Assessment of nutritional status and its correlations during the rehabilitation of severe brain-injured patients

PhD thesis

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List of abbreviations

ANCOVA – Analysis of Covariance

AND/ASPEN – Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition

BAPEN – British Association of Parenteral and Enteral Nutrition

BIA – Bioelectrical Impedance Analysis

BIVA – Bioelectrical Impedance Vector Analysis

BMI – Body Mass Index

CT – Computer Tomography

DEXA – Dual Energy X-ray Absorptiometry

EBM – Evidence Based Medicine

ECW/TBW ratio – Extracellular/Total Body Water ratio

ESPEN – European Society for Clinical Nutrition and Metabolism

FFM – Fat-free Mass

FFMI – Fat-free Mass Index

FIM – Functional Independence Measure

FM – Fat Mass

FMI – Fat Mass Index

GCS – Glasgow Coma Scale

GLIM – Global Leadership Initiative on Malnutrition

HFJ – High Frequency Jet Ventilation

IARN – International Association of Rehabilitation Nutrition

ICU – Intensive Care Unit

IL1 – Interleukin 1

IL6 – Interleukin 6

IQR – Interquartile Range

JARN – Japanese Association of Rehabilitation Nutrition

mBMI – Modified Body Mass Index

MNA – Mini Nutritional Assessment

MR – Magnetic Resonance

MUST – Malnutrition Universal Screening Tool

NIV – Non-invasive Ventilation

NRS 2002 – Nutritional Screening Tool 2002

PEG – Percutaneous Endoscopic Gastrostomy

SCI – Spinal Cord Injury

SE – Standard Error

SGA – Subjective Global Assessment

SMM – Skeletal Muscle Mass

SMMI – Skeletal Muscle Mass Index

SNST – Spinal Nutrition Screening Tool

STROBE-nut – Strengthening the Reporting of Observational Studies in Epidemiology-Nutritional Epidemiology

TBI – Traumatic Brain Injury

TBW – Total Body Water

TNFα – Tumour Necrosis Factor Alpha

I. Introduction

1.1. Definition and epidemiology of malnutrition

Malnutrition is a nutritional state that leads to a deterioration of function due to unfavourable changes in body composition, which includes undernutrition and overnutrition, and the relative or absolute absence or excess of one or more nutrients. The concept of sarcopenia was first noted in the 1980s as the age-related loss of lean body mass, leading to reduced mobility and reduced independence. Since 2010, the definition has been supplemented by consensus with the simultaneous reduced muscle function, but the diagnostic tools and cut-off points that can be used to identify sarcopenia are still not completely clear to professionals. (1) Malnutrition and sarcopenia are recognized public health problems worldwide, which affect 15-30% of patients in hospitals and nursing homes. This rate reaches 30-50% among patients admitted to inpatient rehabilitation institutions. (2) Malnutrition can increase the number of complications during rehabilitation and worsen outcomes. Inadequate and/or deteriorating nutritional status may negatively affects the patient's active participation and the effectiveness of rehabilitation, causes secondary complications and increases the cost of care. (3-4)

A recent systematic review of studies published between 2015 and 2020 (5) found that inadequate initial nutritional status often leads to further nutritional deterioration ranging from 2% to 65% of hospitalised patients. A few researches used body mass index (BMI = the quotient of the square of body weight in kilograms and the square of body height in metres) and modified BMI (mBMI = multiplying BMI by the serum albumin in grams/litre) as an indicator of malnutrition. A few utilised validated screening tools (Nutritional Risk Screening 2002 – NRS 2002 and Malnutrition Universal Screening Tool – MUST). The rest of the studies used assessment tools such as the Mini Nutritional Assessment (MNA), Subjective Global Assessment (SGA), the diagnostic criteria of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition (AND/ASPEN), of the European Society for Clinical Nutrition and Metabolism (ESPEN), and of the Global Leadership Initiative on Malnutrition (GLIM). The highest level of nutritional deterioration was reported for neurological patients (38%-65%) when malnutrition was assessed using a screening tool. At the same time, 91% of acute stroke patients were well-nourished at the time of admission. Comparing results of the articles is difficult, because different screening and assessment methods were used in the studies. Table 1. summarizes the most frequently used malnutrition risk screening and assessment tools.

Table 1. Approaches of the most frequently used malnutrition risk screening and assessment tools (6-7)

	Screening tools		**Assessment tools**				
	Malnutrition Universal Screening Tool (MUST, 2004)	**Nutritional Risk Screening 2002 (NRS 2002, 2003)**	**Subjective Global Assessment (SGA, 1987)**	**Mini nutritional assessment (MNA, 1996)**	**AND/ASPEN Criteria for malnutrition (2012)**	**ESPEN criteria for malnutrition (2015)**	**GLIM (2019)**
Reduced food intake	x	x	x	x	x	x	x
Severity of illness/inflammation	x	x	x	x	x	x	x
Anorexia			x	x			
Weakness			x	x			
Loss of weight unintentionally	x	x	x	x	x	x	x
BMI	x	x		x		x	x
Lean/fat-free/muscle mass			x	x	x	x	x
Fat mass			x		x		
Fluid retention			x		x		
Muscle function (e.g. grip strength)			x		x		
Overall validity	All inpatients and outpatients	All inpatients	Cancer, surgery, liver diseases	Elderly	Awaiting for validation	All inpatients and outpatients	Awaiting for validation

AND/ASPEN=Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition; ESPEN=European Society for Clinical Nutrition and Metabolism; GLIM=Global Leadership Initiative on Malnutrition; BMI=Body Mass Index

1.2. Problems of nutritional status assessment and malnutrition diagnosis

Malnutrition and cachexia are conditions that can be defined in different ways and can be difficult to categorize, yet only a limited number of examinations and laboratory methods are available in clinical settings for their assessment and diagnosis.

1.2.1. Malnutrition risk screening

Malnutrition screening is often confused with the terminology nutritional assessment in the clinical practice, but while screening is a quick and easy procedure with a questionnaire, assessment is a deeper exploration of nutritional status (8).

Hospital acquired malnutrition is still unacceptably high. One of the problem's major reasons is that the use of nutrition screening seems to be low priority in care settings even though there are many available internationally validated tools already, whereas their utilization has limitations like using them in their own, they are not sensitive enough to various diseases and there is still no consensus concerning which tools are the best for general use. (9) In outpatient care, the use of risk screening is not routinely performed at all. (10) Applicable malnutrition screening tools for rehabilitation patients have not been investigated till the last few years even though malnutrition is associated with worse outcome in this population. (11)

In spite of the fact that the prevalence of malnutrition in patients with traumatic brain injury (TBI) and spinal cord injury (SCI) is notorious and well-documented, there is still very limited specialized literature information on the screening methods that can be used in these patient groups, and the existing studies used different tools. So, there is a need of finding patient group-specific nutritional screening and assessing methods that are sensitive enough in order to realize individualized patient care in rehabilitation settings. (12) However, Spinal nutrition screening tool (SNST) exists that is unvalidated in Hungary yet (13), and which could be used in Hungarian rehabilitation medicine, but it became clear that due to poor validation study designs and results, it is inadequate to make recommendations for malnutrition screening based on current validation evidence alone. (14) Specialized screening test for brain-injured people has not yet been developed. (15)

1.2.2. Malnutrition diagnostic criteria systems

During the past 30 years, many different malnutrition diagnostic tools have been evolved and validated in different populations and different levels of health care settings. The exact number of methods created so far is not known, but an exploratory search found more than 100 alternatives with approaches that help to decide for professionals whether a patient could be identified and treated as malnourished or not. (16)

In order to develop an internationally uniform system of the diagnostic criteria for malnutrition, the working group formed from the biggest international clinical nutrition societies launched an initiative in 2016, during which a two-step criteria system for diagnosing malnutrition was developed (Global Leadership Initiative on Malnutrition, GLIM criteria) on a consensus basis, but this is still waiting for validation. As a first step, screening must be performed using a validated malnutrition risk screening scale chosen arbitrarily. As a second step, it is necessary to evaluate the diagnostic elements of the screened patients, which were divided into phenotypic (reduced body weight, low BMI, low muscle mass) and etiological (reduced food intake or assimilation, disease burden/inflammatory condition) groups. We face with diagnosis of malnutrition if at least one phenotypic and at least one etiological factor exists, and the severity of malnutrition must be considered based on the phenotypic elements. (7)

1.2.3. Body composition measurement by bioelectrical impedance analysis

Nowadays professionals can choose from many devices for body composition analysis, from different imaging methods (dual energy X-ray absorptiometry (DEXA), CT, MR, bedside ultrasound) to bioelectrical impedance analysis (BIA) devices. Each method has different advantages and disadvantages. In addition to calculating fat-free mass (FFM), fat mass (FM), skeletal muscle mass (SMM), total body water (TBW) and fat-free mass index (FFMI), professional BIA devices provide further calculations. (17) Such is the tracking of phase angle, with which we obtain specific data regarding the total cell mass, and the bioelectrical impedance vector analysis (BIVA) is suitable for determining the cell membrane, cell integrity and cell functions. These advanced calculations are suitable for determining the initial nutritional status and for monitoring the effectiveness of the intervention (18). In 2004, the recommendation of the European Society for Clinical Nutrition and Metabolism (ESPEN) was published for the first time in Europe, according to which the body composition analysis based on BIA measurement is suitable for examining the body composition of both healthy and sick people. (19-20) In their 2015 guideline, the pathological cut-off values of the FFMI for men and women were accepted. (21) Although we are aware of many known limitations of BIA-based analysis (22-23), and we must be careful when interpreting the obtained results, based on the scientific researches so far, it is remarkably effective in hypertensive pathology, sports, women health and elderly. Furthermore, the phase angle and BIVA tests provide promising results for predicting meta-inflammation, assessing differences between different types of diabetes therapy, in cancer cachexia and in impaired fluid balance. (24)

1.3. „Rehabilitation nutrition”

Researches on the issue of rehabilitation nutrition began to unfold in the last decade, mainly through the work of the Japanese Association of Rehabilitation Nutrition (JARN), which was established in 2011. The Association created the term "rehabilitation nutrition" in order to separate nutrition therapy integrated into rehabilitation therapy – which supports higher functionality and quality of life – from the previously existing terminology of "nutritional rehabilitation" (which deals mainly with hunger in developing countries). On their initiative, the International Association of Rehabilitation Nutrition (IARN) was founded in 2019, with the aim of starting research on rehabilitation nutrition at an international level and having high-evidence results. In its systematic review and meta-analysis published in 2020, JARN pointed out that for many patient groups in rehabilitation, we do not have clinical guidelines that deal with feeding/nutrition problems and provide help in solutions. Guidelines for the rehabilitation of certain pathologies, such as cerebrovascular diseases, hip fractures, and oncology patients, barely mention the importance of nutrition. (25) A review published in 2021 discusses the role of nutritional status in relation to functionality and self-care of patients admitted to rehabilitation. It summarized the results of previous studies on the clear positive effects of changes in FM and SMM on the outcome. Despite this, we do not yet have a malnutrition diagnostic method that can be used to monitor the nutritional status of patients in rehabilitation institutions and its changes in an objective, accurate, and reproducible way. (26)

1.4. Special issues of nutritional status in the case of severe brain-injured patients

Dietitians working in both critical care and rehabilitation of brain injured people need to make efforts to become acquainted with the interventions, equipment and medications (specifically regarding drug-nutrient interactions), to provide that their nutritional assessments and therapy recommendations are adequate and safe. (27)

1.4.1. Anthropometry

In addition, patients are often bedridden and immobile, making accurate weight and height measurements really challenging. In some cases, it is possible to weigh patients with beds with built-in scales, but the resulting weights should be interpreted with caution when weight-based equations are used. Oedema and fluid retention can cause weight gain of 10–20% in a single day, making anthropometric measurements commonly used elsewhere imprecise. (27) It is possible to estimate height, but it should be considered that the estimation methods, e.g. ulna length or knee height are not validated for critically ill patients. Thus, they prove to be informative only. (28-29)

1.4.2. Metabolic response following brain injuries

In order to a better understanding of body composition changes following brain injuries, the known processes till now of the biochemical responses may help. The changes that arise following stress are different from those to starvation. Those alterations are standing for mobilising tissues in an attempt to survive as a compensatory progress. This mechanism takes priority even in the presence of starvation, although the cause of the processes is not yet fully clarified. (27) TBI may cause an abnormal conditioning of nervous, endocrine and inflammatory systems in order to enable a continuous supply of substrates for cell growth and repair. These changes may be caused by a metabolic response to stress and by direct injury to the brain, which is the main organ responsible for regulation and homeostasis. Possible changes in regulatory systems can be traced back to the following alterations (30):

- Increased production of proinflammatory cytokines tumour necrosis factor alpha (TNFα), interleukin 1 (IL-1) and interleukin 6 (IL-6)
- Increased circulation of hormones (catecholamines, glucagon, cortisol)
- Production of acute phase proteins (e.g. C-reactive protein) from liver and muscles

- Increased cardiac output and hypertension, leading to elevated CO_2 production and O_2 consumption

Depending on the extent of affected brain areas, homeostasis, nervous system and endocrine regulation are impaired. The consequences are not fully elucidated processes, abnormal cell metabolism and strong cerebral and systemic inflammatory reactions are probable (the purpose of which is to mobilize metabolic substrates for the metabolism of damaged cells). The result is systemic catabolism, leading to hyperglycaemia, protein loss, and increased energy requirements. (31) These alterations lead to the decrease of FFM and SMM (therefore a large amount of metabolically active cell loss occurs), which, in addition to structural roles, also function as an autocrine, paracrine, endocrine organs in the synthesis of vital essential molecules and in the mobilization of metabolic substrates. Effective nutritional therapy can play a major role in easing the catabolic response and prolonged hypermetabolism. (32) Figure 1. summarises the complex biochemical alterations following TBI for a better understanding.

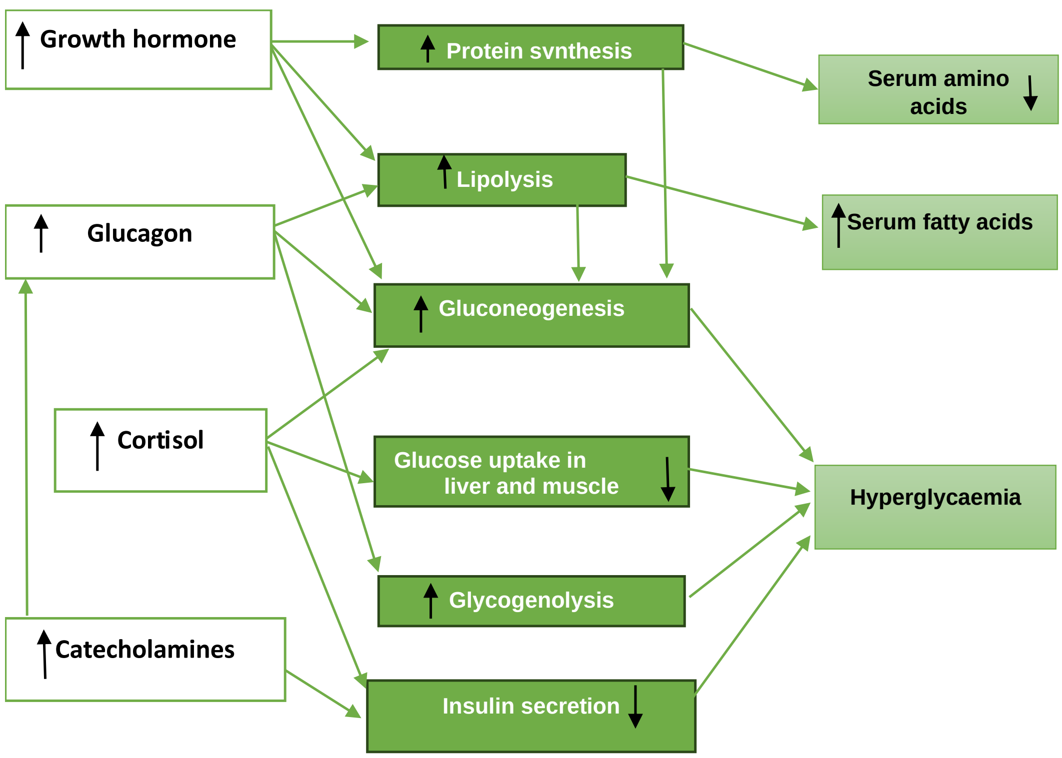


Figure 1. Metabolic responses to traumatic brain injury (TBI) (30)

II. Objectives

1. The main objective of these studies is to develop a nutritional status assessment method that can be used in rehabilitation inpatient care which is able to monitor the realization of the set dietary goals.
2. Our goal is to assess the applicability of internationally validated malnutrition risk screening methods and anthropometric measurements in inpatient rehabilitation patient groups.
3. Our goal is to explore the nutritional characteristics and problems of severe brain-injured patients, to observe their nutritional documentation used in the supply chain of health care, and to explore the correlations of body composition measured upon admission to rehabilitation and to compare these correlations between severe brain-injured patients and other patient groups in rehabilitation.
4. Our further goal is to investigate the suitability of BIA-based body composition analysis in order to monitor the effects of set dietary goals, taking into account independent parameters influencing body composition outside of therapy. Figure 2. below illustrates the theoretical connection and interdependence of our objectives.

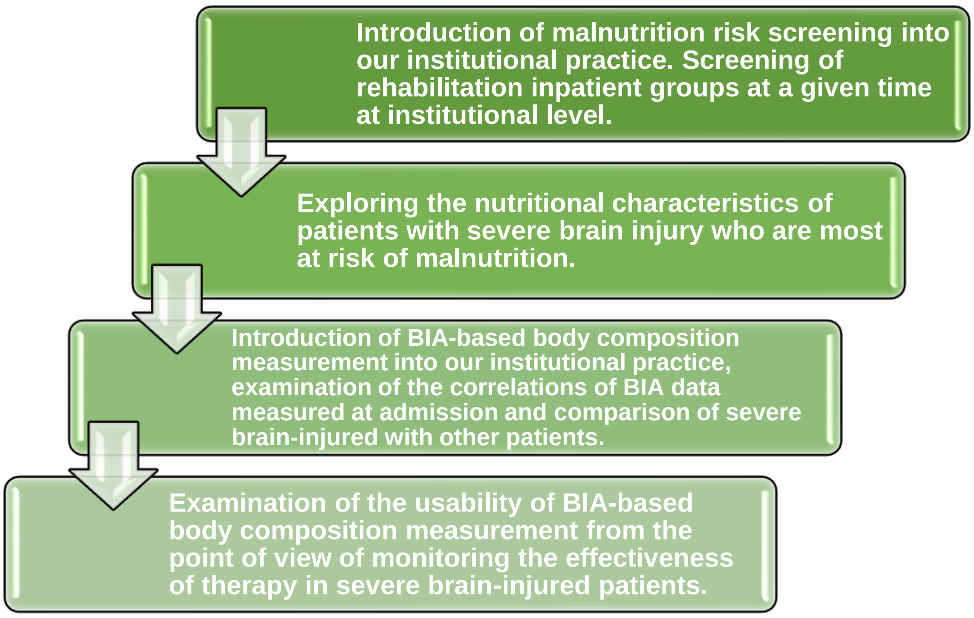


Figure 2. The structure of our researches

2.1. General hypotheses

I assume that the internationally validated malnutrition risk screening methods are not sensitive for rehabilitation patient groups and can be used least of all in the case of severe brain-injured patients.

I assume that severe brain-injured patients' nutritional status and its changes cannot be established and followed through anthropometric examinations and BMI calculations by using them alone, despite the fact that a significant positive change in their impairment and disability status can be detected.

I assume that the FMI and SMMI of traumatic brain-injured patients are significantly lower compared to stroke patients.

2.2. Correlation type hypotheses

I assume that the logical strong positive correlations of BMI with fat mass and skeletal muscle mass is significantly weakened in the case of severe brain injuries.

I assume that fat mass and skeletal muscle mass do not always correlate in rehabilitation patient groups.

I assume that the extracellular/total body water (ECW/TBW) ratio correlates with BMI, fat mass, skeletal muscle mass and phase angle, and more expressed negative correlations can be demonstrated in the case of brain-injured individuals.

I assume that in brain-injured patients, the phase angle presents significant positive correlations with FFMI, skeletal muscle mass and fat mass.

I assume that the time spent in the ICU has a negative correlation with FMI and SMMI.

2.3. Variance type hypotheses

I assume that changes in the body composition of severe brain-injured patients and the effectiveness of the therapy can be monitored using a BIA-based body composition measuring device during their rehabilitation and that significant positive changes can also be detected in the FMI and the SMMI.

I assume that the changes in FIM scores, FMI and SMMI values are significantly influenced by the cause of injury, age, gender and the number of days spent in the ICU.

III. Methods

Our one-centred researches followed the tenets of the Declaration of Helsinki and was approved by the Institutional Ethics Committee (reference number: 19/2018/10/31) of the National Institute for Medical Rehabilitation of Hungary (that is a part of the National Institute of Locomotor Diseases and Disabilities). During our studies, no intervention other than the Institution's dietetic practice took place. Informed consent was obtained from all patients or their relatives.

3.1. Patients

3.1.1. Institutional malnutrition risk screening in inpatient rehabilitation

The cross-sectional survey lasted five days in December 2018 and was carried out by the dietitians of the Institute on all inpatients at the given time. If necessary, physiotherapists were involved in case of patients who were difficult to mobilize. 331 patients were included in the study, during which they were screened for the risk of malnutrition using the MUST screening method. The World Health Organisation’s body mass index classification was used to assess BMI. (33) During the anthropometric measurements, upper arm circumference and the ulna length/height percentile were used in some cases due to the dietetically challenging specialization of the Institute. (28-29) Height was estimated based on the ulna length in case of 2 patients, and the BMI of 5 patients was inferred based on their upper arm circumference. In addition to the demographic and anthropometric data, the types of diets and the formulas, as well as their quantities were recorded.

3.1.2. Exploring the nutritional characteristics of severe brain-injured patients during early rehabilitation

A prospective observational study was carried out between 01.10.2018 and 30.09.2020. in the Institution's Brain Injury Early Rehabilitation Department (Coma Centre). Anthropometric examination and malnutrition risk screening were performed using the NRS 2002 method within 48 hours after admission and upon discharge. (34) The impairment and disability scales were recorded at admission and at discharge. We summarized the nutrition related diagnoses based on the anthropometric examinations and food consumption. To monitor the energy and nutrient intake, we used a Per os intake documentation data sheet kept by the nurses. Energy and nutrient values consumed were calculated with the help of CT-Ecostat software. We also collected the secondary complications detected when the patients were admitted, the factors affecting their nutrition, and the information about preliminary nutrition therapy found in the documentation.

Clinical nutrition was developed with the help of a dietitian and a speech-language therapist integrated into the multi-professional rehabilitation team. The calculation of the energy and nutrient dosage target value was determined based on simplistic weight-based equations. The target intake values were calculated based on current body weight. The energy target value for a BMI value of 50 and above, and the protein targets for a BMI value of 30 and above were calculated with reference to ideal body weight. (35) The ideal body weight was determined using the modified Broca index (men: ideal body weight (kg) = [height (cm) - 100] x 0,9), women: ideal body weight (kg) = [height (cm) - 100] x 0,85). (36) The treatment of the patients on 8 beds at the Coma Centre was managed by an intensive care specialist. Depending on their condition, functional disorders and load ability, a specialist nurse, dietitian, physiotherapist, music therapist, psychologist, and speech-language therapist dealt with the patient from 7 a.m. to 2 p.m. Among the patients admitted and treated for post-acute rehabilitation at the Coma Centre, 73 patients with severe brain injury could be included in the study. As an exclusion criterion, a patient who did not meet the documented criteria for severe brain injury (Glasgow Coma Scale value was below 8 for at least 24 hours) or who spent less than a week at the Unit could not be included in the study.

3.1.3. Examining the correlations of body composition upon admission to rehabilitation

During our next cross-sectional study, the malnutrition risk screening was supplemented by BIA-based body composition analysis when patients were admitted to rehabilitation care. In May 2021, 41 patients were included in the study unintentionally, if the measurements could be performed within 48 hours after admission. The correlations of the body composition of the heterogeneous sample in terms of underlying diseases were further investigated in the breakdown of severe brain-injured and mixed patient groups. The NRS 2002 scale was used for malnutrition risk screening, and the Seca mBCA 525

BIA device was used for body composition examination. Exclusion criterion was an implanted pacemaker or any other implanted electrical device.

3.1.4. Changes in body composition of severe brain-injured patients during rehabilitation

We examined the changes in body composition of brain-injured patients through a prospective observational study in the Brain Injury Rehabilitation Unit. Inclusion of the patients was carried out between 02 May and 01 June 2022. Nutritional epidemiology (STROBE-nut) statement was used. (37) The NRS 2002 method was used for malnutrition risk screening. BIA-based portable Seca mBCA 525, and Seca mBCA 515 (in case of patients who were able to stand) were used for body composition analysis. The inclusion criterion was admission to inpatient rehabilitation for traumatic brain TBI or stroke. The exclusion criterion was implanted pacemaker or any other implanted electronic device. Of 64 potentially eligible participants, 22 were included in the study (Figure 3.).

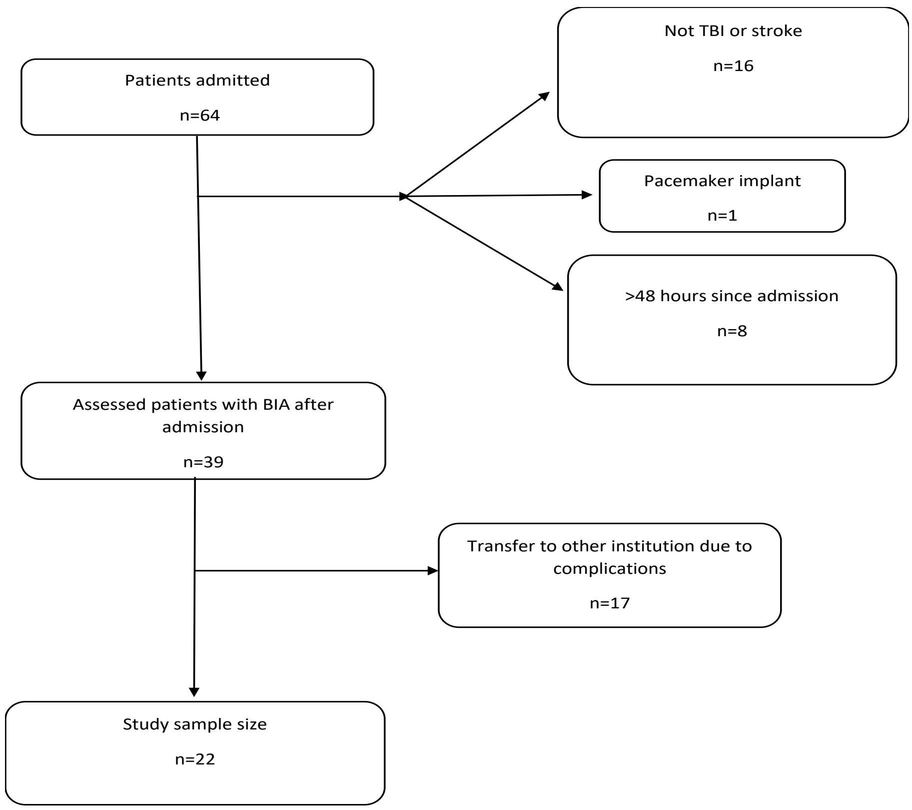


Figure 3. Flow chart of the study Changes in body composition of severe brain-injured patients during rehabilitation

Inpatient rehabilitation was provided by a multi-professional team led by a rehabilitation physician consisting of activation nursing, nutritional therapy, physical therapy, occupational therapy and neuropsychology (minimum 3 hours daily). According to current recommendations (38-39) 25-30kcal/kg/d (average 1800-2200kcal) and 1-2g/kg/d protein content diets were provided in the form of a normal diet (8 oral and 4 via percutaneous endoscopic gastrostomy (PEG) with enteral formulas), texture modified (puréed) diet (n=4), diabetic diet with 160g carbohydrates (n=4) and kidney-bland (low protein and low phosphorus) diet (n=1). Oral nutritional supplements were used in 2 participants (protein enriched). Admission fat mass and skeletal muscle mass were also taken into account regarding simplistic weight-based equations (macronutrients in grams/total body weight in kilograms).

3.2. Assessments

3.2.1. Impairment and disability scales

Functional scales used in rehabilitation were applied to monitor the results achieved by the treatments. The Glasgow Coma Scale (GCS) was used to assess and monitor the state of consciousness determined by the attending physician. The Barthel-index, which measures self-care, was completed by the admitting nurse, and then by the dismissal upon discharge. The Functional Independence Measure (FIM) scale measures the patient's functionality and was completed by consensus at the first team meeting after admission, and then the final FIM assessment was completed at the last team meeting before discharge. (40-43)

3.2.2. Malnutrition risk screening

Digital scale, chair scale and bed scale were used for anthropometric measurements and if necessary, the patients were mobilized with the help of a physiotherapist. In some cases, we measured height in the supine position if the patient was not able to stand.

3.2.2.1. Malnutrition Universal Screening Tool (MUST)

The MUST developed by the British Association of Parenteral and Enteral Nutrition (BAPEN) was used for screening the risk of malnutrition at the institutional level, which is the most widespread internationally validated five-step measurement method specialized for adults in various forms of care. After correction for age, the method also predicts the number of care days, the direction of outcome and death. (44) During the MUST screening, current BMI, unwanted weight loss in the months prior to admission, the effects of acute illnesses and risk conditions are noted down. After the screening, there is no risk of malnutrition in the case of a patient who receives a score of 0, while those with a score of 1 are at medium risk, in this case it is necessary to monitor the energy and nutrient intake, and the screening must be performed weekly. Patients with a score of 2 or more face a high risk of malnutrition and nutritional intervention is necessary in their case.

3.2.2.2. Nutritional Risk Screening 2002 (NRS 2002)

In our further researches, we started to screen our patients with the NRS 2002 questionnaire developed by Kondrup et al., which according to the ESPEN guidelines is the preferred method in hospitals and which, compared to the theoretical approach of the previous questionnaires, was replaced with Evidence Based Medicine (EBM) criteria, dividing weight loss into grades, the reduced nutrient intake, the abnormal BMI and the severity of the disease to be treated. (45) The method of calculating the NRS 2002: the severity of the disease (0-3 points) is added to the severity of the impaired nutritional status (BMI, undesirable body weight loss, nutrient intake: 0-3 points), and for over 70 years an additional 1 point is added. A total score of 0 means no risk, a score of 1-2 means a medium level of risk, and a score of 3 and above means that the patient has a high risk of malnutrition.

3.2.3. Bioelectrical impedance analysis

Body composition was determined with Seca mBCA 515 or portable 525 BIA devices (Seca gmbh & co. kg, Hamburg) depending on walking ability, which were validated for clinical use with the help of the 4-compartment model. (46) The device conducts a weak alternate current into the body from the feet to the hands at 9 frequencies by the portable (1, 2, 5, 10, 20, 50, 100, 200, 500 kHz) and 19 frequencies by the standing device (1; 1.5; 2; 3; 5; 7.5; 10; 15; 20; 30; 50; 75; 100; 150; 200; 300; 500; 750; 1,000 kHz) through electrodes placed at 8 anatomically definable points and determines body composition by measuring current conductivity and current influencing properties of the human tissues.

Since the device examines the human body as five different segments (upper limbs, trunk and lower limbs), upper limbs must not touch the trunk (make a minimum angle of 15^o with the trunk) nor the lower limbs during the measurement, and it is necessary to position lower limbs shoulder width apart. If possible, the measurement should take place after emptying the bladder in order to obtain the most accurate test results. Measurements were taken after the overnight fast and before physical activity. The procedure is painless, harmless, and lasts about 30 seconds.

The Seca Analytics 115 software was used to collect and export bioimpedance measurement data. The FFMI, FM, SMM, ECW/TBW ratio and phase angle measured by the device were used to define correlations of body composition examined upon admission to rehabilitation in the breakdown of severe brain-injured and mixed patient groups. When examining body composition changes in severe brain-injured patients, the FMI and SMMI values were included in the study. Participants were examined within 48 hours of admission if the patient's condition allowed and then before discharge.

3.3. Statistical analyses

Statistical analysis was performed using Microsoft Office Excel 16 and SPSS (Version 26.0. Armonk, NY, IBM Corp.). The significance limit was set at $\alpha = 0.05$.

After the institutional malnutrition risk screening, we presented the threat of malnutrition detectable by the screening method in inpatient rehabilitation care through descriptive calculations, when we used frequencies, furthermore location and dispersion indicators.

Nutritional characteristics of severe brain-injured patients during early rehabilitation were presented through descriptive calculations. The changes of impairment and disability scales, as well as the anthropometric and NRS 2002 risk screening data were also examined to assess improvement in their condition. Of the conditions of parametricity, the normal distribution of the continuous body weight was not verified with the Kolmogorov-Smirnov test, therefore, similarly to the ordinal measurement level NRS 2002 scores, BMI, GCS, Barthel-index and FIM variables the extent of changes was determined using the Wilcoxon signed-rank test.

We started the examination of the correlations of body composition in the breakdown of brain-injured and mixed patient groups by presenting the correlations between gender distributions, underlying diseases, risk of malnutrition and time elapsed to rehabilitation using cross-tabulation analyses (Likelihood ratio and Mann-Whitney U tests) and Spearman's rank correlation test. The exploration of the correlations and their strengths of the BIA data was analysed using the Spearman's rank correlation test.

During the examination of the changes in BIA data of severe brain-injured patients, Spearman correlation was used to measure the correlations between continuous variables, and Mann-Whitney U-test was used for a one-way comparison of groups (gender, cause of injury). Due to the different times between measurements across patients, interpolated BIA values were created for day 18 for each patient (minimum number of days between two measurements across the sample) to make the changes comparable. To determine changes and interactions in FIM and BIA values over time, repeated measure multi-criteria mixed sample ANCOVA (Analysis of covariance) models were used. To find out whether the changes are influenced by demographic and pre-rehabilitation factors, the effects of age, gender, time spent in ICU and the cause of brain injury were used as covariates in the model. Principal component analysis was used to eliminate the problem of multicollinearity between the covariates.

IV. Results

4.1. Institutional malnutrition risk screening in inpatient rehabilitation

The results of the data collected in December 2018 (N=331, average age is 59 years) are presented in Figure 4., based on which we can talk about the risk of malnutrition in the case of 44% of the patients. The sample consists of 176 men and 155 women (53%/47%).

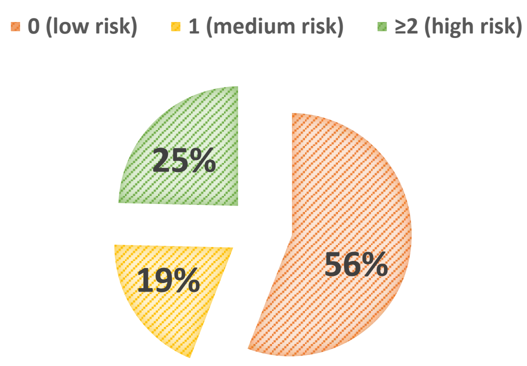


Figure 4. Malnutrition risk of the Institution's patients in 2018 according to Malnutrition Universal Screening Tool (MUST). (N=331)

The boxplot illustrating the BMI distribution of the Institution's patients (Figure 5.) shows that 50% of the patients fall into the interquartile range of 22-29.9 kg/m^2. The average BMI is 26 kg/m^2 (SD=6.36; Mdn=25.13), the lowest value is 15, while the highest BMI is 50.2 kg/m^2 (normal reference range: 18.5-24.99 kg /m^2).

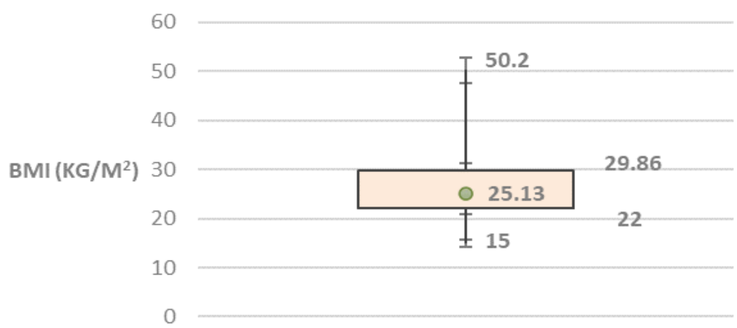


Figure 5. Body mass index (BMI) distribution of the Institution's patients (N=331)

Table 2. summarizes the most common types of diets used without claiming to be complete. Individual diets typically mean diets adapted to the co-existence of several diseases, in some cases the professional provision of a diet followed for individual trends and/or religious reasons with the intake of nutrient ratios that support rehabilitation therapy (e.g. protein enrichment). Diets other than those listed below at the Institute result from various combinations of the listed diets.

Table 2. Types of diets most often used in our Institution

Most common diets used at our Institution	Most common individual diets at our Institution
energy and protein enriched	diabetes with protein enrichment
gently seasoned	diet low in energy and fat, crystalloid carbohydrate-free, moderately high in protein, and rich in water-insoluble dietary fibres
diabetes 180g carbohydrate	pancreas diet with modified carbohydrate composition
diabetes 160g carbohydrate	protein-rich with modified carbohydrate composition
low-calorie	protein-rich and meat-free
low-cholesterol	puréed with modified carbohydrate composition
meat-free	low- calorie and low-protein, low-purine and rich in water-insoluble dietary fibres
dairy-free	low in histamine
lactose-free	vegan
lactose and gluten-free	modified carbohydrate composition, protein-rich, mildly spiced, puréed version
gluten-free	diabetes dialyzed (rich in energy and protein, modified carbohydrate composition, low potassium, sodium, phosphorus)
low-protein	energy-rich, protein-rich, modified carbohydrate composition
low-purine	energy and protein-rich enteral tube feeding + per os puréed
low-fat, low in water-insoluble dietary fibres	energy and protein-rich enteral tube feeding
low-fat, relatively low-protein, low sodium	liquid
low in dietary fibres, dairy-free, mildly spiced	puréed
syncumar-interaction considering	minced

At the time of the survey, the types of formulas used by us were listed in Table 3. In case of a total of 40 patients, we used food intended for special medical purposes at the given time, of which 34 patients consumed oral formulas as a supplement, 5 patients received an exclusive enteral tube formula diet, and in the case of one patient, enteral tube formula was used as a supplement. In most cases (N=13), oral nutritional support with a high protein content was used.

Table 3. Types of formulas used at the time of the survey

Formulas	Consumers at the time of the survey (N)
protein-rich oral supplement	**13**
protein rich and low glycaemic index oral supplement	**4**
protein module oral supplement	**7**
semi-elemental oral supplement	**1**
extra rich in energy oral supplement	**7**
rich in energy enteral tube formula	**4**
protein rich enteral tube formula	**2**
glutamine oral supplement	**1**
arginine rich oral supplement	**1**

The difference in the risk of malnutrition between the patients of the different departments can be seen in Figure 6., based on which, compared to the total number of the Unit, the risk of malnutrition was the highest among the patients in the Brain Injury Rehabilitation Department (62.5% of the patients staying in the Unit).

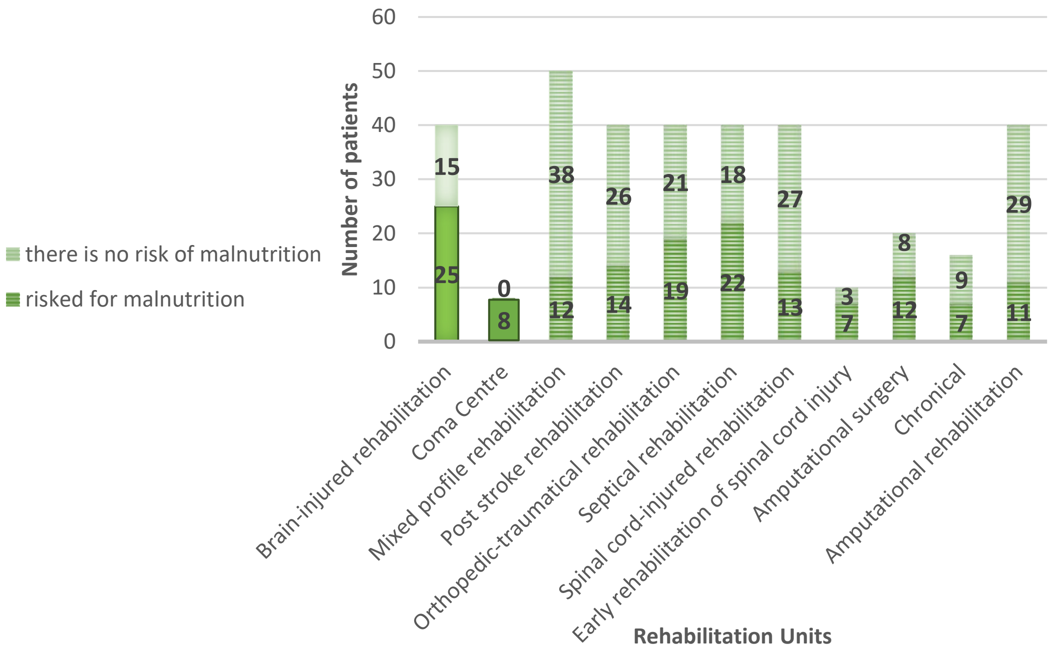


Figure 6. Malnutrition risk among the patients of the different units according to Malnutrition Universal Screening Tool (MUST) (N=331)

4.2. Exploring nutritional characteristics of severe brain-injured patients during early rehabilitation

73 patients with severe brain injury could be included in the study, 47 men and 26 women, their average age was 36 years (17-78, SD=15.54). The clinical picture observed at admission: 19% hemiparesis, 16% tetraparesis, 1% paraparesis, central facial paresis 7%. 57% of patients were not paretic. 61% of the patients arrived infected with a multiresistant pathogen, 9% with pneumonia, and 15% in a septic state. 48 patients had a tracheal cannula when they arrived at the department. Brain injuries are mainly resulted from trauma (N=59), to a lesser extent from stroke (N=12) or cerebral anoxia (N=2). 42 patients were admitted directly from the ICU, 11 from neurosurgery, 7 from neurology, 4 each from traumatology and internal medicine, 2 from the rehabilitation department of another institute, 1 from home and 1 from nursing department. Patients spent an average of 33 days (0-140, SD=22.7) in the ICU, and an average of 49 days (10-252, SD=43.1) elapsed from the accident (brain damage) to admission to the early rehabilitation unit.

67.12% of the final reports contained information on the patients' prior nutrition at the time of admission to rehabilitation. It was clarified whether parenteral nutrition was used in the documentation of only 18 patients (24.65%, it was used in 9 cases, for a maximum of 8 days) and it was revealed in the case of 40 patients (54.79%) whether nasogastric tube feeding was used (in 34 patients used for a maximum of 12 days). PEG was made in 70% of cases, after insertion it took an average of 19 days until rehabilitation (SD=38). The composition of the ingested food was described in half of the cases, the set nutrient target values were recorded in only 10%.

Upon arrival at the Early Rehabilitation Department, 30% of the patients had problems related to nutrition and the functioning of the gastrointestinal system, the most common of which were dysphagia and constipation, furthermore diarrhoea, atony, regurgitation, and vomiting also occurred. Decubitus was present in 31% of patients (based on severity IV: 17%, III: 4%, II: 7%, I: 3%), most often in the sacral region. The dietary diagnoses established after admission were based on anthropometric measurements are summarized in Table 4. Based on the NRS 2002 malnutrition risk scale, 100% of the patients could be classified at risk groups, within which, according to the anthropometric measurements, sarcopenia occurred in the highest proportion, followed by malnutrition and extreme malnutrition. Average body weight at admission was 61 kg (37-107.8, SD=16), the lowest BMI was 12.30 kg/m^2, the highest BMI value was exceptionally high, 46.40 kg/m2 (SD=5.66 kg/m^2). Based on exclusively anthropometric parameters, only 7 patients (9.58%) could be classified in the normal range. We experienced insufficient energy and nutrient intake in 87.65% of the patients, the reason for this in more than half of the cases was the result of brain damage, but in addition, the inability to provide for oneself, as well as a smaller number of other reasons, such as aversion, mood fluctuations, also contributed to the nutritional disturbance.

Table 4. Nutrition related diagnoses according to anthropometric measurements, malnutrition risk screening (NRS 2002) and nutrient intake examination at the beginning of the early rehabilitation of severe brain-injured patients (N=73)

Nutrition related diagnoses	N	Percent
Medium risk of malnutrition	3	4
High risk of malnutrition	70	96
Malnutrition	23	31,5
Extreme malnutrition	14	19,2
Sarcopenia	34	46,57
Normal nutritional status	7	9,58
Overweight	5	6,84
Obesity	2	2,73
Insufficient energy, nutrient and fiber intake:		
Derived from the brain injury	47	64,38
Inability to feed independently	16	21,91
Other reason (mood fluctuation)	1	1,36
Insufficient fiber intake (other reasons)	3	4,1

The nutritional therapy started in the ward was considerably influenced by several factors, which are listed in Table 5. In terms of nutrition, the fact that some of the patients had to be transferred to another institution for a shorter/longer period than planned due to neurosurgical intervention, shunt placement, consultation or imaging examination is an impedimental factor. Patients transferred for a temporary period were not excluded from the study. In these cases, the continuity of the nutrition therapy started in the department was interrupted. A febrile state, decubitus, and the applied antibiotic courses entailed a modification of the nutrient target values, and the route of nutrition also had to be adapted while non-invasive ventilation and high-pressure oxygen treatment are applied.

Table 5. Factors influencing the nutritional therapy of brain-injured patients during early rehabilitation (N=73)

	N	Minimum	Maximum	Mean	SD
Number of days spent outside the Unit	19	1	78	4	12,91
Number of fever days	19	1	10	4	2,27
Number of antibiotic courses	21	1	4	1,4	0,75
Duration of antibiotic courses (day)	21	5	20	12	6,09
NIV/HFJ treatment (day)	7	1	6	3,7	1,17

NIV=Non-invasive Ventilation; HFJ=High Frequency Jet Ventilation; SD=Standard Deviation

Table 6. shows the changes in anthropometric data, malnutrition risk and impairment and disability scales, when the extent of change was analysed with the Wilcoxon signed-rank test. The results show that while the averages of the anthropometric data (body weight, BMI) did not change significantly, the dispersion of the patients around the sample average decreased slightly by the end of the early rehabilitation of severe brain-injured patients. On the other hand, a significant improvement can be observed in the NRS 2002 risk screening, as well as in scores indicating state of consciousness (GCS), self-care (Barthel-index) and functional state (FIM) during their early rehabilitation (in case of all four scales, $p < 0.001$; $r > 0.5$). Based on NRS 2002 screening, the risk of malnutrition decreased by 26%. The GCS score increased by an average of 23%, the average Barthel-growth by 22, and the FIM scale values increased by an average of 24 points during the stay at the Coma Centre.

Table 6. Extent of changes in anthropological data, risk of malnutrition, and impairment and disability scores of severe brain-injured patients during early rehabilitation (N=73)

		Weight (kg)	**BMI (kg/m^2)**	**NRS 2002**	**GCS**	**Barthel-index**	**FIM**
Mean(SD)	Admission	61,07(16,17)	21,31(5,66)	5,35(1,13)	10(2,68)	5(10,50)	24(12,29)
	Discharge	61,09(14,85)	21,45(5,46)	3,95(1,53)	12(2,87)	27(25,11)	48(26,01)
Z value		-1,479	-1,479	-6,277	-5,592	-6,220	-6,681
p value		0,139	0,139	<0,001	<0,001	<0,001	<0,001
Effect size (r)		0,180	0,180	0,724	0,645	0,718	0,771

BMI=Body Mass Index; NRS 2002=Nutritional Risk Screening 2002; GCS=Glasgow Coma Scale; FIM=Functional Independence Measure

At the Coma Centre, the average length of stay was 48 days (8-177, SD=34.62), from which most of patients were transferred to the rehabilitation department (N=54), and the rest got to nursing department (N=11), to home (N=4), to ICU (N=2) and to neurosurgery (N=2).

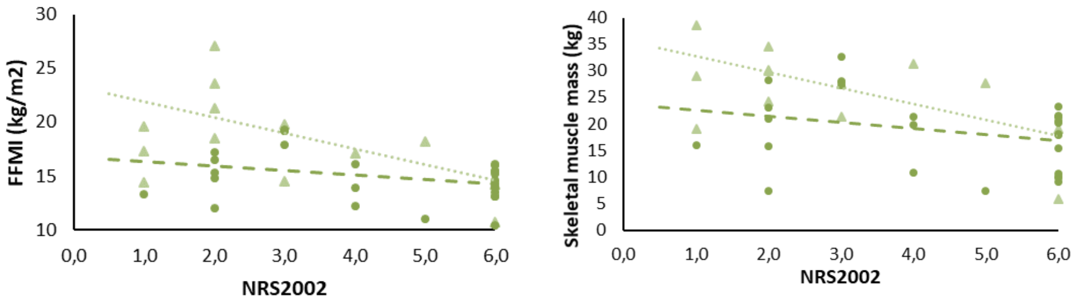
4.3. Examining the correlations of body composition upon admission to rehabilitation

In the sample of 41 patients, the majority of admitted patients came from another institution after acute care, and six were admitted from their homes for programmed rehabilitation treatment. Patients transferred from the acute department spent an average of 72 days in another hospital before being admitted to rehabilitation (SD=66 days, min=10 days). The sample consists of 26 men and 15 women. The average age of the patients was 43 years (SD=18.60 years, min=18 years, max=86 years). The sample has a heterogeneous composition in terms of underlying diseases. After admission, the body compositions of 27 brain-injured, 3 spinal-cord-injured, 2 Guillain-Barré syndrome, 4 lymphoedema, 2 musculoskeletal and 3 post-covid patients were analysed.

Based on the NRS 2002 screening, all patients could be classified into the risk categories (moderate risk: 34%, high risk: 66%). We used the Likelihood ratio test to examine the gender distribution between the various underlying diseases, a significant difference between genders can be detected (p=0.02). Among the patients included in the study, there is a male predominance among those with central nervous system injuries, while there is a predominance of women in cases of recurrent, chronic conditions, such as lymphedema. Using the Mann-Whitney U test, a significant, medium-strength difference between the sexes was also demonstrated in terms of the results of the malnutrition risk scale, where in the case of men, there is a higher proportion of medium and high-risk patients based on the NRS 2002 scores (Z=-2.454 p= 0.014 r=0.388). When interpreting the difference, however, it is also necessary to take into account the fact that the gender distribution of the underlying diseases is different, so the gender difference seen in the NRS 2002 score is probably not due to the difference between genders in the tendency of malnutrition, but to the difference in the underlying diseases. Those patients who have had more than a year between the onset of their underlying disease and rehabilitation have a significantly lower risk of malnutrition (Z= -2.635 p=0.008 r=0.416), which effect can probably also be traced back to the difference in underlying diseases, since this group consists predominantly of patients suffering from chronic diseases (lymphoedema, musculoskeletal). In the case of central nervous system injured patients, significantly more patients have a higher risk of malnutrition than those with other primary diseases (Z= -3.286 p=0.001 r=0.519), and this result supports the effect of underlying diseases on NRS 2002 scores. Using Spearman's correlation test, we found no correlation between the results of the malnutrition risk screening and the number of days until admission in the case of patients who came to rehabilitation less than a year after the onset of the underlying disease (r = -0.172 p=0.380). This result confirms that, in the case of rehabilitation patient groups, the risk screening methods are not sensitive enough when used by themselves, and the risk exists regardless of the number of days that have passed until admission in the case of patients from other institutions.

Spearman's rank correlation test was used to examine the strength of the correlations of body composition data. We compared the results of the NRS 2002 method with the bioimpedance measurements. We found a strong negative correlation between the NRS 2002 method and BMI (r= -0.662 p<0.001). Compared to the strong negative correlation obtained with BMI, the relationship of NRS 2002 with fat-free mass index (FFMI) (r= -0.487 p= 0.001) and skeletal muscle mass (r= -0.476 p = 0.002) appeared to be weaker, while no correlation was found with fat mass (r= -0.140 p=0.384), so the fat mass of patients with a high NRS 2002 score at risk of severe malnutrition is not necessarily low, and a patient with a low risk or no risk may also have a fat mass that can be considered as a risk. Compared to the strength of the relationship with BMI, the variability observed between the malnutrition risk screening method and the estimated body composition may be caused by the primary disease of different severity.

Next, we examined the correlations of the NRS 2002 with the results of the bioimpedance measurements in the breakdown of brain-injured and mixed patient groups (Figure 7). There is no difference in the correlations with BMI between the two groups (brain-injured: r= -0.583; mixed group: r= -0.523), on the other hand, the correlation of NRS 2002 with FFMI in the brain-injured group is weaker than in the case of other diseases. A similar pattern can be seen in its correlation with skeletal muscle, where also a weaker correlation can be seen in the case of the brain-damaged group than in the mixed group. Based on this, it is confirmed that even though all the scales of the malnutrition risk screening methods work with BMI, we cannot use them alone for risk screening of severe cases in rehabilitation care.



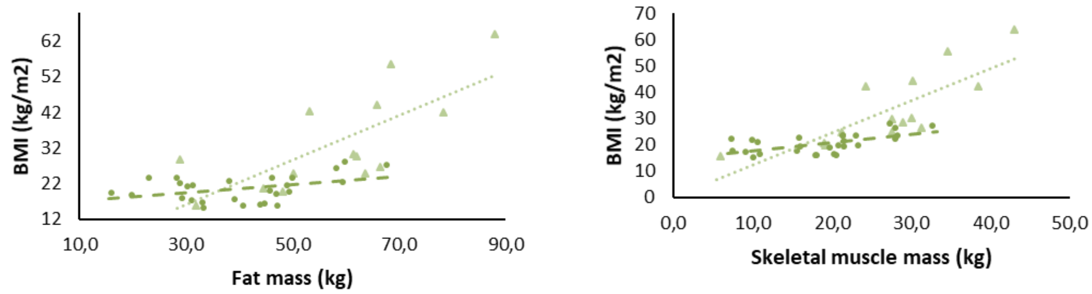
Δ: mixed patient group (r= -0,412 p= 0,143)
○: brain-injured group (r= -0,270 p= 0,173)

Δ: mixed patient group (r= -0,396 p= 0,161)
○: brain-injured group (r= -0,253 p= 0,203)

a, *b,*

Figure 7. Correlations of NRS 2002 scores with fat-free mass index (FFMI) and skeletal muscle mass (N=41)

In the entire sample, BMI shows a strong correlation with fat mass (r=0.609 p<0.001) and skeletal muscle mass (r=0.800 p<0.001). Examining the brain-injured and mixed patient groups separately, the expected trends can still be observed in the non-brain-injured group, but in the case of brain-injured patients, this correlation is significantly weakened (Figure 8.). The pattern can probably be explained by the fact that patients with an outstanding BMI value (for example, but not exclusively with lymphoedema) also have a relatively high skeletal muscle mass, and in some cases, proportionally high fat mass can be detected in brain-injured patients with low BMI values.

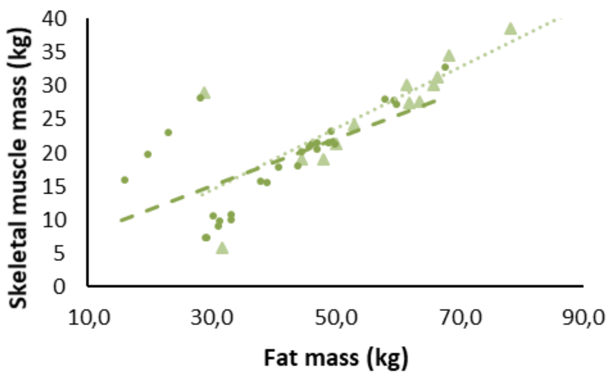


Δ: mixed patient group (r=0,705 p=0,005)
○: brain-injured group (r=0,264 p=0,184)
a,

Δ: mixed patient group (r=0,798 p<0,001)
○: brain-injured group (r=0,576 p=0,002)
b,

Figure 8. Correlations of body mass index (BMI) with fat mass and skeletal muscle mass (N=41)

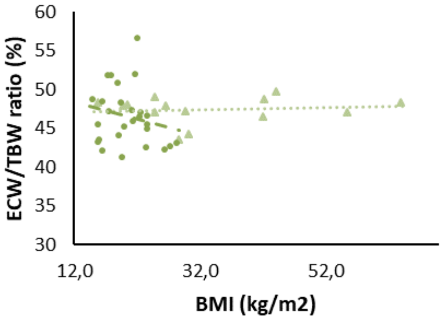
In the entire sample, there was a strong correlation between skeletal muscle mass and fat mass (r= 0.730 p<0.001), the correlation did not differ even when the sample was divided into two groups of brain-injured and mixed patients, the correlation was even stronger in the latter group (Figure 9.). The strong correlation between skeletal muscle and fat mass observed mainly in the non-brain-injured patient group is probably typical of patients who have a chronically high BMI, but whose proportions do not show a low amount of muscle mass due to continuous mobilization.



Δ: mixed patient group (r= 0,855 p<0,001)
○: brain-injured group (r=0,615 p=0,001)

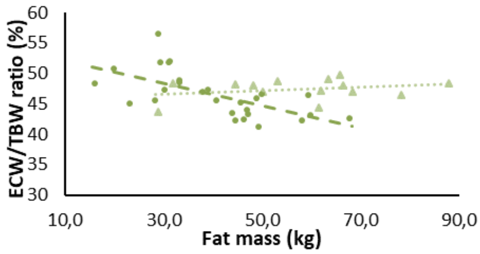
Figure 9. Correlation between skeletal muscle mass and fat mass (N=41)

BMI did not show a significant relationship with the ratio of extracellular and total body water (ECW/TBW) in the whole sample (r= -0.061 p=0.704), nor in brain-injured and mixed groups. In the examination of further correlations of water spaces with fat and skeletal muscle mass, the last one showed significant relation in the entire sample (with fat mass: r= -0.237 p=0.135; with skeletal muscle mass: r= -0.402 p=0.009), no significant relationship was found between the results of the mixed group. Only in the brain-injured group can a significant correlation be observed of fat and skeletal muscle mass with water spaces, despite the fact that the BMI of brain-injured people is not related to the ECW/TBW ratio. The negative correlation can partly be traced back to fluid homeostasis, which is overturned due to protein loss, which is particularly characteristic of brain-injured patients. The tissues of human body show more than simple resistance against the test current. The device measures the phase shift between voltage and current at 50kHz, which can be characterized by a complex resistance, so-called impedance (the quotient of the amplitude of the sinusoidal voltage and current, and the angle is the phase difference between the two). The ratio of water spaces was also compared with the phase angle which is referring to the total cell mass, the test showed a correlation both for the entire sample (r= -0.711 p<0.001) and for the breakdown for the two patient groups separately (Figure 10.). In most cases, the low phase angle in the study is associated with a high ECW/TBW ratio, which presumably proves the effect of the metabolically active total cell mass on the fluid spaces.



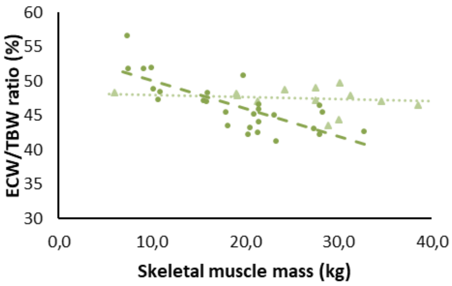
Δ: mixed patient group (r=0,024 p=0,935)
○: brain-injured group (r= -0,228 p=0,252)

a,



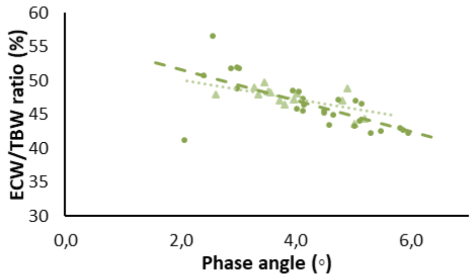
Δ: mixed patient group (r=0,178 p=0,543)
○: brain-injured group (r= -0,669 p<0,001)

b,



Δ: mixed patient group (r= -0,125 p=0,670)
○: brain-injured group (r= -0,766 p<0,001)

c,

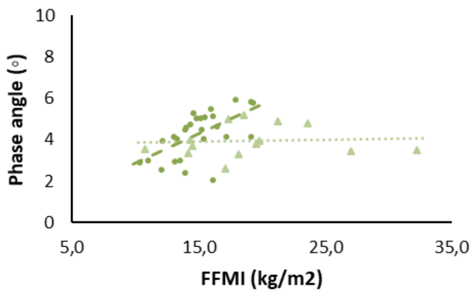


Δ: mixed patient group (r= -0,552 p=0,041)
○: brain-injured group (r= -0,672 p<0,001)

d,

Figure 10. Correlations of extracellular and total body water ratio (ECW/TBW) with body mass index (BMI), fat mass, skeletal muscle mass and phase angle (N=41)

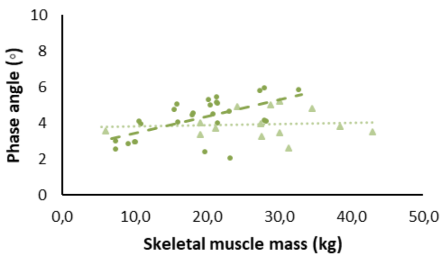
A pattern similar to the results related to water spaces can be seen when examining the phase angle. During the examination of the correlations of the phase angle with FFMI, skeletal muscle mass and fat mass, strong correlations were found in all cases in the brain-injured patient group. In the entire sample, only the FFMI is correlated to the value of the phase angle (r=0.372 p=0.017). In the mixed patient group, we did not find a correlation in any case. Dividing the sample into two groups, the relationships of the phase angle are is illustrated in Figure 11.



Δ: mixed patient group (r=0,174 p=0,553)

○: brain-injured group (r=0,638 p<0,001)

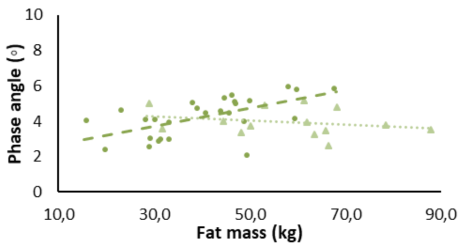
a,



Δ: mixed patient group (r= -0,042 p=0,887)

○: brain-injured group (r=0,544 p<0,001)

b,



Δ: mixed patient group (r= -0,301 p=0,296)

○: brain-injured group (r=0,588 p<0,001)

c,

Figure 11. Correlations of phase angle with fat-free mass index (FFMI), skeletal muscle mass and fat mass (N=41)

4.4. Changes in body composition of severe brain-injured patients during rehabilitation

Characteristics of participants and main outcome measures are presented in Table 6. Based on NRS 2002 malnutrition risk screening, all patients were considered at risk.

Table 6. Severe brain-injured patient's characteristics and main outcome measurements during the examination of changes in their body composition during rehabilitation (N=22)

		TBI (N=11)			**stroke** (N=11)		
		Mean (SD)	Median (IQR)	Min-Max	Mean (SD)	Median (IQR)	Min-Max
	age	37(12)	36(27-47)	18-53	59(17)	63(47-75)	29-77
	number of days till rehabilitation	58(60)	45(22-50)	10-225	126(293)	29(13-49)	12 - >365
	number of ICU days	22(18)	16(10-40)	0-48	3(7)	0(0-2)	0-23
	days between two BIA measurements	57(48)	29(25-100)	19-169	36(17)	38(21-46)	18-75
Admission	**FIM**	36(34)	19(18-37)	18-108	95(28)	106(84-113)	25-116
	BMI (kg/m²)	19.7(3.9)	18.6(17.3-21.2)	14.9-28.3	25.9(6.2)	23.6(21.2-29.7)	19.2-38.5
	FMI (kg/m²)	4.7(2.5)	4.7(3-6.3)	0.6-8.9	8.4(3.8)	7.4(5-10.9)	3.7-15.7
	SMMI (kg/m²)	6.1(2.5)	5.7(4.6-7.4)	2.3-11	7.8(1.8)	7.4(6.8-9.7)	5.3-10.7
Discharge	**FIM**	82(43)	92(40-122)	18-126	112(26)	123(107-125)	37-126
	BMI (kg/m²)	20(3.8)	20.9(16.1-22)	14.9-27.9	25.7(5.7)	23.7(21.4-29.3)	19.1-36
	FMI (kg/m²)	4.8(2.3)	4.8(3.2-5.9)	0.8-8.4	7.7(3.4)	6.9(4.8-10.2)	3.4-14
	SMMI (kg/m²)	6.5(1.9)	6.7(4.7-8.2)	3.5-9	8.1(1.9)	7.5(7-10.4)	5.4-11.7

SD=Standard Deviation; IQR=Interquartile Range; TBI=Traumatic Brain Injury; ICU=Intensive Care Unit; BIA=Bioeletrical Impedance Analysis; FIM=Functional Independence Measure; BMI=Body Mass Index; FMI=Fat Mass Index; SMMI=Skeletal Muscle Mass Index

The average time between two BIA measurements was 47 days (SD=37; min=18; max=169; less than 60 days in 17 out of 22, 75 days in one, 100-110 days in two, 169 days in one). In the following sections, the measurement taken at the time of admission will be referred to as the initial measurement, and the data interpolated to the 18th day as the second measurement.

The relationships between demographic factors and the cause of brain injury were examined using Mann-Whitney U-test and Spearman's correlation. In comparison to

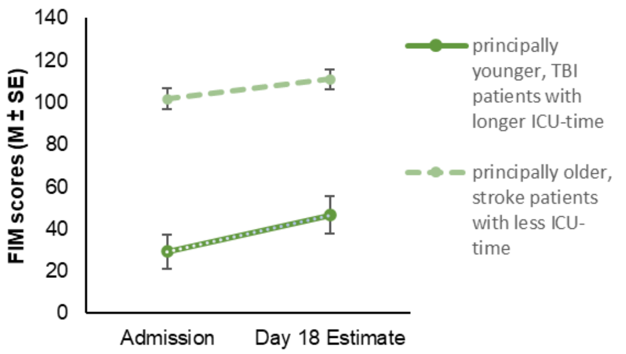
TBI patients, stroke patients were significantly older (U=17.5 p=0.002 r=0.603) and spent significantly less time in ICU (U=19.5 p=0.003 r=0.603). This explains a negative correlation between age and ICU days (r=-0.612 p= 0.001). No gender difference between groups was found with Fisher's exact test (p=0.330 φ=0.189). Women tended to be slightly younger (U=34 p=0.073 r=0.320).

Mann-Whitney U-test and Spearman's correlation were used to examine correlations of post-admission BIA results with age, gender and days spent on ICU. BMI increases significantly with age (r=0.591 p=0.002), is significantly higher among male patients (U=13.5 p=0.001 r=0.619) and higher in case of stroke (U=27 p=0.014 r=0.469). All of these can presumably explain the negative correlation between BMI and ICU-days (r=-0.411 p=0.029). Fat Mass Index (FMI) is also positively correlates with age (r=0.506 p=0.008), higher in case of stroke (U=22 p=0.005 r=0.539), which can partially explain the negative correlation between ICU-days and FMI (r=-0.561 p=0.003), but FMI is not related to gender. Significant positive relationship can also be detected between Skeletal Muscle Mass Index (SMMI) and age (r=0.531 p=0.006). In case of men, SMMI is significantly higher (U=4 p<0.001 r=0.757) and stroke patients have higher SMMI (U=32 p=0.033 r=0.399). Thus, it is not surprising, that as in the previous cases, relationship between SMMI and ICU-days remained negative on a tendency level (r=-0.323 p=0.072).

The factors considered to have potential effects on changes in FMI and SMMI were age, gender, cause of injury and number of days spent in ICU. However, the correlation between these factors was strong (see demographic description), and when entered into the model together, they weakened each other's effects. Thus, a composite value (thereinafter referred to as Composite) was created using a principal component analysis, which organizes the mentioned effects into one dimension. Age, cause of injury and ICU days were included as variables in the merging. The KMO value (controls the sample size in the study) was adequate (KMO=0.719), the one-factor solution explained 73.5% of the variability in the variables, all three variables had a high loading on the Composite value (age b=0.862; cause of injury b=0.862; ICU-days b=-0.848). A higher Composite value indicated that the patient was likely to be more obese, older, suffered a stroke, and has spent less time in ICU, whereas a lower

Composite value means that the patient was likely to be younger, a TBI patient, and spent more days in ICU.

Changes of FIM values were analysed in a repeated measure four-criteria ANCOVA model. Significant effect of Time can be demonstrated, the FIM value estimated on day 18 is significantly higher than the value at admission. The interaction between Time and ICU-days, age and gender in the present sample did not influence the degree of increase in FIM values. The main effect of ICU-days is significant, the initial and second FIM values of those receiving longer intensive care treatment are lower (initial: r=-0.693 p<0.001; second survey: r=-0.700 p<0.001) checked by Pearson's correlation test, but the increase in FIM does not depend on it (r=0.082 p=0.704). The main effect of age on the FIM value can also be detected. The initial FIM value of older people (r=0.684 p<0.001) and the second value (r= 0.639 p=0.001) is higher as well, also examined with Pearson's correlation. However, the change in FIM was not influenced by age neither (r=-0.273 p=0.196). No gender effect can be detected regarding the initial and second values. The changes of FIM values are illustrated in Figure 12. For the purpose of representability, the continuous Composite value was displayed in two points (low and high Composite).

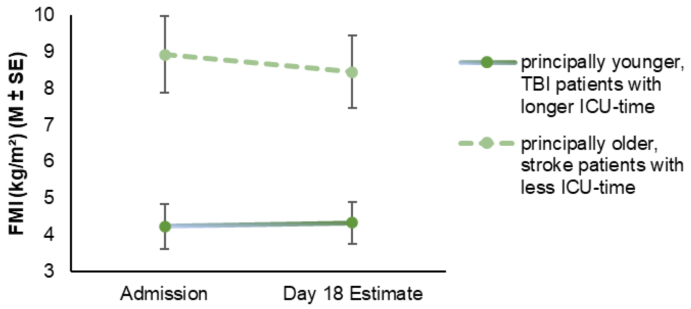


		F(df)	p	Part.η²
Main effects	Time	8.640(1,20)	0.008	0.302
	ICU-days	9.232(1,20)	0.006	0.316
	Age	5.686(1,20)	0.027	0.221
	Gender	0.055(1,20)	0.818	0.003
Interactions	Time-ICU-days	0.391(1,20)	0.539	0.019
	Time-Age	2.763(1,20)	0.112	0.121
	Time-Gender	1.580(1,20)	0.073	0.073

FIM=Functional Independence Measure; SE=Standard Error; TBI=Traumatic Brain Injury; ICU=Intensive Care Unit

Figure 12. Changes of FIM scores from admission to day 18 of inpatient stay (N=22)

Body composition changes were investigated with a series of three-way mixed-sample ANCOVA models. The effect of Time on FMI values was not significantly different between men and women. However, the Time-Composite interaction was significant suggesting that the changes in FMI differed across high vs. low Composite values. Figure 13. shows that the interaction between the two groups is disordinal. Specifically, no changes in FMI were observed in patients with low Composite values whereas a decrease in FMI was seen in patients with high Composite values. The initial and second FMI values for the high Composite group were also higher. No difference in FMI change was found between genders.

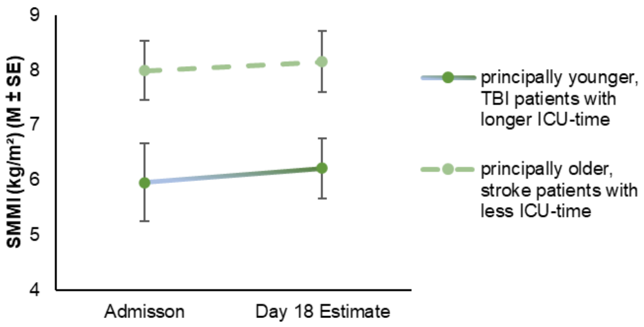


		F(df)	p	Part.η²
Main effects	Time	2.061(1,19)	0.167	0.098
	Composite	9.224(1,19)	0.007	0.327
	Gender	2.013(1,19)	0.172	0.096
Interactions	Time-Gender	0.123(1,19)	0.730	0.006
	Time-Composite	7.254(1,19)	0.014	0.276

FMI=Fat Mass Index; SE=Standard Error; TBI=Traumatic Brain Injury; ICU=Intensive Care Unit

Figure 13. Changes in Fat Mass Index from admission to day 18 of inpatient stay (N=22)

As to SMMI, the main effect of Time indicated a significant increase in SMMI in all patients but no main effect of the Composite variable. The interaction of Time and Composite was also not significant because of similar changes in the two Composite groups (Figure 14.). Although men had higher SMMI in both initial and second measurements, the changes over time did not differ between men and women.



		F(df)	p	Part.η²
Main effects	Time	5.202(1,19)	0.034	0.215
	Composite	2.475(1,19)	0.132	0.115
	Gender	18.927(1,19)	<0.001	0.499
Interactions	Time-Gender	2.853(1,19)	0.108	0.131
	Time-Composite	0.029(1,19)	0.866	0.002

SMMI=Skeletal Muscle Mass Index; SE=Standard Error; TBI=Traumatic Brain Injury; ICU=Intensive Care Unit

Figure 14. Changes in Skeletal Muscle Mass Index from admission to day 18 of inpatient stay (N=22)

4.5. Examination of hypotheses

4.5.1. General hypotheses

The cross-sectional institutional survey, the prospective study at the Coma Centre and the cross-sectional NRS 2002-correlation examinations proved that the internationally validated malnutrition risk screening methods are not sensitive for rehabilitation patient groups and can be used least of all in the case of severe brain-injured patients.

The prospective study at the Coma Centre and the cross-sectional BMI-correlation examinations proved that severe brain-injured patients' nutritional status and its changes cannot be determined and followed through anthropometric examinations and BMI calculations by using them alone, despite the fact that a significant positive change in their impairment and disability status were detected.

The prospective study of body composition changes proved that the FMI and SMMI of traumatic brain-injured patients are significantly lower compared to stroke patients.

4.5.2. Correlation type hypotheses

The cross-sectional BIA-correlation examinations proved that the strong positive correlations of BMI with fat and skeletal muscle mass is significantly weakened in the case of severe brain injuries.

My assumption, that fat mass and skeletal muscle mass do not always correlate in rehabilitation patient groups was not proved by the cross-sectional BIA-correlation examinations, a strong positive significant correlation was detected in all cases.

My assumption that the ECW/TBW ratio correlates with BMI, fat mass, skeletal muscle mass and phase angle, and more expressed negative correlations can be demonstrated in the case of brain-injured individuals was partially proved only. BMI did not correlated with ECW/TBW ratio in any cases. ECW/TBW presented significant strong correlations with fat mass and skeletal muscle mass in only brain-injured cases. Phase angle correlated with ECW/TBW ratio in every case.

The cross-sectional BIA-correlation examinations proved my assumption that in brain-injured patients, the phase angle presents significant positive correlations with FFMI, skeletal muscle mass and fat mass.

My assumption that the time spent in the ICU has a negative correlation with FMI and SMMI was proved by the correlation matrix evolved at the beginning of my prospective study of body composition changes.

4.5.3. Variance type hypotheses

The prospective study of body composition changes proved my assumption that changes in the body composition of severe brain-injured patients and the effectiveness of the therapy can be monitored using a BIA-based body composition measuring device during their rehabilitation and that significant positive changes can also be detected in the FMI and the SMMI.

My assumption that the changes in FIM scores, FMI and SMMI values are significantly influenced by the pre-rehabilitation factors like cause of injury, age, gender and the number of days spent in the ICU was not proved by the prospective study of body composition changes. FIM scores, as well as FMI and SMMI values changed in positive ways independently from cause of injury, age, gender and the number of days spent in the ICU.

V. Discussion

It can be observed that much of the patients possess with severe malnutrition at the time of admission to the rehabilitation institution. Currently, we do not have an internationally validated, coherent tool for diagnosing malnutrition or for monitoring changes in nutritional status. (26) Based on current evidence, nutritional status assessment can be fulfilled based on a multi-component complex assessment. As a first step, after anthropometric measurements, we calculate BMI. However, the index based on body weight and height parameters does not separate FFM, FM and TBW. Despite the fact that the categories of BMI can be considered predictive in terms of comorbidity factors and mortality risks (8), relying on the index alone can be a distorting parameter in estimating body composition.

As a next step, we score the threat of malnutrition using validated scales that measure the risk of malnutrition, which take into account unwanted weight loss and the severity of the disease in addition to BMI data. Their disadvantage is that they are less sensitive to certain diseases (47), so it is clear that the development of a criteria system that measures the risk of malnutrition in a more sensitive way is necessary for patient groups in inpatient rehabilitation who require extensive special care.

The assessment of nutritional status can be completed by the analysis of laboratory data. During the examination of the nutritional status - based on current evidence - using laboratory parameters, only urine creatinine, the absolute lymphocyte cells and short half-life transport proteins (transferrin, prealbumin, IGF-1, retinol-binding protein) assure meaningful information. (48) At the moment, there are limits to the implementation of these tests in our institutional practice related to laboratory capacity.

We started to introduce malnutrition risk screening into our practice with the MUST scale, which is most often used in inpatient and outpatient care. The high number of patients in the overweight category during our cross-sectional study confirms that malnutrition is not limited to BMI values below the reference range. Abdominal obesity is common in some groups of patients in rehabilitation institutions, such as spinal cord injuries and lower limb amputees, and malnutrition can also appear in the form of overnutrition, which is an additional difficulty in mobilisation. Our Institution also treats patients struggling with chronic lymphoedema, which explains the outlier values. Due to the underlying diseases appearing in the study (for example, central nervous system damage, major amputation, polytrauma), the real risk and nutritional status were difficult to categorize. After that, we set ourselves the goal of finding a more sensitive screening method for rehabilitation patients in order to routinely implement it in our practice to help set nutritional goals and track the results achieved during rehabilitation treatments.

After the institutional level study, it was established that it is not enough to plan and provide the basic diets of medical institutions, as well as the individual diets from their combinations. After patient admission, prescribed diets by treating physicians are provided supplemented with dietetical recommendations. It is necessary to strive to individualize the basic diets of medical institutions in order to achieve a body composition that supports rehabilitation. It is also important to control the diets of patients who are on a suggested diet upon admission already, because the dietetical goals change at the start of rehabilitation therapy in case of patients arriving both from acute care and from home.

During our institutional level risk screening study, we currently encounter a lot of controversial information in the specialised literature about the nutritional goals and characteristics of brain-injured patients, who proved to be the group of patients most at risk of malnutrition. Hypermetabolism, hyper catabolism, hyperglycaemia, acute phase response and changes in the immune system characterize brain-injured people. The cause of the mechanism is not yet clear completely, the energetic deficit is associated with an increase in basal metabolism and cellular energy exposure at the same time. (49)

We started screening our patients with the NRS 2002 questionnaire, which, compared to the theoretical approach of the previous questionnaires, was replaced with Evidence Based Medicine (EBM) criteria, dividing weight loss, reduced nutrient intake, abnormal BMI and the severity of the disease to be treated into grades.

During the exploration of nutritional characteristics in the Early Rehabilitation Department (Coma Centre), we found that the setting up and subsequent implementation of nutritional therapy is influenced by many other factors in addition to the individual nutritional status, to which it is necessary to adapt the dietary goals. In addition to gastrointestinal complications, we also experienced decubitus, contracture, dysphagia, and difficulty in cooperation in nearly a third of the patients admitted to the Coma Centre at the time of admission. More than half of the patients arrived with a tracheal cannula, and 43% of them had paresis.

From the point of view of nutrition therapy, it is necessary to use and record a precise and reproducible measurement technique in the patients' documentation, with the help of which the feeding started in the intensive care and neurological wards can be continued in the rehabilitation department. Considerable number of patients come to rehabilitation malnourished, which significantly affects their further treatment. (50) During the early rehabilitation of brain-injured people, acute, temporary transfers and interventions were also necessary, which affected the nutrition of the patients as well. The longest time the patient spent in another institution was 78 days. Because of this, uniform documentation of the applied nutrition becomes particularly important in the various care departments in order to maintain the continuity of nutrition therapy. Bronchoscopy, operations performed under anaesthesia or other minor interventions were other causes of temporary disturbance of feeding. Our study showed that in the medical documentation (final report) of patients admitted for neurorehabilitation, in just over half of the cases, there was no information at all about nutrition, even less about the method, and only 10% contained accurate data about the composition of the food and the set target values. During the acute care and rehabilitation of brain-injured patients, it is necessary to assess the nutritional status, document the nutritional therapy data, and display it in the final reports, because two thirds of feed discontinuations are attributable to avoidable causes. (27) This also indirectly affects (basic) patient care and its financing to a great extent in an economic sense. (51)

Based on our prospective study at the Coma Centre, the extent of improvement in body weight and BMI values of brain-injured patients cannot be considered significant, but this does not mean that the ratios of fat-free body mass, skeletal muscle mass, fat mass and body water – which give total body weight – did not change significantly in the department during the stay. The determination of these and the monitoring of changes is possible with body composition analyses, which can also be used for screening out those with really high fat tissue and sarcopenic obese patients from among patients with high BMI. (20) In the case of the NRS 2002 scores, there was a significant improvement during the stay in the ward. This can probably be explained by the fact that when using the screening method, it is also necessary to score the amount of food intake, and the aim is to realize the optimal nutritional goals during the stay in the ward. Despite this, the NRS 2002 measurement method does not prove to be sensitive enough in the case of neurological cases, especially in the case of severe brain injuries, since due to the severity of the underlying diseases. (14,47) It still classifies all patients in the risk groups even at the time of discharge (medium risk: 11 people (15%), high risk: 62 people (85%). This result also supports our statement that it is justified to supplement the malnutrition risk screening with body composition analyses that is suitable for differentiating the total body weight and clinically validated also. Influencing pathological body composition into positive direction is also important for vital biochemical processes beside its structural role (synthesis of essential molecules, mobilization of vital metabolic substrates).

For an informative and as precise as possible estimation of body composition, it is necessary to introduce into clinical practice relatively cheap, fast, accurate, and reproducible measurement techniques in accordance with the latest recommendations, both from a nutritional therapeutic and pathophysiological point of view (52). For rehabilitation institutions, comfortable, radiation-free portable BIA devices prove to be the most optimal.

In addition to the risk screening, we introduced the use of a professional BIA device that meets the mentioned criteria into our practice. We began to examine the correlations between the BIA data and the patterns of these correlations by breaking down the most severe brain-injured group and the other rehabilitation patient groups in 41 people upon admission to rehabilitation. All patients participating in the study belonged to medium or high-risk groups based on NRS 2002 screening. Despite the fact that the screening method is based on BMI, the correlations of the NRS 2002 scores with the body composition data were lower than expected in the present sample, and could be considered the weakest in the case of brain-injured group. Examining body composition parameters, the correlation of BMI with skeletal muscle and fat mass is also the weakest in the case of brain-injured people, so in their case, malnutrition is limited to the least objective symptoms. There was a strong correlation between skeletal muscle mass and fat mass in the mixed patient group, which can provide novel help in setting of nutrient targets. Based on the patterns of the correlations of the water spaces, it can be concluded that BIA-based analysis can be an early warning sign of an oedematous or hypoproteinaemic state, which is even more expressed in the case of brain-injured group compared to other patients. In the present sample, the value of the phase angle referring to the total cell mass showed the strongest positive correlations with the FFMI, skeletal muscle mass and fat mass in the case of brain-injured patients, based on which its prognostic properties may arise in the case of these severe central nervous system injuries (18,48).

In Hungary, neither a malnutrition diagnostic tool nor a study related to the correlations of body composition has been conducted in rehabilitation patient groups. In the international literature, there are studies with various measurement methods and patient groups regarding the analysis of body composition and its effect on the outcome. The use of examined BIA parameters and indexes is very varied in the studies, and those researches that are based on BIA method, devices use simple or different numbers of multifrequencies from different manufacturers. These differences lead to mismatches in the estimation of body composition. (52) Regarding the rehabilitation departments, studies were mainly carried out on the elderly population, cardiology and pulmonology rehabilitation patient groups. In case of severe central nervous system injuries, there are very few BIA-related studies available internationally, which mainly discuss significant correlations related to functionality, by using devices with different frequencies and examining different parameters of body impedance as well (53-55). We found only one preprint publication regarding neurological patients with the same 9-frequency measuring device we use which established among 18 subacute SCI patients that more patients with abnormal nutritional status could be screened out by measuring FFMI with assessment supplemented by BIA analysis than by using BMI only. (56)

The changes in FIM, FMI and SMMI were examined among 11 stroke and 11 TBI patients undergoing rehabilitation in our Institution and receiving an individually tailored nutritional intervention. The changes between the admission and the values estimated for the 18th day were examined while taking into account other characteristics potentially affecting body composition to get a more comprehensive picture of the outcomes of set nutritional goals. Significant increase in FIM scores occurred during the rehabilitation of brain-injured patients independently from age, gender, or the number of days spent on ICU, despite the fact that age and ICU-time significantly influenced the initial FIM scores. The first main finding is that in patients with low fat mass at admission, FMI did not change over the first 18 days of rehabilitation, whereas in those with high fat mass, a decrease was observed. The second main finding is the overall increase in SMMI independent of gender, age, days spent in ICU and the cause of brain injury. Contrary to our prediction, pre-rehabilitation characteristics did not influence the dynamics of fat mass and skeletal muscle mass changes during the rehabilitation programme.

In a Japanese poststroke rehabilitation department, a non-significant decrease in percent muscle mass was measured in the 4th week of treatment, which somewhat contrasts with our study, although in that study 3-frequency BIA analysis was used and the nutritional therapy was not mentioned. (57) A study of post-COVID patients using a 4-frequency BIA reported a significant decrease in fat mass (in kg) by the time of discharge, although the time between two assessments was quite longer and variant between patients than here. (58) None of the previous stroke or TBI studies reported changes in FMI and SMMI by BIA during rehabilitation nor are there studies that examined characteristics that may influence body composition results. Taking gender into account only, a strong correlation between SMM and muscle strength was found independently of it in healthy individuals. (59) When ICU survivors were compared to an age-gender-height matched controls, the increase in lean body mass was milder yet the increase in fat mass was greater in the year after critical illness. (60)

Due to the heterogeneity of literature related to body composition, it is extremely difficult to compare results, therefore it is necessary to strive to examine same BIA parameters and indexes in the different studies. It would be necessary to publish results of as many BIA analysers from same manufacturer and/or measuring at same frequencies, tested on special patient populations at an international level.

To examine the effectiveness of the diets based on changes in body composition as objectively as possible, other factors potentially affecting fat mass and muscle mass should also be taken into account. The results of our studies help to set the stage for future studies of body composition aimed at a better understanding of factors associated with changes in fat mass and muscle mass as a result of individually prescribed nutritional therapy or in more controlled studies of brain-injured patients.

The limitation of our body composition measuring studies is the small sample size due to the complexity of the measurements and standardized circumstances, the severe underlying diseases and the inclusion criteria. Although in our Institution nutritional targets are tailored to individual needs, during the examination of BIA-changes, we did not monitor the actual intake and disturbances in appetite or the influence of weekend days and any other interruptions, which may also affect the changes in FMI and SMMI. We did not account for the baseline level or changes in muscle strength and muscle quality, which also should be considered when interpreting the results.

VI. Conclusions

During my researches, I examined the characteristics, correlations and interactions of nutritional status assessment and its monitoring in rehabilitation inpatient care, specifically for severe brain-injured patients.

In order to achieve the nutritional goals set in neurorehabilitation, a uniform assessment and documentation of nutritional status and dietetical interventions used are necessary both in the pre-acute care unit and in the rehabilitation departments, in order to have nutritional therapy can be done that supports the high-level rehabilitation of patients with severe brain injury. Even in the acute care departments, additional efforts are needed to ensure that patients with severe brain injuries arrive at the rehabilitation department with as minimal secondary complications as possible and in an adequate nutritional state. In case of successful rehabilitation of brain-injured patients, social reintegration with a good standard of living can be expected. (61)

An accurate measurement technique is necessary from the point of view of nutritional therapy, especially in departments that rehabilitate patients with multiple risk factors (severe central nervous system injuries, polytraumatized patients, long-term ICU patients). Based on our present studies, the multifrequency BIA device is suitable for differentiating the total body weight of rehabilitation patients by measuring fat-free body mass, fat mass, water spaces, and skeletal muscle mass divided into five body segments and tracking their changes.

Our treatment protocols developed in our Institution, which appraise nutrition and nutritional status, moreover provide nutritional therapy to screened patients, contributes to the success of rehabilitation. It becomes necessary to set up a combined criteria system to determine and monitor the nutritional status of severe brain-injured patients. It is recommended to combine malnutrition risk screening with the measure of FFMI, FMI, SMMI data at the same time, supplemented with phase angle monitoring, which can contribute to the objective measurement of the effectiveness of rehabilitation therapy by evaluating together with the data of the impairment and disability scales.

The following new scientific results have been gotten from the analysis of the collected data:

1. For the first time in Hungary, I conducted the examination for malnutrition risk screening and assessment of nutritional status applicable in rehabilitation patient groups.

2. Nutrition-related characteristics experienced during the early rehabilitation of severe brain-injured patients were assessed and nutrition-related documentation properties of the supply chain of health care were examined for the first time in Hungary.

3. Body impedance correlations were found that fill literature gaps at an international level.

4. A combined criteria system was identified for the objective monitoring of the nutritional status of severe brain-injured patients using BIA data for the first time.

5. Body impedance correlations were examined in the breakdown of brain-injured and other patient groups in rehabilitation for the first time, as well as the differences in the dynamics of body composition changes between TBI and stroke patients.

6. The applicability of BIA-based body composition changes was examined for the first time evaluating on severe brain-injured patients by eliminating prediction errors, during which it was established that in order to assess the effectiveness of nutritional interventions on changes in body composition, it is necessary to consider different demographic and pre-rehabilitation characteristics.

VII. Summary

Deteriorating nutritional status negatively affects the effectiveness of rehabilitation, but we do not have a validated malnutrition diagnostic method yet. The purpose of our studies was to examine the nutritional characteristics of rehabilitation inpatients, specifically patients with severe brain injuries, and to develop a methodology for assessing their nutritional status. Institutional malnutrition risk screening was followed by the exploration of nutritional therapeutic features during the early rehabilitation of severe brain-injured ones. After the introduction of bioelectrical impedance analysis (BIA) into our institutional practice, it was established based on the data measured on admission, that the obvious strong correlations of Body mass index (BMI) with body composition were significantly weakened in case of brain injuries. A strong correlation between skeletal muscle and fat mass was observed in all cases. BMI correlated with extracellular- and total body water ratio only in case of brain injuries and phase angle showed the strongest correlations with BIA data in case of them also. When determining whether BIA is suitable for monitoring the changes in body composition of brain-injured patients for whom individualized nutritional goals were set during rehabilitation, a significant increase in Functional independence measure scores occurred during inpatient stay independently from age, gender, or the number of days spent in intensive care unit (ICU). We found that the estimated changes in Fat Mass Index (FMI) over approximately the first 3 weeks of rehabilitation depend on the initial level of FMI. The high FMI, corresponding mainly to older, stroke patients, who spent less time in ICU, decreased whereas the low FMI, corresponding to younger, TBI patients, who spent more time in ICU, remained steady. In contrast, skeletal muscle mass index increased in all participants regardless of time spent in ICU, cause of injury, age and gender.

Our novel body impedance correlations in rehabilitation patient groups with the exploration of differences between brain-injured and other patients, as well as examining body composition changes taking into account various independent variables (factors affecting body composition outside of therapy), the present studies can provide gap-filling results both at national and international level and may contribute to the effectiveness of nutritional therapy used in rehabilitation of severe brain-injured patients, and to future studies related to body composition analyses.

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IX. Bibliography of the candidate's publications

9.1. Publications related to the topic of the dissertation

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5. **TÓTH B,** SÁRGA D. Institute-level assessment of nutritional status in a rehabilitation department - nutritional characteristics of patients with severe central nervous system injury **(**Intézeti szintű tápláltságiállapot-felmérés rehabilitációs osztályon – súlyos központi idegrendszeri sérülést szenvedett betegek táplálási sajátosságai). Rehabilitáció. 2018;28(4):134-138.

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The cumulated impact factor of the indicated journals as first author (based on the latest data currently known): **2,8**

9.2. Publications unrelated to the topic of the dissertation

1. **TÓTH B.** Dietetical and nutritional strategies (Dietetikai és táplálkozási stratégiák). In: Vekerdy-Nagy Zs, Cserháti P, Polgár A, Zsebe A (eds.): Methodology of rehabilitation and physical medicine (A rehabilitációs és fizikális medicina módszertana). Budapest (Hungary): Medicina Könyvkiadó Zrt.; 2023. p. 314-323., 10 p. Chapter (Chapter in Book)

9.3. Citable abstracts related to the topic of the dissertation

1. **TÓTH B,** DÉNES Z. Correlations of body composition upon admission to rehabilitation **(**A testösszetétel összefüggései rehabilitációra történő felvételkor). A Magyar Rehabilitációs Társaság XLI. Vándorgyűlése és 2022. évi Továbbképző Tanfolyama. Siófok, 2022. szeptember 29 – október 1. Rehabilitáció. 2022;32(3):135-136.

2. **TÓTH B.,** DÉNES Z.: Testösszetétel meghatározása a rehabilitációs táplálásterápiához. A Magyar Rehabilitációs Társaság XL. Vándorgyűlése és 2021. évi Továbbképző Tanfolyama. Szeged, 2021. október 7-9. Rehabilitáció. 2021;31(3):142-143.

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4. SÁRGA D, **TÓTH** B. Institutional Nutritional Status Survey – specifity of the nutritional therapy of neurologically injured patients. 21. World Congress of Clinical Nutrition: Joining medicine, food and agriculture for healthier nutrition. Budapest, Hungary, 6-8 October, 2017. Program and Abstract book p. 92.

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X. Acknowledgements

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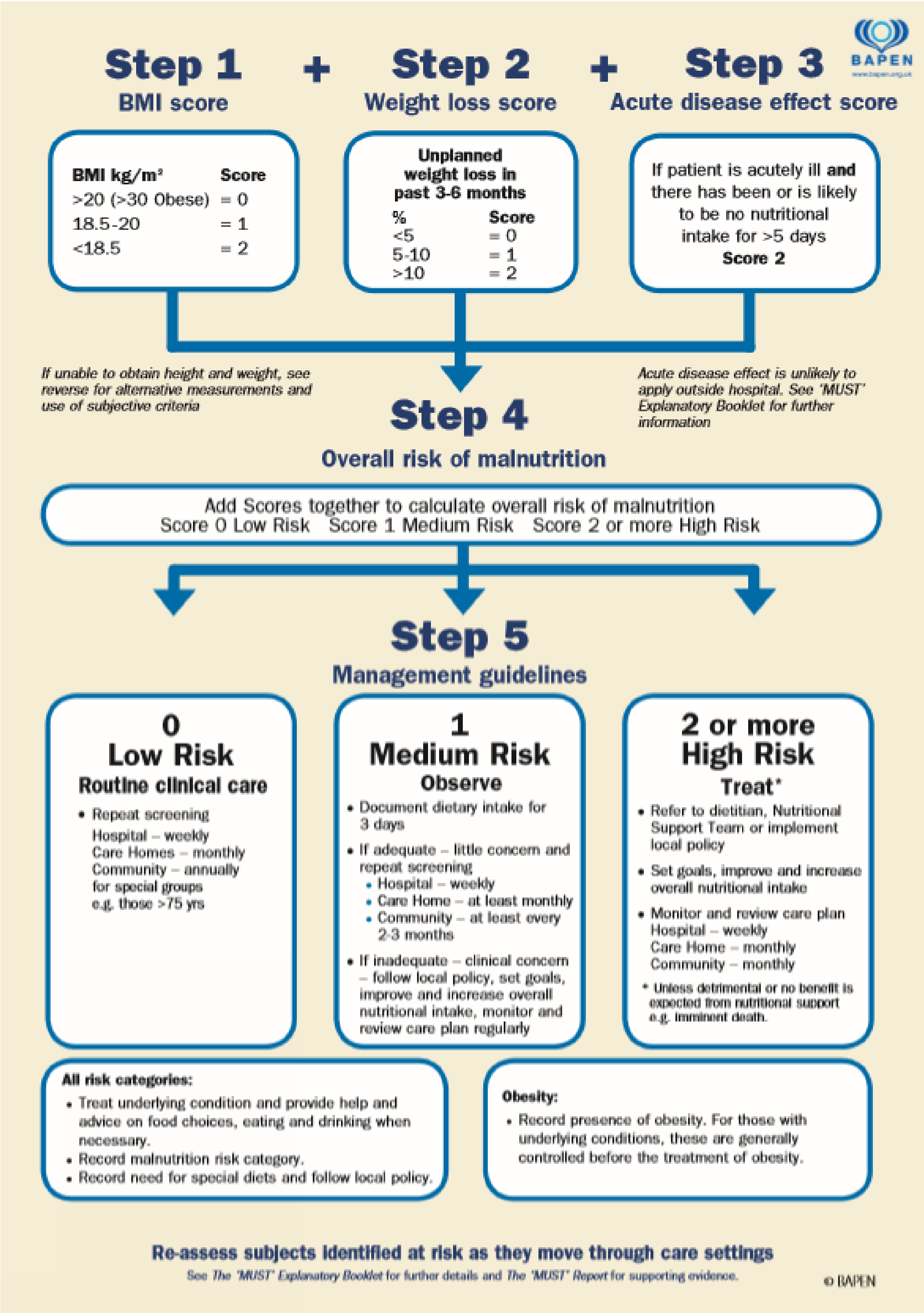
I am grateful to my family, who made it possible for me to complete my studies and showed me extraordinary patience, understanding and support.

XI. Appendices

11.1. Malnutrition Universal Screening Tool – MUST



11.2. Nutritional Risk Screening 2002 – NRS 2002

	Step 1: Initial screening	Yes	No
1	Is BMI <20.5?		
2	Has the patient lost weight within the last 3 months?		
3	Has the patient had a reduced dietary intake in the last week?		
4	Is the patient severely ill ? (e.g. in intensive therapy)		

Yes: If the answer is 'Yes' to any question, the screening in Step 2 is performed.
No: If the answer is 'No' to all questions, the patient is re-screened at weekly intervals. If the patient e.g. is scheduled for a major operation, a preventive nutritional care plan is considered to avoid the associated risk status.

Step 2: Final screening			
Impaired nutritional status		**Severity of disease** (≈ increase in requirements)	
Absent **Score 0**	Normal nutritional statusA	Absent **Score 0**	Normal nutritional requirements
Mild **Score 1**	Wt loss >5% in 3 months or Food intake below 50–75% of normal requirement in preceding week.	Mild **Score 1**	Hip fracture* Chronic patients, in particular with acute complications: cirrhosis*, COPD*. ***Chronic hemodialysis, diabetes, oncology.***
Moderate **Score 2**	Wt loss >5% in 2 months or BMI 18.5 – 20.5 + impaired gen. condition or Food intake 25–50% of normal requirement in preceding week	Moderate **Score 2**	Major abdominal surgery* Stroke* ***Severe pneumonia, hematologic malignancy.***
Severe **Score 3**	Wt loss >5% in 1 months (>15% in 3 months) or BMI <18.5 + impaired general condition or Food intake 0–25% of normal requirement in preceding week in preceding week.	Severe **Score 3**	Head injury* Bone marrow transplantation* ***Intensive care patients (APACHE>10).***
Score:	+	**Score:**	**= Total score:**
Age	if ≥ 70 years: add 1 to total score above		**= age-adjusted total score:**

Score ≥3: the patient is nutritionally at-risk and a nutritional care plan is initiated

Score < 3: weekly rescreening of the patient. If the patient e.g. is scheduled for a major operation, a preventive nutritional care plan is considered to avoid the associated risk status.

NRS-2002 is based on an interpretation of available randomized clinical trials. *indicates that a trial directly supports the categorization of patients with that diagnosis. Diagnoses shown in *italics* are based on the prototypes given below.

Nutritional risk is defined by the present **nutritional status** and risk of impairment of present status, due to **increased requirements** caused by stress metabolism of the clinical condition.

A nutritional care plan is indicated in all patients who are
1) severely undernourished (score = 3), or
2) severely ill (score = 3), or
3) moderately undernourished + mildly ill (score 2 +1), or
4) mildly undernourished + moderately ill (score 1 + 2).

Prototypes for severity of disease
Score = 1: a patient with chronic disease, admitted to hospital due to complications. The patient is weak but out of bed regularly. Protein requirement is increased, but can be covered by oral diet or supplements in most cases.
Score = 2: a patient confined to bed due to illness, e.g. following major abdominal surgery. Protein requirement is substantially increased, but can be covered, although artificial feeding is required in many cases.
Score = 3: a patient in intensive care with assisted ventilation etc. Protein requirement is increased and cannot be covered even by artificial feeding. Protein breakdown and nitrogen loss can be significantly attenuated.

11.3. Glasgow Coma Scale - GCS

Category	Responses	Scores
Eye opening (E)	E4 spontaneous	4
	E3 to verbal stimulus	3
	E2 to pain	2
	E1 no response to pain	1
Verbal (V)	V5 orientated	5
	V4 confused	4
	V3 inappropriate words	3
	V2 incomprehensible sounds	2
	V1 no response to pain	1
Grimace (G)	G5 spontaneous normal facial/oromotor activity, as sucks tube, coughs	5
	G4 less than usual spontaneous ability or only responds to touch	4
	G3 vigorous grimace to pain	3
	G2 mild grimace or some change in facial expression to pain	2
	G1 no response to pain	1
Motor (M)	M6 obeys commands	6
	M5 localizes to pain stimulus	5
	M4 withdraws from pain	4
	M3 abnormal flexion to pain	3
	M2 abnormal extension to pain	2
	M1 no response to pain	1
Total	E+V+M for non-intubated patient, and E+G+M for intubated patient	15

11.4. Barthel-index

THE BARTHEL INDEX

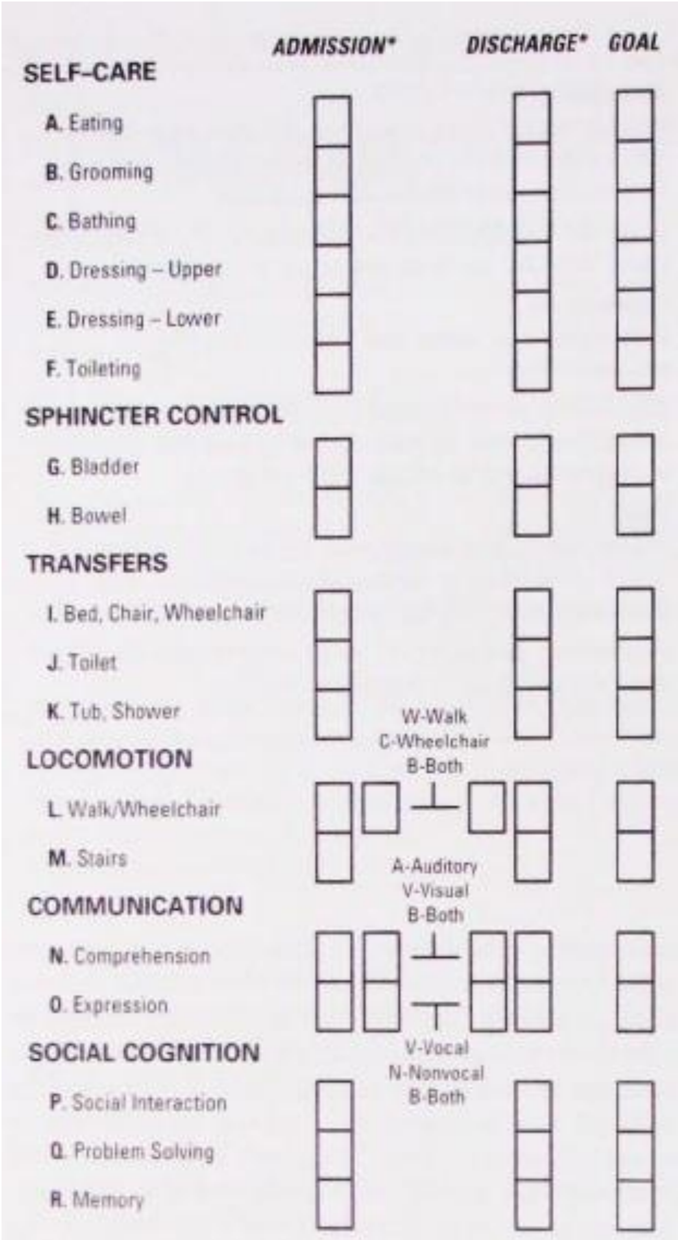
Patient Name: ____________________

Rater Name: ____________________

Date: ____________________

Activity	Score
FEEDING 0 = unable 5 = needs help cutting, spreading butter, etc., or requires modified diet 10 = independent	____
BATHING 0 = dependent 5 = independent (or in shower)	____
GROOMING 0 = needs to help with personal care 5 = independent face/hair/teeth/shaving (implements provided)	____
DRESSING 0 = dependent 5 = needs help but can do about half unaided 10 = independent (including buttons, zips, laces, etc.)	____
BOWELS 0 = incontinent (or needs to be given enemas) 5 = occasional accident 10 = continent	____
BLADDER 0 = incontinent, or catheterized and unable to manage alone 5 = occasional accident 10 = continent	____
TOILET USE 0 = dependent 5 = needs some help, but can do something alone 10 = independent (on and off, dressing, wiping)	____
TRANSFERS (BED TO CHAIR AND BACK) 0 = unable, no sitting balance 5 = major help (one or two people, physical), can sit 10 = minor help (verbal or physical) 15 = independent	____
MOBILITY (ON LEVEL SURFACES) 0 = immobile or < 50 yards 5 = wheelchair independent, including corners, > 50 yards 10 = walks with help of one person (verbal or physical) > 50 yards 15 = independent (but may use any aid; for example, stick) > 50 yards	____
STAIRS 0 = unable 5 = needs help (verbal, physical, carrying aid) 10 = independent	____
TOTAL (0–100):	____

11.5. Functional Independence Measure – FIM


ADMISSION* DISCHARGE* GOAL

SELF-CARE
A. Eating
B. Grooming
C. Bathing
D. Dressing – Upper
E. Dressing – Lower
F. Toileting

SPHINCTER CONTROL
G. Bladder
H. Bowel

TRANSFERS
I. Bed, Chair, Wheelchair
J. Toilet
K. Tub, Shower

LOCOMOTION
L. Walk/Wheelchair
M. Stairs

W-Walk
C-Wheelchair
B-Both

COMMUNICATION
N. Comprehension
O. Expression

A-Auditory
V-Visual
B-Both

V-Vocal
N-Nonvocal
B-Both

SOCIAL COGNITION
P. Social Interaction
Q. Problem Solving
R. Memory

FIM levels:

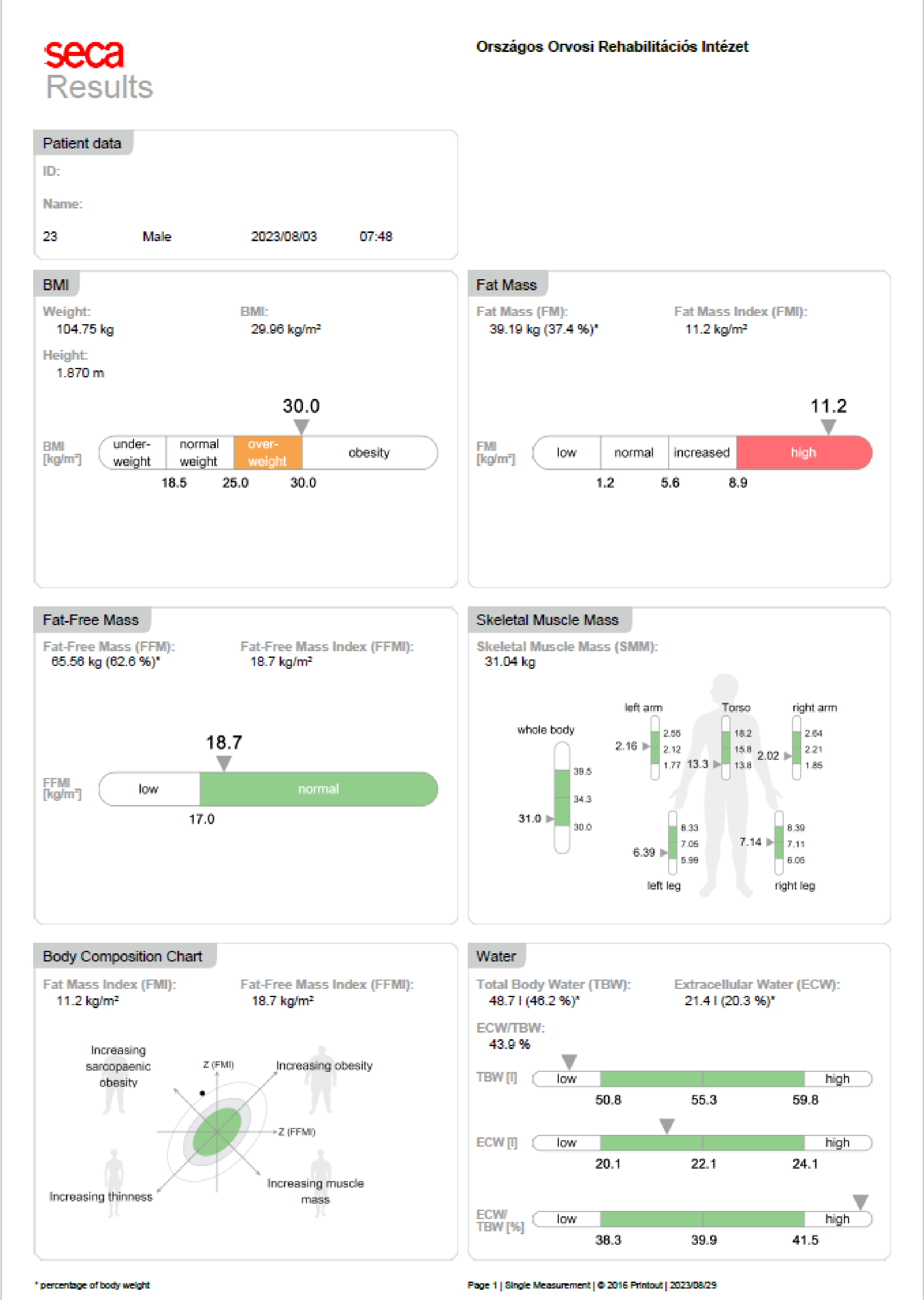
No Helper: 7. Complete Independence (Timely, Safety); 6. Modified Independence (Device)

Helper - Modified Dependence: 5. Supervision (Subject = 100%); 4. Minimal Assistance (Subject = 75% or more); 3. Moderate Assistance (Subject = 50% or more)

Helper - Complete Dependence: 2. Maximal Assistance (Subject = 25% or more); 1. Total Assistance or not Testable (Subject less than 25%)

The total score for the FIM: Motor subscale (the sum of the individual motor subscale items) will be a value between 13 and 91. Cognition subscale (the sum of the individual cognition subscale items) will be a value between 5 and 35. The total score for the FIM instrument (the sum of the motor and cognition subscale scores) will be a value between 18 and 126.

11.6. Results document of Seca mBCA devices



seca

Results

Országos Orvosi Rehabilitációs Intézet

Patient data

ID:

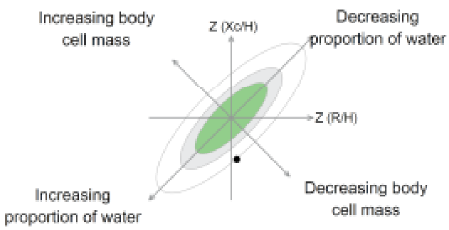
Name:

23	Male	2023/08/03	07:48

BIVA

Resistance (R): 516.0 Ω

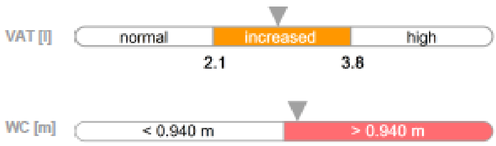
Reactance (Xc): 48.2 Ω



Visceral Adipose Tissue & Waist Circumference

Visceral Adipose Tissue (VAT): 2.9 l

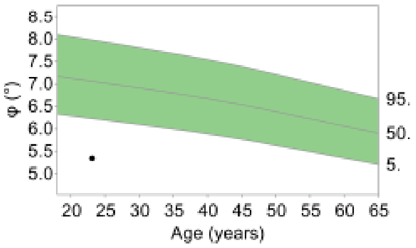
Waist Circumference (WC): 1.00 m



Phase Angle

Phase Angle (φ): 5.3°

Percentile: 1.



Energy

Total Energy Expenditure: 3177 kcal/day

Recommended Energy Intake:

Physical Activity Level: 1.4

Duration:

Resting Energy Expenditure: 2269 kcal/day

Therapy Goal:

11.7. Images about measurements with Seca mBCA devices

11.8. Per os intake documentation data sheet

Név:				Per os bevitel							
dátum:		név	mennyiség	dátum:		név	mennyiség	dátum:		név	mennyiség
reggeli	étel			reggeli	étel			reggeli	étel		
	folyadék				folyadék				folyadék		
ebéd	étel			ebéd	étel			ebéd	étel		
	folyadék				folyadék				folyadék		
uzsonna	étel			uzsonna	étel			uzsonna	étel		
	folyadék				folyadék				folyadék		
vacsora	étel			vacsora	étel			vacsora	étel		
	folyadék				folyadék				folyadék		

XII. List of tables and figures