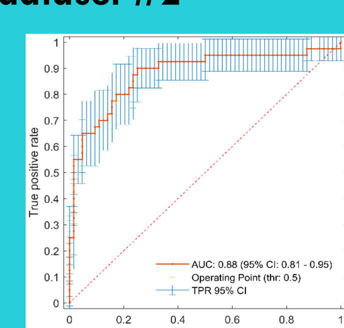
- **KCL dataset #1**

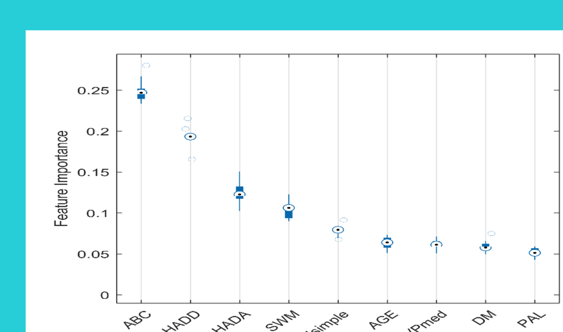




Classification performance (ROC AUC, left) and feature importance ranking (right) excluding all baseline evaluation scales as input to the model except from EQ and HAD.

- **KCL dataset #2**





Classification performance (ROC AUC, left) and feature importance ranking (right) excluding all baseline evaluation scales as input to the model except from ABC and HAD-D/A.

Conclusions:

- Digital cognitive measures may provide a novel and valuable biomarker for risk of falls assessment in older adults, allowing for early detection and implementation of preventive intervention strategies.
- Subjective measures of balance confidence (ABC), depression and anxiety (HAD-D/A), along with digitized assessment of cognition (CANTAB) can reliably discriminate healthy subjects from vestibular patients.

References:

[1] Maver S.L. *et al.*, Lower limb reaction time discriminates between multiple and single fallers, Physiother Theory Pract.; 27(5):329-36, 2011.
[2] O'Halloran A.M. *et al.*, Falls and falls efficacy: the role of sustained attention in older adults, BMC Geriatr., 19; 11:85, 2011.
[3] Nagamatsu L.S. *et al.*, Mind-wandering and falls risk in older adults, Psychol Aging.; 28(3):685-691, 2013.

EMBalance/NKUA dataset analysis

Datasets description:

EMBALANCE dataset features	
Broad category	Number of features
Patient demographics	2
Clinical examination	14
Vestibular tests	2
Auditory tests	15
Ear intervention	3
Disabilities	5
Symptoms	24
Autonomic symptoms	7
Vertigo triggering symptoms	14
Medication	27
Other treatment	11
Disease diagnosis	22

- 1000 patients diagnosed with peripheral and central vestibular disorders
- Patients from UCL, UKLFR, NKUA and Univ. of Antwerp
- More than 160 variables available
- After preprocessing, 247 patients with vestibular rehabilitation as a module of their treatment plan:
  - 147 patients characterized as "Improved"
  - 100 patients as "Not improved"

NKUA dataset features
Age
Gender
Duration of symptoms
Diagnosis
DHI score (baseline and discharge)
FGA score (baseline and discharge)

- 200 patients diagnosed with peripheral and central vestibular disorders
- 8 variables available
- Improvement defined as a difference of 18 points for DHI in pre- and post-rehabilitation scores
- 200 patients with vestibular rehabilitation as a module of their treatment plan:
  - 136 patients "Improved"
  - 64 patients "Not improved"

Methodology:

- Extensive search in the available feature space for each dataset to isolate the most informative features.
- Classification process with the RIPPER algorithm, rule learning-based classifier which provides classification rules that can be interpreted in human language ("If (condition1) and/or (condition2) then class=…").
- Cost-sensitive classification is performed (if needed) to negate the effects of class imbalance in classification performance.
- 10-fold cross-validation, using fold one for testing and the remaining nine for training interchangeably.

Results:

EMBalance Classification Rules		
Factor associated with no improvement of symptoms	Cases	False Positives
Diagnosis of Psychological Disorders	19.8	0.5
Diagnosis of Migrainous vertigo (Vestibular Migraine)	10.3	1.7
Diagnosis of Unilateral Peripheral Vestibular Dysfunction/Failure	69.5	22.7
Having headache as symptom	91.1	29.5
Having hearing loss in both ears	20.7	7.1
Having difficulty walking in darkness	20.7	7.1
Having difficulty walking on uneven surfaces	22.3	8.7
Having oscillopsia	4.0	0.0
NKUA Classification Rules		
Duration of symptoms >= 24 months AND FGA at baseline <= 23	14.0	0.0

Conclusions:

Patients who should be considered for VRT are those:

- with stable central or peripheral vestibular deficits
- of recent onset
- with relatively intact psychological, acoustic, visual and proprioceptive systems.

Patients who are <u>not</u> good candidates for VRT are those:

- with unstable lesions, i.e. those with fluctuating symptoms of imbalance
- with mental comorbidities (especially anxiety)
- having headaches as a comorbid symptom

References:

[1] Hall C.D. *et al.*, Vestibular Rehabilitation for Peripheral Vestibular Hypofunction: An Evidence-Based Clinical Practice Guideline: American Physical Therapy Association Neurology Section, *J Neurol Phys Ther*, vol. 40, no. 2, pp. 124-55, 2016.
[2] Goto F. *et al.*, Analysis of Factors Affecting the Outcomes of In-hospitalized Vestibular Rehabilitation in Patients With Intractable Dizziness, *Otol Neurotol*, vol. 38, no. 3, pp. 368-372, 2017.
[3] Alghadir A.H. & Anwer S., Effects of Vestibular Rehabilitation in the Management of a Vestibular Migraine: A Review, *Front Neurol*, vol. 9, p. 440, 2018.

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