Gender/sex effects in predicting cognitive outcomes after traumatic brain injury: A machine learning analysis of published data

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Introduction

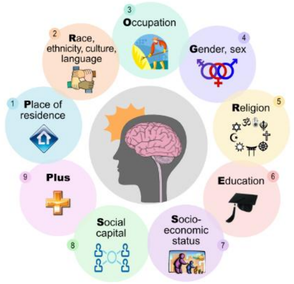

Fig.1: PROGRESS-Plus framework[2]

- Traumatic brain injury (TBI) is an injury caused by an external force
- Its recovery and cognitive outcomes vary based on social variables that intersect with each other (Fig.1)
- Data-driven research can capture the role of many variables in outcomes simultaneously

Objectives

1. To describe the process of preparing data for machine learning (ML) to predict cognitive outcomes after TBI
2. To present preliminary findings on how samples' gender/sex composition affects the prediction after TBI

Methods

- We published the study protocol[3] and registered it on PROSPERO (CRD42024547456)
- We followed the process depicted in Fig. 2

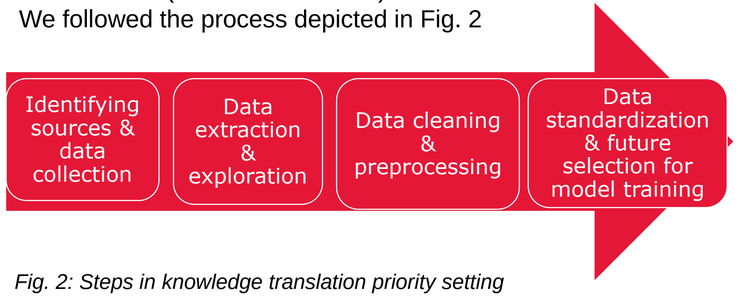

Fig. 2: Steps in knowledge translation priority setting

Results

- We included 30 cohort studies that investigated cognitive outcomes after TBI
- We extracted 219 cognitive data points and 22 PROGRESS-Plus data points of 2,364 participants with TBI (72% male, mean age 32 years; 55% mild, 45% moderate/severe TBI)
- We had 34 data point outcomes for mild TBI and 37 for moderate/severe TBI
- We report results on moderate/severe TBI (Figs.3-5)
- High correlations resulted in the need of principal component analysis (PCA, Figs 3,4)

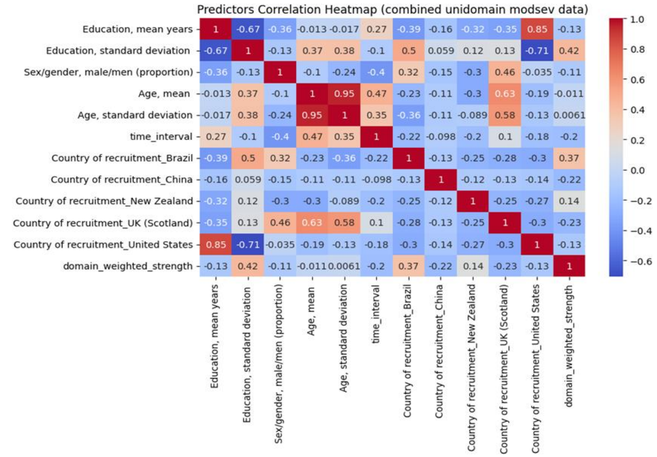

Fig.3: Correlation heat map between PROGRESS-Plus parameters and change in cognition

index	PC1	PC2	PC3
Education, mean years	-0.38158795152113334	0.4894080513397468	-0.259380897571164
Education, standard deviation	0.434992214168068 66	-0.2723624092478349	-0.5554711640808702
Country of recruitment_United States	-0.4209771464394825	0.42599033983351453	-0.05655874428333918
Age, mean	0.4169507773427187	0.465700265262628	-0.169838857055754
Age, standard deviation	0.40434095253300983	0.4704924172397797	-0.23441708896211697
Country of recruitment_UK (Scotland)	0.38808645225095983	0.258052041137558	0.7329241675176464

Fig.4: Results of PCA

Results, continued

- The strength of the association between gender/sex variable (proportion of the sample) and change in cognition was 0.41, 0.33, and 0.38 for moderate/severe TBI, when using gradient boosting, random forest model, XGBoost algorithms, respectively (Fig. 5)

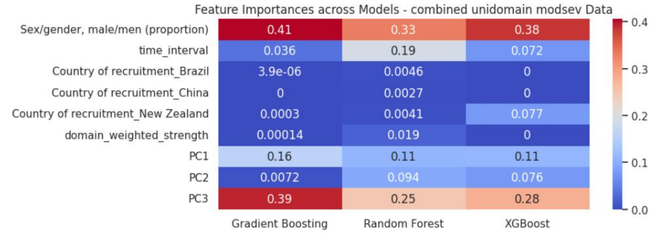

Fig.4: Association between gender/sex variable and change in cognitive outcomes for moderate/severe TBI

Key lessons learned

- PROGRESS-Plus data gaps shows limited representation of key groups with TBI in research → high generalizability bias
- The prototype tool we developed in this project provides meaningful results that raise enthusiasm, confirming the value of ML approaches in making use of the TBI data

Future Steps

- The underlying ML models, while promising, require further refinement to improve accuracy and reliability, particularly when working with sparse data.

References

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2. Cochrane. https://methods.cochrane.org/equity/projects/evidence-equity/progress-plus
3. Orhan, F., Kurutkan, M.N. BMC Health Serv Res https://doi.org/10.1186/s12913-025-12502-5

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