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Ver.	Date	Status	Author (Beneficiary)	Description
2.5.1	24/1/18	Draft	Marina Kotsani (INSERM) Eva Zacharaki (UoP) Spiros Kaloyannis (UoP)	First Draft
2.5.2	28/1/18	Draft	Athanase Benetos (INSERM)	Several Revisions
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2.5.4	31/1/18	Final	Marina Kotsani (INSERM) Athanase Benetos (INSERM)	Contributions' integration and final corrections

EXECUTIVE SUMMARY

The present report (D2.5) constitutes the second version of the deliverable 2.4 Completion of quantification campaign.

It's first version (D2.4, M18) reported the specific tests targeted to the quantification and the optimization of the FrailSafe framework, whereas, the present version provides some results indicating the correlation of several parameters monitored by the FrailSafe devices with selected clinical parameters, in order to identify those that are more performant in identifying frailty.

This deliverable is related to task 2.2 Clinical monitoring of older people, in the context of which participants of the study are followed up for a period of time and monitored for their frailty level and its transition, by several clinical and technological means. Data collected during this follow up are integrated into the FrailSafe system framework, build up a clinically annotated database of divers variables and can be used to more precisely and early quantify frailty aspects, identify risk profiles, construct prediction models and quantify and fine-tune the intervention services that will be developed in WP5. Collected data are analysed with several tools such as cluster, spectral and factor analysis, so as to reveal indicators that are descriptive of frailty triggering events and risk assessment models (WP4).

The main focus of the present deliverable is to point out the role of selected clinical parameters in highlighting the most relevant FrailSafe devices'-derived variables that will contribute to the most pertinent frailty prediction model. More detailed reference to the approach towards the detection of patterns and associations between clinical indicators and frailty states, and the analysis of multidimensional time series towards revealing associations among signals and symptoms that are connected to the frailty syndrome is presented in the deliverable D4.1_Offline analysis of data (M24), as well as the usage of existing and new developed techniques within the FrailSafe project towards offline data management, preprocessing and analysis.

After the introductory section (1), the present deliverable briefly mentions selected clinical and technical frailty metrics that have been employed in the presented analysis (2 and 3). A more detailed presentation of these metrics has been presented in D2.4.

In section 4 follows a brief presentation of the procedure of data analysis, the details of which are presented in D4.2.

Section 5 presents the main results of the correlation between several variables of the FrailSafe integrated system, aiming at revealing the first indications of the most pertinent technical metrics in terms of prediction of clinical frailty status.

DOCUMENT INFORMATION

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Status	Draft ☐		Final ☒	
Nature	Report ☒	Demonstrator ☐	Other ☒ (data)	
Dissemination Level	Public ☒	Consortium ☐		
Abstract (for dissemination)	The deliverable reports on the clinical and technical metrics that are employed for the quantification of various frailty aspects, their interrelationship and their integration process into the FrailSafe system framework in order to develop frailty biomarkers, prediction models and eventually preventive strategies in the stage of the final integrated FrailSafe product.			
Keywords	Quantification, clinical metrics, technical metrics, integration process, interrelationship between variables, aspects of frailty, system fine-tunning, system calibration, validation, prediction, biomarkers.			

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Table of contents

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List of Tables

List of abbreviations and acronyms

(*in alphabetic order*)

BMI	Body Mass Index
D	Deliverable
ECG	Electrocardiogram
GDS-15	Geriatric Depression Scale 15 items
GPS	Global Positioning System
IMU	Inertial Measurement Units
MMSE	Mini Mental State Examination
MNA	Mini Nutritionnel Assessment
MoCA	Montreal Cognitive Assessment
TUG	Timed get Up and Go test
WP	Work Package
WWBS	Wearable WBAN System
WWS	Wearable Wellness System

1. Introduction

One of the main purposes of this project is to identify and propose new frailty metrics. For operational and methodological reasons since the beginning of the study the Fried's classification of frailty status has been employed (1). Still, the objectives of the study go beyond the detection of the predictive value and the description of the evolution of the frailty status according to Fried's phenotype. They rather aspire to construct, fine-tune and optimise a combined frailty metric and prediction model, integrating data obtained by various resources.

On the one hand, these resources refer to classical evaluations and measurements conducted into the framework of Comprehensive Geriatric Assessment (CGA). This source of information, even though widely recognized and highly appreciated as the gold standard method to evaluate frailty aspects in a comprehensive and reliable way, it also bears some restrictions and inherent drawbacks, as described previously in D 2.4.

Almost contradictory to the idea of reliable early screening of high risk profiles is the fact that in order to identify the persons who will most likely benefit from early interventions, we employ rapidly administered but not always sensitive enough tools, often lacking the opportunity of early detection of mild subclinical phenotypes.

The FrailSafe framework aims to surpass these disadvantages by proposing a novel model of health care delivery.

The integrated FrailSafe approach proposes an ecological, real-time, large scale monitoring system, where multiple objective data are available for analysis, virtual patient modelling, algorithmic processing, individualised profile determination, and tailored interventional propositions. The latter could be a personalised guidance program delivered by technological means in an adjustable frequency and intensity, fine-tuned by the very system's feedback loop.

However, before reaching its ultimate goal as a complete early diagnosis and intervention system, the FrailSafe framework has to be tested and validated for its detection and prognostic properties. These prognostic properties cannot be evaluated before the end of the study period, since a capable amount of time is required in order the study's outcomes to emerge and detectable and clinically meaningful differences to occur. On the other hand, the frailty detection properties of each and every item of the FrailSafe system can be evaluated, by correlating the results obtained by the FraiSafe devices, with selected clinical indices that are though to be the most performant and representative to reflect multi-domain frailty status.

2. Clinical metrics

Clinical evaluation assesses eleven domains of the general health and well-being status of a person and investigates the multiple aspects of frailty, beyond classical frailty operational definitions. These domains are: medical health status, general condition, lifestyle habits, physical performance, nutritional condition, cognitive performance, psychological situation, social context, materialistic environmental context and self-assessment of wellness.

Table 1 summarizes the domains assessed during the clinical evaluation sessions and the most important items composing each domain, which were examined for correlations with the metrics obtained from the FrailSafe devices. More details about this categorization, as well as about the possible relation of each item with the FrailSafe devices' metrics are presented in D2.4 (M18). The table also includes the statistical nomination of each variable, as it is presented in section 5 of the present deliverable.

Table 1. Clinical metrics. Domains investigated by the clinical evaluation and nomination of the variables for the statistical analysis.

Items		**Variable's statistical name**
Medical Domain (M)	Number of Comorbidities (M)	comorbidities_number
	Comorbidity's impact (M, P, s, ψ)	significant_comorbidities_number
	Polymedication (M, p, c)	medication_number
	Hospitalisations (M)	*Hard outcome-not analysed in that stage*
	Orthostatic hypotension (M, p)	ortho_hypotension
	Visual impairment (M, S, p)	vision
	Hearing impairment (m, S, c)	audition
General Condition Domain (M, ψ)	Unintentional weight loss (M, ψ)	weight_loss
	Self-reported exhaustion (M, p, ψ)	exhaustion
Lifestyle domain (P, M, ψ,s)	Smoking (M, ψ, p, s)	smoking
	Alcohol (M, Ψ, S)	alcohol_units
	Physical Activity (P, M, ψ, s)	activity_regular
Functional capacity domain (M, P, s, c, Ψ)	Basic Activities of Daily living (M, P, s, c, Ψ)	*Hard outcome-not analysed in that stage*
	Instrumental Activities of Daily Living (M, P, s, c, Ψ)	*Hard outcome-not analysed in that stage*
Physical	Balance (single foot standing) (P,	balance_single

Condition (P, m, c)	m)	
	Gait-related task speed* (P, c) (Timed Get Up and Go test)	gait_get_up gait_get_up_nom
	Gait - speed 4 m (P, m)	gait_speed_4m
	Lower limb strength (P, m)	raise_chair_time
	Grip strength –dynamometer (P, m)	grip_strength_abnormal
	Low physical activity (P, M, s, ψ)	low_physical_activity
	Falls (P, m, Ψ)	*Hard outcome-not analysed in that stage*
	Fractures (P, M)	*Hard outcome-not analysed in that stage*
Nutritionnal domain (M, Ψ, c, s)	Too low BMI (M, Ψ, p, c, s)	bmi_score
	Too high BMI (M, Ψ, P, c, s)	bmi_score
	High waist circumference (M, Ψ, P, c, s)	waist
	Lean body mass (M, P, ψ)	lean_body_mass
	MNA screening and total (when applicable) score (M, Ψ, p, c, s)	mna_screening_score mna_screening_score_nom mna_total mna_total_nom
Cognitive Domain (C, ψ, m, s)	MMSE scores (C, ψ, m)	mmse_total_score
	MoCA score (C, ψ, m)	MoCA_score MoCA_score_nom
	Subjective memory complaint (C, ψ, m, s)	memory_complain
	Natural language analysis (C, Ψ)	*Not suitable for the present correlation analysis*
Psychological Domain (Ψ, S, c)	GDS-15*(Ψ, S, c)	depression_total_score depression_total_score_nom
	Self-rated anxiety (Ψ, S, c)	anxiety_perception anxiety_perception_nom
	Natural language analysis (C, Ψ)	*Not suitable for the present correlation analysis*
Social Domain (S, Ψ, m)	Living conditions (S, Ψ, p, m)	*Not suitable for the present correlation analysis*
	Leisure activities (S, Ψ, p, m)	leisure_out leisure_out_nom
	Membership of a club (S, Ψ, p, m)	leisure club
	Number of visits and social interactions per week (S, Ψ, p)	social_visits social_visits_nom
	Number of telephone calls exchanged per week (S, ψ, m)	social_calls social_calls_nom
	Approximate time spent on phone per week (S, ψ, m)	social_phone social_phone_nom
	Approximate time spent on	social_skype

	videoconference per week (S, ψ)	social_skype_nom
	Number of written messages sent by the participant per week (S, ψ, m, p)	social_text social_text_nom
Environmental Domain (S, P, m)	Subjective suitability of the housing environment according to participant's evaluation (S, P, m)	house_suitable_participant
	Subjective suitability of the housing environment according to investigator's evaluation (S, P, m)	house_suitable_professional
	Number of steps to access house (P, S, m)	stairs_number
Wellness domain (Ψ, S, M, P, c)	Quality of life self-rating (Ψ, S, M, P, c)	life_quality life_quality_nom
	Self-rated health status (M, Ψ)	health_rate
	Self-assessed change since last year (M, ψ)	health_rate_comparison
	Self-rated anxiety (Ψ, S, M, P, c)	anxiety_perception anxiety_perception_nom
	Self-rated pain (M, P, ψ)	pain_perception pain_perception_nom
Tags (reflecting impact of each item on each of the aspects of frailty) This tagging system has been employed in order to express the inter-domain interaction of the several studied parameters and the various aspects of frailty each one could depict Physical/functional: P dominant, p recessive Medical: M dominant, m recessive Social: S dominant, s recessive Cognitive: C dominant, c recessive Psychological: Ψ dominant, ψ recessive		
Abbreviations: BMI: Body Mass Index, GDS-15: Geriatric Depression Scale 15 items, MMSE: Mini Mental State Examination, MNA: Mini Nutritional Assessment, MoCA: Montreal Cognitive Assessment.		

Detailed description of the items involved in the evaluation of each domain, the rational supporting the choice of their measuring methods and scales, their grading system, as well as the annexes of the actual questionnaires and operational procedures followed for the collection of all these data, are described in detail in the Deliverable 2.1 Clinical Study Methodology (M6, revised M12).

3. Technical metrics

The FrailSafe system devices are used during the lending of the material to the participants houses (FrailSafe sessions) and provide the technical metrics that are integrated into the FrailSafe system database.
Several technical devices and applications provide metrics that are translated into meaningful clinical measurements and, likewise the clinical metrics, reflect variable domains of frailty. The metrics derived from each FrailSafe device are described in D2.4 and D4.2.

Exploratory data analysis so far has correlated features derived from the WWBS system, the Flappy and Red Wings serious games and from the GPS application, with the aforementioned clinical parameters.

3.1 Sensorized strap/vest (WWS and WWBS)

The sensorized strap/vest which is manufactured by Smartex is equipped with a series of sensors which provide useful measurements for FrailSafe participants. These measurements can be grouped in these categories:

- ECG measurements:
  The main measurement of this category is the value of the ECG signal coupled together with a quality index which shows how accurate the measurement actual is. This helps ignoring measurements for which the quality is low because strap was not placed properly. Using the ECG signal, the vest software calculates useful clinical measurements such as Heart Rate, Heart Rate Variability, and R-R interval distance in ECG signal. These metrics, expressing cardiovascular activation patterns, in clinical terms, reflect mainly on medical, physical/functional and maybe psychological aspects of frailty.
- IMU measurements:
  The strap is equipped with a “light” IMU measuring only the participant’s specific force in X-Y-Z axis (using an accelerometer), while he/she is wearing the strap. The new vest is equipped with 3 IMUs, each one of which is capable of measuring the participant’s specific force, angular rate, and the magnetic field surrounding the body in X-Y-Z axis using accelerometer, gyroscope and magnetometer, respectively. These measurements are might not be directly connected with clinical parameters, however they are needed in order to run Fall Detection and Activity Classification algorithms. These metrics, expressing activity patterns, in clinical terms, reflect mainly on medical, physical/functional and probably social aspects of frailty.

- Respiration measurements:

  The strap is also equipped with a piezoelectric point placed on the thorax, which is used to measure the pressure on the thorax caused by the participant's breathing. The strap uses this measurement to calculate the Respiratory Rate, and the Breathing Amplitude of the participant. These metrics, expressing cardiorespiratory activation patterns, in clinical terms, reflect mainly on medical, physical/functional and maybe psychological aspects of frailty.

- Activity attributes:

  Additionally some measurements are provided about the activity the participant performs while wearing the strap. There is a simple activity recognition (lying, standing, walking, running) which however is not as accurate as the activity classification algorithm developed by the UoP. Also there is a counter measuring the number of steps the participant has done while wearing the strap, and the step period which shows how fast/slow the steps are being done. These metrics, expressing activity patterns, in clinical terms, reflect mainly on medical, physical/functional and probably social aspects of frailty. For gait speed detection, a cognitive component could be implied.

The individual features that are extracted from the WWBS system and correlated to the clinical parameters are shown in table 2. A more detailed description of the individual features of the FrailSafe devices is presented in the D4.2.

Table 2. Features derived from the WWBS system

acc_energy_1	br_energy_1	ecg_hrv_energy_1
acc_entropy_1	br_entropy_1	ecg_hrv_entropy_1
acc_kurt_1	br_kurt_1	ecg_hrv_kurt_1
acc_mean_1	br_mean_1	ecg_hrv_mean_1
acc_mode_1	br_mode_1	ecg_hrv_mode_1
acc_perc5_1	br_perc5_1	ecg_hrv_perc5_1
acc_perc95_1	br_perc95_1	ecg_hrv_perc95_1
acc_skew_1	br_skew_1	ecg_hrv_skew_1
acc_std_1	br_std_1	ecg_hrv_std_1
ba_energy_1	ecg_hr_energy_1	ecg_rr_energy_1
ba_entropy_1	ecg_hr_entropy_1	ecg_rr_entropy_1
ba_kurt_1	ecg_hr_kurt_1	ecg_rr_kurt_1
ba_mean_1	ecg_hr_mean_1	ecg_rr_mean_1
ba_mode_1	ecg_hr_mode_1	ecg_rr_mode_1
ba_perc5_1	ecg_hr_perc5_1	ecg_rr_perc5_1
ba_perc95_1	ecg_hr_perc95_1	ecg_rr_perc95_1
ba_skew_1	ecg_hr_skew_1	ecg_rr_skew_1
ba_std_1	ecg_hr_std_1	ecg_rr_std_1
Acc: accelerometer metrics; ba: breathing amplitude; br: breathing rate; ecg; electrocardiograme		

However, the results will be presented by mentioning significant correlations between clinical variables and the general features of the WWBS metrics, since each individual feature will not be recorded independently from the rest (the FrailSafe device will be administered as a single device and all relevant features will be simultaneously recorded) and, therefore, it would be meaningless to distinguish individual technical features when searching for clinical relevance. The same applies for the features derived from the GPS logger, as well as the serious games features (described bellow).

3.2 GPS logger (smartphone)

The GPS (Global Positioning System) logger application for the smartphone collects the measurements about the geographic location of the participants. The location is obtained by receiving a signal from GPS satellites, thus it is accurate only for the outdoor localization of the participant (in a macroscopic scale). The specific measurements obtained are the latitude, longitude, and elevation of each geographic location, together with the accuracy of the measurement and the orientation of the movement. The GPS logger application additionally measures the number of steps the participant has made, using the phone sensors. Combining subsequent points of the location of the participant, we can derive to other measurements with more clinical value such as the speed of movement and the gait speeds, the distances covered, the usage of vehicles and the maximum distances from the starting point expressing a large amplitude of locomotion patterns. These measurements can indicate physical/functional, medical, social and even cognitive aspects of frailty.

The individual features that are extracted from the GPS logger and correlated to the clinical parameters are shown in table 3. A more detailed description of the individual features of the FrailSafe devices is presented in the D4.2.

Table 3. Features derived from the GPS logger.

area_covered
average_walk_speed
radius_covered
stop_time_perc
total_distance
total_duration
total_steps
total_stop_time
total_vehicle_time
total_walk_time
track_avg_distance
track_avg_duration
track_max_distance
track_max_duration
track_number
vehicle_time_perc
walk_time_perc

3.3 Serious games

The flappy/red wings serious game has been developed by Brainstorm and records a log file with measurements connected with the game such as the speed that the flappy is moving, the distance it has covered, the height which is at, and the number of lives the player still has. Additionally, as the game is operated by the dynamometer, the force of the participant is being recorded. Combining the subsequent measurements of the log files, we can derive the total time the participant played the game, the total distance covered (total score), and the maximum grip strength on the dynamometer.

In clinical terms, these measurements express the grip strength and stamina, indicating overall body strength, reflecting medical and physical/functional aspects of frailty but also some elements of the cognitive function, like the executive function, the reflexes, the information and reaction treatment speed and efficacy and the concentration. This serious game, is actually an exergame, that could also give indices about the brain-motor coordination and its efficacy, reflecting both the physical/functional and the cognitive aspect of frailty, although sometimes restricted by biasing medical local conditions (wrist arthritis).
The individual features that are extracted from the serious games and correlated to the clinical parameters are shown in table 4. A more detailed description of the individual features of the FrailSafe devices is presented in the D4.2.

Table 4. Features derived from the dynamometer-related serious games.

avg_max_redwings_force	Force_mode	Lives_mode
avg_redwings_duration	Force_perc5	Lives_perc5
avg_redwings_fatigue	Force_perc95	Lives_perc95
avg_redwings_score	Force_skew	Lives_skew
Distance_energy	Force_std	Lives_std
Distance_entropy	Heigth_energy	max_redwings_duration
Distance_kurt	Heigth_kurt	max_redwings_fatigue
Distance_mean	Heigth_mean	max_redwings_force
Distance_mode	Heigth_mode	max_redwings_score
Distance_perc5	Heigth_perc5	Speed_energy
Distance_perc95	Heigth_perc95	Speed_entropy
Distance_skew	Heigth_skew	Speed_kurt
Distance_std	Heigth_std	Speed_mean
Force_energy	Lives_energy	Speed_mode
Force_entropy	Lives_entropy	Speed_perc5
Force_kurt	Lives_kurt	Speed_perc95
Force_mean	Lives_mean	Speed_skew

4. The integration process in terms of data analysis

The analysis of the FrailSafe data followed a number of steps that include the

- conversion of data
- handling of missing values and outliers
- time synchronization of different channels
- temporal mapping of the recordings to the clinical measurements
- feature extraction from the measurements of the FS devices,
- regression between FS variables and clinical metrics.

Details on the individual steps are provided in the deliverable D4.2. Briefly about the last step, it involves the estimation of a linear model that maps the set of FrailSafe variables (extracted from WWSX, games, or GPS) to the individual clinical variables that define the different clinical domains (see deliverables D2.1 and D2.4). Since the number of extracted FS variables is large and we have no prior knowledge on their importance, we performed lasso regression which –together with the model estimation– performs also feature selection, i.e. it selects a subset of variables and estimates their weights (β coefficients), while it "forces" the rest of the variables to get a zero weight. Spearman correlation is then calculated between the score that is estimated by the linear prediction model and the target variable (each clinical metric). This is performed for both numeric and ordinal variables, while categorical variables were not present in this study. The analysis was performed using the whole dataset (until end of M24) without data splits. Table 5 presents the Size of the source samples for each correlation dataset. The significance level was defined at α=0.05. All correlation results were significant (p-value<0.05), and therefore the individual p-values are not shown in the presented results.

Table 5. Size of source samples

FrailSafe system derived metric *(referring to days of recordings by each device)*	Clinical questionnaires *(referring to the closest, in terms of time, clinical evaluation to the use of each device)*
Games: 840	191
WWBS: 227	120
GPS: 1281	223

According to general convention, the Spearman's correlation index (r_s) it considered to indicate different degrees of strength of correlation according to its absolute value. This interpretation is shown in table 6.

Table 6. Spearman's correlation index interpretation according to its value.

Spearmann's absolute value	Strength of correlation
0-0.19	Very weak
0.2-0.39	Weak
0.4-0.49	Moderate
0.5-0.59	Moderate to strong
0.6-0.79	Strong
0.8-1	Very strong

5. Correlations between clinical and technical metrics

At the current stage of the study correlations have been searched between FrailSafe devices' "technical" metrics and most representative clinical parameters. The Comprehensive Geriatric Assessment that took place during the clinical evaluation visits is though to be the closest approximation to the "truth" regarding frailty status, so far. Of course, the FrailSafe project aims to highlight novel and more pertinent frailty indices, ideally based on "technical" metrics, but this procedure will be achieved after the evaluation of the proxy and hard outcomes, therefore at the end of the project. Consequently, at the present moment, the means to test and reveal the technical metrics' performance, has been to try to correlate them with clinical metrics known to reflect several aspects of frailty.

A composite metric has been derived out of each application, expressing the global performance in the tablet/dynamometer games, the GPS and the WWBS recordings, using the individual features presented in tables 2-4. In this section, we present the correlations between this composite metric and each clinical variable. This approach has been chosen over presenting the whole analysis dataset, because it is though to be more meaningful in practical means: when distributing a FrailSafe application in practice, what will be important is a simple and comprehensible metric that will carry the greatest amount of information possible, in terms of frailty detection and prediction. The composite global metric derived from various measurements from a FrailSafe application/device better serves this purpose and is more easily comprehensible and interpretable in correlation with clinical metrics.

Clinical metrics, on the other hand, had undergone separate analysis as numerical and nominal parameters, so the same variable can appear in results both ways. The exploratory character of the analysis allows such an approach in the novel operation this project attempts. The statistical nomination of clinical variables is presented in table 1.

5.1 Correlation of the clinical parameters with the WWBS metrics

Table 7 presents the results of the correlation analysis of clinical parameters with the composite metric derived from the WWBS system.

Table 7. Correlation indices between numerical and nominal clinical parameters and the WWBS composite metric

parameter	correlation
mna_total	0,97
mna_total_nom	0,84
lean_body_mass	0,67
comorbidities_number	0,67
gait_speed_4m	0,66
social_text_nom	0,61
waist	0,60
social_phone_nom	0,59
social_phone	0,59
balance_single	0,59
bmi_score	0,58
social_visits	0,58
stairs_number	0,58

life_quality	0,58
social_skype_nom	0,53
social_text	0,53
medication_number	0,52
MoCA_score	0,51
mmse_total_score	0,51
significant_comorbidities_number	0,51
activity_regular	0,50
social_calls_nom	0,49
social_visits_nom	0,48
raise_chair_time	0,47
vision	0,47
cognitive_total_score_nom	0,46
mna_screening_score	0,46
leisure_out	0,45
health_rate	0,44
grip_strength_abnormal	0,43
audition	0,43
social_calls	0,42
leisure_out_nom	0,41
smoking	0,40
alcohol_units	0,40
anxiety_perception_nom	0,40
social_skype	0,39
ortho_hypotension	0,39
memory_complain	0,37
anxiety_perception	0,37
house_suitable_participant	0,36
screening_score_nom	0,35
depression_total_score	0,35
pain_perception	0,35
leisure_club	0,34
gait_get_up_nom	0,33
depression_total_score_nom	0,33
gait_get_up	0,32
health_rate_comparison	0,31
low_physical_activity	0,30
pain_perception_nom	0,30
house_suitable_professional	0,27
life_quality_nom	0,17
weight_loss	0,17

The most significant numerical parameters collated with the WWBS metrics are the MNA total score presenting a very strong correlation (r_s= 0.97 as numerical and 0.84

as nominal variable). However, results concerning the MNA total score should be interpreted with prudence, because of the small amount of data regarding this test (MNA total test is performed only when the MNA screening test is indicative of a nutritional problem with a score <12), and it refers exclusively to persons at a high risk of malnutrition.

On the other hand, strong correlations are observed with the lean body mass (r_s= 0.67), the number of medical comorbidities (r_s= 0.67), the gait speed (r_s= 0.66), parameters mostly correlated with physical frailty, as well as the social attachment as expressed by the written texts sent by the participants (r_s= 0.61), social frailty indicator.

The presence of social frailty indices (time and the number of phone calls, the number of social visits, the number of skype calls etc) continues also in the moderate to strong correlations with the WWBS's metrics. Nutritional frailty parameters are also correlated with the composite WWBS metric (waist circumference (r_s= 0.60) and BMI (r_s= 0.58)). Similarly, some medical parameters also show moderate to strong correlations with the WWBS metrics, like the number of medication (r_s= 0.52) and the number of comorbidities with a significant impact on the person's functional status (r_s= 0.55). Physical parameters like balance (r_s= 0.59) and regular activity (r_s= 0.50), are also correlated with WWBS metrics and the same goes for the main tests reflecting global cognitive efficiency, the MMSE (r_s= 0.51) and the MoCA (r_s= 0.51) scores.

The correlation of medical parameters with the WWBS system's metrics is not a surprise, since it is mainly designed to record "medical parameters" like the ECG, the heart rate, the breathing pattern. Its seems that these measurements, along with the movement analysis properties of the WWBS is somehow capable of identifying frailty parameters that go beyond the medical and physical level, extending to nutritional, social and cognitive frailty. Quite surprisingly enough, the WWBS composite metric seems to be either moderately or at least weakly correlated with almost all clinically-derived variables. This feature holds much promise about using the WWBS system at least to identify frailty. It remains for the outcome analysis (that will be presented in D9.8) to determine if WWBS holds frailty prediction properties as well.

5.2 Correlation of clinical parameters with the GPS metrics

Table 8 presents the results of the correlation analysis of clinical parameters with the composite metric derived from the GPS application.

Table 8. Correlation indices between numerical and nominal clinical parameters and the GPS composite metric

parameter	**correlation**
mna_total_nom	0,57
mna_total	0,45
gait_speed_4m	0,38
activity_regular	0,36
waist	0,30
social_text_nom	0,30
balance_single	0,27
social_text	0,27
significant_comorbidities_number	0,26
comorbidities_number	0,26
lean_body_mass	0,24
social_visits	0,23
vision	0,23
social_visits_nom	0,23
grip_strength_abnormal	0,21
life_quality_nom	0,21
house_suitable_participant	0,20
social_phone	0,19
low_physical_activity	0,19
medication_number	0,19
anxiety_perception	0,18
pain_perception	0,18
screening_score_nom	0,17
anxiety_perception_nom	0,17
cognitive_total_score_nom	0,17
audition	0,17
leisure_out	0,17
life_quality	0,17
gait_get_up	0,16
social_phone_nom	0,16
MoCA_score	0,16
depression_total_score_nom	0,15
weight_loss	0,15
pain_perception_nom	0,15
social_skype_nom	0,15
gait_get_up_nom	0,15
depression_total_score	0,14
mna_screening_score	0,14
social_calls	0,14
leisure_out_nom	0,14
memory_complain	0,13
social_skype	0,13

smoking	0,13
house_suitable_professional	0,13
health_rate	0,13
leisure_club	0,12
social_calls_nom	0,12
mmse_total_score	0,12
stairs_number	0,11
alcohol_units	0,11
ortho_hypotension	0,11
health_rate_comparison	0,10
raise_chair_time	0,09
bmi_score	0,06

Similarly to WWBS, the strongest correlation with the GPS metrics is observed with the MNA total score, with the restrictions, however, mentioned in the previous section 5.2.

Weaker correlations are observed with the gait speed (r_s= 0.38), the presence of regular physical activity (r_s= 0.36), the balance test (r_s= 0.27) and the abnormal grip strength (r_s= 0.21), which constitute physical/functional frailty metrics.

Apart from the monitoring of the physical aspect, the GPS application roughly outlines a social frailty profile (correlations with written texts exchange and social visits frequency, both as numerical and as nominal variables).

The aspect of nutritional frailty reappears in the correlations of this application also, as expressed with the waist circumference (r_s= 0.30) and the lean body mass (r_s= 0.24).

Medical conditions are also reflected in the GPS enregistered performance, namely the number of comorbidities with a significant impact on the individual's functional status (r_s= 0.26), the number of all accumulated comorbidities (r_s= 0.26) and the visual problems (r_s= 0.23). Interestingly, a correlation, although weak, is observed between the GPS composite metric and the self-evaluated quality of life (r_s= 0.21).

5.3 Correlation of clinical parameters with the games' metrics

Table 9 presents the results of the correlation analysis of clinical parameters with the composite metric derived from the table/dynamometer games.

Table 9. Correlation indices between numerical and nominal clinical parameters and the games composite metric

parameter	correlation
gait_speed_4m	0,60
mna_total_nom	0,59
comorbidities_number	0,55
social_text_nom	0,55
balance_single	0,53
mna_total	0,49
medication_number	0,47
lean_body_mass	0,47
social_phone	0,44
social_text	0,41
social_visits	0,41
social_phone_nom	0,41
social_visits_nom	0,40
social_calls_nom	0,36
significant_comorbidities_number	0,35
grip_strength_abnormal	0,34
life_quality	0,34
social_skype	0,34
activity_regular	0,34
social_skype_nom	0,33
waist	0,32
mna_screening_score	0,32
stairs_number	0,32
MoCA_score_nom	0,31
MoCA_score	0,31
leisure_out	0,31
leisure_out_nom	0,30
social_calls	0,30
alcohol_units	0,28
low_physical_activity	0,28
mna_screening_score_nom	0,28
anxiety_perception	0,26
bmi_score	0,26
anxiety_perception_nom	0,25
pain_perception	0,24
vision	0,23

mmse_total_score	0,23
raise_chair_time	0,22
gait_get_up_nom	0,21
depression_total_score	0,20
ortho_hypotension	0,19
gait_get_up	0,19
health_rate	0,18
leisure club	0,15
house_suitable_professional	0,15
depression_total_score_nom	0,14
house_suitable_participant	0,14
life_quality_nom	0,14
health_rate_comparison	0,14
smoking	0,13
memory_complain	0,13
pain_perception_nom	0,13
audition	0,11
weight_loss	0,04

The most significant parameters showing moderate to strong correlations with the game's metrics are the gait speed (r_s= 0.60), the MNA total score (r_s= 0.59), and the number of medical comorbidities (r_s= 0.55), the number of written texts sent by the participant (r_s= 0.55) and the balance test (r_s= 0.53).

These features can be indicative of the person's physical status, since the dynamometer-dependent games require a certain physical performance and, at the same time, evaluate physical parameters, like grip strength, that reflect general physical condition (sarcopenia). This could also explain the correlations observed with lean body mass (r_s= 0.47) and abnormal grip strength (r_s= 0.34), although this latest is perharps weaker than expected. A test that also goes beyond its apparent expression of somatic performance is the gait speed test, that reflects general physical and functional status and is shown to have even hard outcome predictive properties (2-7). The gait speed is found to be strongly correlated with the games' metrics.

Games' metrics could also correlate with apparently social clinical parameters for reasons of familiarity with technological devices (those who send sms or emails regularly may be more capable of handling a tablet game). Other social parameters moderately correlated with the games' performance are the number of social visits (r_s= 0.41 as numerical and 0.40 as nominal variable), and the time spent on phone calls (r_s= 0.41), as well as their number (r_s= 0.36). So, it seems that is goes beyond a simple devices' handling dexterity and it may be that people who are more socially open are more willing to endorse to more novel and original activities, like the virtual game playing.

Surprisingly enough, global cognitive efficiency, as expressed by the MoCA test is found to be only weakly correlated with games' performance (r_s= 0.31), implying that, at least in a cross-sectional detection level, dynamometer-dependent virtual games reflect mostly physical rather than cognitive parameters of frailty. Similarly the correlation between the games and the MMSE is also weak (r_s= 0.23). It remains to see, in the latest phase of the study, if there is any indication of prediction of cognitive frailty longitudinally, according to the initially recorded performance in games.

6. References

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