Supplementary material

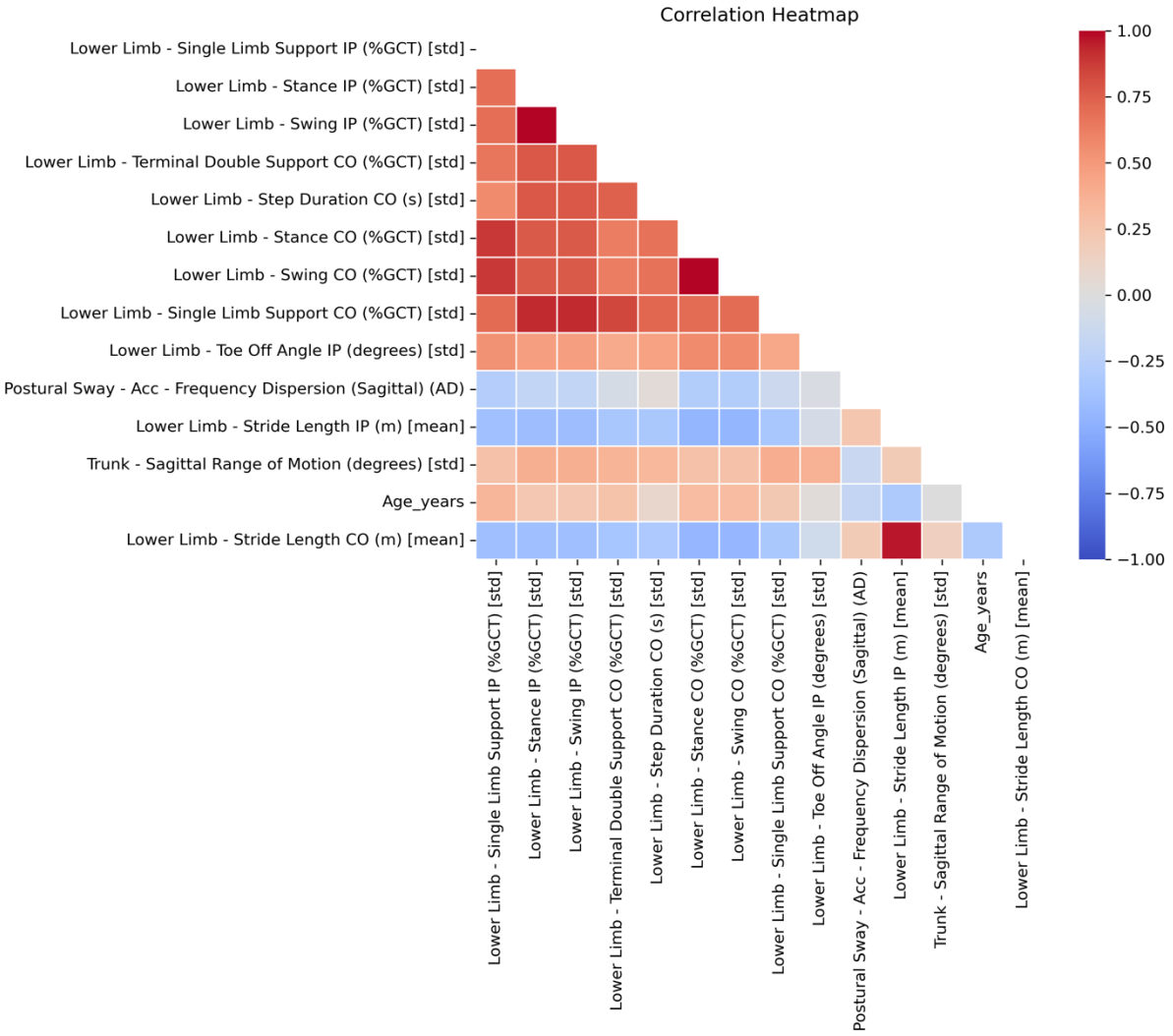
Supplementary Table 1 – List of features used in the current analysis. Asterisk (*) indicates the features that showed significant difference between fallers and non-fallers.

Lower Limb - Cadence IP (steps/min) [mean]
Lower Limb - Cadence IP (steps/min) [std]
Lower Limb - Cadence CO (steps/min) [mean]
Lower Limb - Cadence CO (steps/min) [std]
Lower Limb - Double Support IP (%GCT) [mean]
Lower Limb - Double Support IP (%GCT) [std]
Lower Limb - Double Support CO (%GCT) [mean]
Lower Limb - Double Support CO (%GCT) [std]
Lower Limb - Elevation at Midswing IP (cm) [mean]
Lower Limb - Elevation at Midswing IP (cm) [std]
Lower Limb - Elevation at Midswing CO (cm) [mean]
Lower Limb - Elevation at Midswing CO (cm) [std]
Lower Limb - Gait Cycle Duration IP (s) [mean]
Lower Limb - Gait Cycle Duration IP (s) [std]
Lower Limb - Gait Cycle Duration CO (s) [mean]
Lower Limb - Gait Cycle Duration CO (s) [std]
Lower Limb - Gait Speed IP (m/s) [mean]
Lower Limb - Gait Speed IP (m/s) [std]
Lower Limb - Gait Speed CO (m/s) [mean]
Lower Limb - Gait Speed CO (m/s) [std]
Lower Limb - Lateral Step Variability IP (cm)
Lower Limb - Lateral Step Variability CO (cm)
Lower Limb - Circumduction IP (cm) [mean]
Lower Limb - Circumduction IP (cm) [std]
Lower Limb - Circumduction CO (cm) [mean]
Lower Limb - Circumduction CO (cm) [std]
Lower Limb - Foot Strike Angle IP (degrees) [mean]
Lower Limb - Foot Strike Angle IP (degrees) [std]
Lower Limb - Foot Strike Angle CO (degrees) [mean]
Lower Limb - Foot Strike Angle CO (degrees) [std]
Lower Limb - Toe Off Angle IP (degrees) [mean]
Lower Limb - Toe Off Angle IP (degrees) [std] *
Lower Limb - Toe Off Angle CO (degrees) [mean]
Lower Limb - Toe Off Angle CO (degrees) [std]
Lower Limb - Single Limb Support IP (%GCT) [mean]
Lower Limb - Single Limb Support IP (%GCT) [std] *
Lower Limb - Single Limb Support CO (%GCT) [mean]
Lower Limb - Single Limb Support CO (%GCT) [std] *
Lower Limb - Stance IP (%GCT) [mean]
Lower Limb - Stance IP (%GCT) [std] *
Lower Limb - Stance CO (%GCT) [mean]
Lower Limb - Stance CO (%GCT) [std] *

Lower Limb - Step Duration IP (s) [mean]
Lower Limb - Step Duration IP (s) [std]
Lower Limb - Step Duration CO (s) [mean]
Lower Limb - Step Duration CO (s) [std] *
Lower Limb - Stride Length IP (m) [mean] *
Lower Limb - Stride Length IP (m) [std]
Lower Limb - Stride Length CO (m) [mean] *
Lower Limb - Stride Length CO (m) [std]
Lower Limb - Swing IP (%GCT) [mean]
Lower Limb - Swing IP (%GCT) [std] *
Lower Limb - Swing CO (%GCT) [mean]
Lower Limb - Swing CO (%GCT) [std] *
Lower Limb - Terminal Double Support IP (%GCT) [mean]
Lower Limb - Terminal Double Support IP (%GCT) [std]
Lower Limb - Terminal Double Support CO (%GCT) [mean]
Lower Limb - Terminal Double Support CO (%GCT) [std] *
Lower Limb - Toe Out Angle IP (degrees) [mean]
Lower Limb - Toe Out Angle IP (degrees) [std]
Lower Limb - Toe Out Angle CO (degrees) [mean]
Lower Limb - Toe Out Angle CO (degrees) [std]
Lumbar - Coronal Range of Motion (degrees) [mean]
Lumbar - Coronal Range of Motion (degrees) [std]
Lumbar - Sagittal Range of Motion (degrees) [mean]
Lumbar - Sagittal Range of Motion (degrees) [std]
Lumbar - Transverse Range of Motion (degrees) [mean]
Lumbar - Transverse Range of Motion (degrees) [std]
Trunk - Coronal Range of Motion (degrees) [mean]
Trunk - Coronal Range of Motion (degrees) [std]
Trunk - Sagittal Range of Motion (degrees) [mean]
Trunk - Sagittal Range of Motion (degrees) [std] *
Trunk - Transverse Range of Motion (degrees) [mean]
Trunk - Transverse Range of Motion (degrees) [std]
Upper Limb - Arm Swing Velocity IP (degrees/s) [mean]
Upper Limb - Arm Swing Velocity IP (degrees/s) [std]
Upper Limb - Arm Swing Velocity CO (degrees/s) [mean]
Upper Limb - Arm Swing Velocity CO (degrees/s) [std]
Upper Limb - Arm Range of Motion IP (degrees) [mean]
Upper Limb - Arm Range of Motion IP (degrees) [std]
Upper Limb - Arm Range of Motion CO (degrees) [mean]
Upper Limb - Arm Range of Motion CO (degrees) [std]
Turn Velocity (degrees/s) [mean]
Turn Velocity (degrees/s) [std]
Steps in Turn (#) [mean]
Steps in Turn (#) [std]
Postural Sway - Acc - 95% Ellipse Axis 1 Radius (m/s^2)
Postural Sway - Acc - 95% Ellipse Axis 2 Radius (m/s^2)
Postural Sway - Acc - 95% Ellipse Rotation (radians)
Postural Sway - Acc - Sway Area (m^2/s^4)
Postural Sway - Acc - Centroidal Frequency (Hz)
Postural Sway - Acc - Centroidal Frequency (Coronal) (Hz)

Postural Sway - Acc - Centroidal Frequency (Sagittal) (Hz)
Postural Sway - Acc - Frequency Dispersion (AD)
Postural Sway - Acc - Frequency Dispersion (Coronal) (AD)
Postural Sway - Acc - Frequency Dispersion (Sagittal) (AD) *
Postural Sway - Acc - Jerk (m^2/s^5)
Postural Sway - Acc - Jerk (Coronal) (m^2/s^5)
Postural Sway - Acc - Jerk (Sagittal) (m^2/s^5)
Postural Sway - Acc - Mean Velocity (m/s)
Postural Sway - Acc - Mean Velocity (Coronal) (m/s)
Postural Sway - Acc - Mean Velocity (Sagittal) (m/s)
Postural Sway - Acc - Path Length (m/s^2)
Postural Sway - Acc - Path Length (Coronal) (m/s^2)
Postural Sway - Acc - Path Length (Sagittal) (m/s^2)
Postural Sway - Acc - RMS Sway (m/s^2)
Postural Sway - Acc - RMS Sway (Coronal) (m/s^2)
Postural Sway - Acc - RMS Sway (Sagittal) (m/s^2)
Postural Sway - Acc - Range (m/s^2)
Postural Sway - Acc - Range (Coronal) (m/s^2)
Postural Sway - Acc - Range (Sagittal) (m/s^2)
MDS-UPDRS-III_total
MOCA_total
Age_years *
Disease duration

<u>Supplementary Figure 1</u> Correlation matrix of the selected features for 60 months' time. Collinearities were evident within the selected features list, with strong correlations particularly among the gait variability features. Therefore, the models chosen to predict future fallers were selected because they perform well in the presence of collinearities.



<u>Supplementary Table 2</u> – Mann-Whitney U statistics for significant features for the 60-month time window

FEATURE	MANN-WHITNEY U	P-VALUE
LOWER LIMB - TOE OFF ANGLE IP (DEGREES) [STD]	1140.0	0.0018
LOWER LIMB - SINGLE LIMB SUPPORT IP (%GCT) [STD]	1201.5	0.0002
LOWER LIMB - SINGLE LIMB SUPPORT CO (%GCT) [STD]	1142.5	0.0017
LOWER LIMB - STANCE IP (%GCT) [STD]	1173.5	0.0006
LOWER LIMB - STANCE CO (%GCT) [STD]	1148.0	0.0014
LOWER LIMB - STEP DURATION CO (S) [STD]	1077.0	0.0012
LOWER LIMB - STRIDE LENGTH IP (M) [MEAN]	457.0	0.0024
LOWER LIMB - STRIDE LENGTH CO (M) [MEAN]	464.0	0.003
LOWER LIMB - SWING IP (%GCT) [STD]	1173.5	0.0006

LOWER LIMB - SWING CO (%GCT) [STD]	1148.0	0.0014
LOWER LIMB - TERMINAL DOUBLE SUPPORT CO (%GCT) [STD]	1158.5	0.001
TRUNK - SAGITTAL RANGE OF MOTION (DEGREES) [STD]	1126.0	0.0028
POSTURAL SWAY - ACC - FREQUENCY DISPERSION (SAGITTAL)	454.5	0.0023
AGE_YEARS	1124.5	0.0028

Supplementary Table 3 – Model performance evaluation

MODEL	HYPER-PARAMETERS	ACCURACY	PRECISION	RECALL	F1	ROC-AUC	ROC-AUC 95% CI LOWER	ROC-AUC 95% CI UPPER	TIME WINDOW (MONTHS)	FEATURE SET (ALL/SELECTED)	CLINICO-DEMOGRAPHICS INCLUDED (YES/NO)
LOG_REG	{'clf__C': 0.0031958012947468166, 'clf__max_iter': 2132, 'clf__solver': 'newton-cg', 'threshold': 0.4557782935917123}	0.92	0.883	1.0	0.931	0.967	0.85	1.0	24	all	Yes
RF	{'clf__n_estimators': 1611, 'clf__max_depth': 28, 'clf__min_samples_split': 6, 'clf__min_samples_leaf': 3, 'clf__max_features': 'log2', 'threshold': 0.3896642860695312}	0.84	0.8	1.0	0.876	0.967	0.85	1.0	24	all	Yes
XGB	{'clf__max_depth': 20, 'clf__n_estimators': 1163, 'clf__learning_rate': 0.03901758155814582, 'clf__subsample': 0.8087678236908055, 'clf__colsample_bytree': 0.3289839451991656, 'clf__min_child_weight': 1, 'clf__scale_pos_weight': 15.287063329122024, 'thres	0.88	0.883	0.9	0.865	0.9	0.8	1.0	24	all	Yes
ELASTIC_NET	{'clf__C': 0.3539925110867631, 'clf__l1_ratio': 0.21101297273980643, 'threshold': 0.2638918207845958}	0.92	0.883	1.0	0.931	0.967	0.85	1.0	24	all	Yes
SVM	{'clf__C': 18.417379710276947, 'clf__kernel': 'linear', 'clf__gamma': 2.2066080427722197, 'clf__degree': 2, 'threshold': 0.44441217013110923}	0.887	0.883	0.933	0.891	0.967	0.85	1.0	24	all	Yes
LOG_REG	{'clf__C': 0.26897846822404786, 'clf__max_iter': 1303, 'clf__solver': 'sag', 'threshold': 0.20495003515533272}	0.92	0.883	1.0	0.931	0.967	0.85	1.0	24	all	No
RF	{'clf__n_estimators': 1194, 'clf__max_depth': 39, 'clf__min_samples_split': 11, 'clf__min_samples_leaf': 6, 'clf__max_features': 'log2', 'threshold': 0.43943314192880295}	0.88	0.883	0.933	0.891	0.967	0.85	1.0	24	all	No
XGB	{'clf__max_depth': 65, 'clf__n_estimators': 1884, 'clf__learning_rate': 0.017265755823930758, 'clf__subsample': 0.6041990595039644, 'clf__colsample_bytree': 0.5142043041554412,	0.84	0.833	0.9	0.836	0.867	0.65	1.0	24	all	No

ELASTIC_NET	'clf__min_child_weight': 1, 'clf__scale_pos_weight': 6.407414089018169, 'thres {'clf__C': 25.770874102861562, 'clf__l1_ratio': 0.8026110897984811, 'threshold': 0.25392576867921995}	0.92	0.883	1.0	0.931	0.967	0.85	1.0	24	all	No
SVM	{'clf__C': 199.80152798543273, 'clf__kernel': 'linear', 'clf__gamma': 0.5911733057714688, 'clf__degree': 2, 'threshold': 0.4353063683428038}	0.92	0.883	1.0	0.931	0.967	0.85	1.0	24	all	No
LOG_REG	{'clf__C': 2.3962368855975105, 'clf__max_iter': 1113, 'clf__solver': 'sag', 'threshold': 0.23651968528040954}	0.92	0.883	1.0	0.931	0.967	0.85	1.0	24	selected	Yes
RF	{'clf__n_estimators': 1928, 'clf__max_depth': 59, 'clf__min_samples_split': 5, 'clf__min_samples_leaf': 3, 'clf__max_features': 'log2', 'threshold': 0.4515188890070245}	0.84	0.85	0.933	0.865	0.933	0.8	1.0	24	selected	Yes
XGB	{'clf__max_depth': 28, 'clf__n_estimators': 396, 'clf__learning_rate': 0.03537805263742179, 'clf__subsample': 0.7287082880755303, 'clf__colsample_bytree': 0.6170373651127488, 'clf__min_child_weight': 1, 'clf__scale_pos_weight': 11.949015906299234, 'thresh	0.92	0.883	1.0	0.931	0.867	0.65	1.0	24	selected	Yes
ELASTIC_NET	{'clf__C': 16.149733534459454, 'clf__l1_ratio': 0.19522477318519407, 'threshold': 0.1401421587363022}	0.92	0.883	1.0	0.931	0.967	0.85	1.0	24	selected	Yes
SVM	{'clf__C': 0.003422465684088275, 'clf__kernel': 'linear', 'clf__gamma': 0.7059288175689866, 'clf__degree': 3, 'threshold': 0.4137859111229378}	0.92	0.883	1.0	0.931	0.967	0.85	1.0	24	selected	Yes
LOG_REG	{'clf__C': 0.9202071986835539, 'clf__max_iter': 1912, 'clf__solver': 'liblinear', 'threshold': 0.26101694468144165}	0.92	0.883	1.0	0.931	0.967	0.85	1.0	24	selected	No
RF	{'clf__n_estimators': 1815, 'clf__max_depth': 56, 'clf__min_samples_split': 5, 'clf__min_samples_leaf': 3, 'clf__max_features': 'log2', 'threshold': 0.4604917632766704}	0.88	0.883	0.933	0.891	0.933	0.8	1.0	24	selected	No
XGB	{'clf__max_depth': 25, 'clf__n_estimators': 1441, 'clf__learning_rate': 0.0877673357652389, 'clf__subsample': 0.8754395360252616, 'clf__colsample_bytree': 0.5187519517473727, 'clf__min_child_weight': 1, 'clf__scale_pos_weight': 10.16525861519159, 'thresho	0.92	0.883	1.0	0.931	0.867	0.65	1.0	24	selected	No

ELASTIC_NET	{'clf__C': 2.5476395643027065, 'clf__l1_ratio': 0.6852508515754069, 'threshold': 0.3440449604112895}	0.92	0.883	1.0	0.931	0.967	0.85	1.0	24	selected	No
SVM	{'clf__C': 0.005921083452658545, 'clf__kernel': 'linear', 'clf__gamma': 1.9669215856292483, 'clf__degree': 5, 'threshold': 0.3567451270650225}	0.92	0.883	1.0	0.931	0.967	0.85	1.0	24	selected	No
LOG_REG	{'clf__C': 0.005642086188488141, 'clf__max_iter': 714, 'clf__solver': 'sag', 'threshold': 0.545600680242065}	0.74	0.893	0.59	0.678	0.676	0.215	0.978	60	all	Yes
RF	{'clf__n_estimators': 1533, 'clf__max_depth': 38, 'clf__min_samples_split': 21, 'clf__min_samples_leaf': 4, 'clf__max_features': 'sqrt', 'threshold': 0.5023481832290014}	0.742	0.808	0.72	0.72	0.778	0.453	0.975	60	all	Yes
XGB	{'clf__max_depth': 69, 'clf__n_estimators': 1756, 'clf__learning_rate': 0.0005433709951144718, 'clf__subsample': 0.9905655545211147, 'clf__colsample_bytree': 0.45750649846014624, 'clf__min_child_weight': 1, 'clf__scale_pos_weight': 9.061855669409242, 'thr	0.698	0.741	0.68	0.673	0.71	0.323	0.967	60	all	Yes
ELASTIC_NET	{'clf__C': 0.06088388286812541, 'clf__l1_ratio': 0.37512236048430037, 'threshold': 0.5165499764027633}	0.74	0.92	0.58	0.652	0.694	0.227	0.984	60	all	Yes
SVM	{'clf__C': 0.001577389532512457, 'clf__kernel': 'poly', 'clf__gamma': 16.718616090057317, 'clf__degree': 3, 'threshold': 0.5226084282511976}	0.607	0.833	0.31	0.432	0.459	0.022	0.919	60	all	Yes
LOG_REG	{'clf__C': 0.005393294307290948, 'clf__max_iter': 852, 'clf__solver': 'liblinear', 'threshold': 0.5297318355566222}	0.718	0.86	0.55	0.635	0.666	0.205	0.978	60	all	No
RF	{'clf__n_estimators': 1720, 'clf__max_depth': 56, 'clf__min_samples_split': 6, 'clf__min_samples_leaf': 4, 'clf__max_features': 'sqrt', 'threshold': 0.5167365470221826}	0.7	0.764	0.68	0.682	0.738	0.39	0.975	60	all	No
XGB	{'clf__max_depth': 40, 'clf__n_estimators': 1523, 'clf__learning_rate': 0.0010866361219808275, 'clf__subsample': 0.9896743893751013, 'clf__colsample_bytree': 0.6835330180368607, 'clf__min_child_weight': 1, 'clf__scale_pos_weight': 3.498467330178081, 'thre	0.718	0.827	0.64	0.666	0.658	0.239	0.975	60	all	No
ELASTIC_NET	{'clf__C': 0.042849851622108616, 'clf__l1_ratio': 0.21058763953491505, 'threshold': 0.49941009313963086}	0.696	0.833	0.59	0.624	0.772	0.332	1.0	60	all	No

SVM	{'clf__C': 0.030846198418782673, 'clf__kernel': 'poly', 'clf__gamma': 4.998807815398268, 'clf__degree': 4, 'threshold': 0.5506922994372738}	0.567	0.7	0.23	0.313	0.5	0.152	0.867	60	all	No
LOG_REG	{'clf__C': 0.7744747828794467, 'clf__max_iter': 2142, 'clf__solver': 'liblinear', 'threshold': 0.5045445296312534}	0.784	0.9	0.71	0.742	0.81	0.41	1.0	60	selected	Yes
RF	{'clf__n_estimators': 1858, 'clf__max_depth': 53, 'clf__min_samples_split': 16, 'clf__min_samples_leaf': 3, 'clf__max_features': 'log2', 'threshold': 0.5990544046759362}	0.784	0.96	0.63	0.712	0.848	0.519	1.0	60	selected	Yes
XGB	{'clf__max_depth': 28, 'clf__n_estimators': 137, 'clf__learning_rate': 0.00761805803260816, 'clf__subsample': 0.777047964205214, 'clf__colsample_bytree': 0.7429468604292498, 'clf__min_child_weight': 9, 'clf__scale_pos_weight': 15.477691016018344, 'thresho	0.784	0.92	0.68	0.719	0.812	0.479	0.992	60	selected	Yes
ELASTIC_NET	{'clf__C': 0.6049813921417699, 'clf__l1_ratio': 0.7428944242438275, 'threshold': 0.4884238159906587}	0.807	0.9	0.75	0.778	0.8	0.388	1.0	60	selected	Yes
SVM	{'clf__C': 0.006733533204648455, 'clf__kernel': 'linear', 'clf__gamma': 0.0007107851511125971, 'clf__degree': 5, 'threshold': 0.5192326659196909}	0.807	0.96	0.67	0.76	0.83	0.509	1.0	60	selected	Yes
LOG_REG	{'clf__C': 0.7213436763518033, 'clf__max_iter': 923, 'clf__solver': 'sag', 'threshold': 0.5015732300425518}	0.807	0.927	0.71	0.76	0.828	0.452	1.0	60	selected	No
RF	{'clf__n_estimators': 1085, 'clf__max_depth': 33, 'clf__min_samples_split': 5, 'clf__min_samples_leaf': 4, 'clf__max_features': 'log2', 'threshold': 0.6121568440899445}	0.784	0.96	0.63	0.712	0.812	0.482	1.0	60	selected	No
XGB	{'clf__max_depth': 70, 'clf__n_estimators': 1247, 'clf__learning_rate': 0.0034069563196480945, 'clf__subsample': 0.5264444276434259, 'clf__colsample_bytree': 0.43372511563091226, 'clf__min_child_weight': 2, 'clf__scale_pos_weight': 14.309653925856248, 'th	0.784	0.96	0.63	0.712	0.788	0.428	1.0	60	selected	No
ELASTIC_NET	{'clf__C': 7.240237570756752, 'clf__l1_ratio': 0.16377671036581645, 'threshold': 0.6030452811371839}	0.807	0.96	0.66	0.74	0.772	0.432	1.0	60	selected	No
SVM	{'clf__C': 0.04781126512504679, 'clf__kernel': 'linear', 'clf__gamma': 0.027506361130383673, 'clf__degree': 2, 'threshold': 0.5305281243732878}	0.807	0.92	0.71	0.773	0.8	0.401	1.0	60	selected	No

Supplementary Table 4 – Confusion Matrix for the 60-month time period. Non-faller cohort (N=74) was resampled to match the sample of fallers (N=23).

True label	**non-faller**	**22**	**1**
	faller	**9**	**14**
		non-faller	**faller**
	Predicted label		

Supplementary Table 5 – Range of Hyperparameters Tuned

MODEL	PARAMETER	RANGE/CHOICES
LOGISTIC REGRESSION	C	1e-4 to 1e2
	max_iter	100 to 3000
	solver	['liblinear', 'newton-cg', 'sag']
RANDOM FOREST	n_estimators	100 to 2000
	max_depth	10 to 80
	min_samples_split	5 to 50
	min_samples_leaf	2 to 20
	max_features	['sqrt', 'log2', None]
XGBOOST	max_depth	20 to 70
	n_estimators	100 to 2000
	learning_rate	1e-4 to 1e-1
	Sub_sample	0.5 to 1.0
	Col_sample_bytree	0.3 to 0.8
	min_child_weight	1 to 20
	scale_pos_weight	1 to 20
ELASTIC NET	C	1e-4 to 1e2
	l1_ratio	0.1 to 0.9
SVM	C	1e-4 to 1e4
	kernel	['linear', 'rbf', 'poly', 'sigmoid']
	gamma	1e-4 to 1e2
	degree	2 to 5