THE MAIN PILLARS OF A PHYSIOTHERAPIST' CONTRIBUTION TO THE DEVELOPING, IMPLEMENTING, AND ASSESSING METHODS DESIGNED FOR IMPROVING POSTURAL CONTROL IN OLD AGE

PhD thesis booklet

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1. Introduction

The concept of *ageing society* focuses on changes in the age structure of the population mainly in a descriptive way, whereas the concept of *longevity society* seeks to reap the benefits of longer life by changing the way we age successfully. The benefits of a longer life can only be understood if age-related changes are not seen as mere constraints on the opportunities of older people, but as facts that need to be considered and adapted to or optimised. The prevalence of functional limitations is a better indicator of health in old age than the prevalence of chronic diseases. The c*ompression of functional decline* reduces the likelihood of over-dependence on others in later life. Hence, in the context of successful ageing, this 'compression of functional decline' or 'compression of disability' should be stressed instead of 'compression of morbidity.' Compression of functional decline can be best grasped through the optimisation of postural control and via its human-specific manifestation, the gait.

Postural control is the process of regulating the spatial position of the body for both stability and orientation. It refers to: 1) on the one hand, controlling that the body's centre of gravity remains above the supporting surface under both static and dynamic conditions; 2) on the other hand, controlling the relation of each body segment to one another and to the environment at any moment in time, to achieve the purpose of the movement.

Postural control is influenced by a combination of three factors: 1) the individual; 2) the purpose of the individual's action, i. e. what the task is; 3) and the characteristics of the environment in which the action takes place.

1.1. Ageing and postural control – functional decline

It has long been recognised that muscle mass and strength decline with age. By the eighties, muscle mass is almost half of the youth average. The lower limb is affected more than the upper limb by the decline.

Effective postural control is also influenced by the limited range of motion of the joints in old age. Reduced flexibility of the spine leads to the typical age-related misalignment of body posture characterised by increased kyphosis; a curving of the thoracic spine that causes a shift (displacement) of the centre of gravity towards the heels, away from the stability limit. The range of motion of other joints may also be limited, which, along with the pain, can make it difficult to perform any balancing strategy quickly and effectively.

As for the age-related changes in muscle synergies, muscle reaction times increase. In particular, the reaction time of peripheral muscles is delayed, often to the extent that they are activated later than the proximal muscles. The activation pattern in old age starts with the activation of the proximal limb muscles, followed by a delay in the distal ones The consequence is that older people use a hip strategy to control their balance even in situations where an ankle strategy would be adequate. The danger is that shear forces are generated between the sole and the ground, which can lead to the elderly person slipping.

Many sensory functions of the sensory organs and the nervous system are impaired.

Visual field loss is very common, with deterioration in visual acuity, contrast sensitivity, and depth perception. The structure and function of the *vestibular system* are also in decline.
The ability to sense vibration, tactile stimuli, and the ability to perceive joint position and motion (kinaesthesia), especially in the lower limb, impairs with age.
In addition to the decreased sensory input, sensory organisation, i.e. the central processing mechanism of sensory information, is also impaired. Difficulties arise in adapting to different situations in which the sensory information available for postural control changes.
In old age, as the sensory and motor systems gradually deteriorate, postural control will only be effective and successful with increased attention.

1.2. Characteristics of walking in old age

The ability to walk is not only a succession of steps, but also 1) being able to walk at the right speed, 2) walking at the right speed to reach destinations near or far, 3) the ability to change direction without falling, and 4) walking as automatically as possible, so that the older individual can focus attention on other things (i.e. to be able to carry something in hand or to talk while walking).
The gait of the elderly slows down, their steps become shorter and, consequently, the full gait cycle becomes shortened, the stride frequency (cadence) or walking rate is also reduced, and an increased walking base (stride width) can be observed as well as feet are turned out more.
Not only do the absolute values of the above parameters change with age as previously mentioned, but they also become more variable. The greater the difference between strides, the greater the *gait variability*, which makes walking unstable and increases the risk of falling.
In old age, the *automaticity of walking* changes and everyday walking requires much more attention than before. If cognitive or manual activity is associated with walking, automatic control is further compromised. An important determinant of independent living, and thus of the so-called healthy life years, is that walking requires as little attention and cognitive control as possible, since in everyday life many activities involve walking while doing another activity that requires attention. When two activities are carried out simultaneously, the two activities interfere with each other, resulting in poorer performance of one or both the activities, because the attentional capacity to the motor and cognitive tasks is limited. When the attentional demands of the two activities exceed the person's attentional capacity, the performance of one or both activities becomes poorer, disturbed, or less focused compared to performance when one activity is carried out.
The attentional or cognitive demands of postural control, including postural control during walking, can be examined in a so-called *dual task situation*, by investigating how postural control in general, or, specifically, during gait is altered when it is associated with an attention-demanding activity. The more the secondary task impairs the performance of what is called the single task, the more attention the single task requires; in other words, the less automatic it is.
Automaticity (of walking) is quantified by the automaticity index (AI), which can be calculated using the following formula:

$$AI = \frac{gait\ velocity_{single\ task}}{gait\ velocity_{dual\ task}} * 100$$

Automaticity means that an activity requires little attention. The closer the automaticity index is to 100%, the less the walking speed deviates in the dual task situation, that is, the more automatic the walking is.

1.3. Fear of falling (FoF) – as cause and consequence

Because of declining postural control, gait deteriorates, and the elderly person fears the occurrence of a possible fall. FoF can be a justified response in certain situations (e.g., when walking on slippery surfaces results in? moving more carefully due to FoF) because it can successfully prevent a fall. This FoF will not affect our actions in the long run or in other situations. FoF becomes pathological when loss of confidence, a persistent feeling of FoF develops. It is also associated with the elderly people limiting their physical activity, which impairs their future functional abilities and increases their risk of being institutionalised. A valid measure to assess the possible existence of pathological FoF is the falls efficacy scale international (FES-I) questionnaire.

2. Objectives

A physiotherapist working with older people can use appropriate diagnostic methods and interventions both to assess and to improve the elderly patient's postural control through effective therapeutic physical exercise programmes, helping them to live a longer healthy (disability-free) life. Hence, the dissertation addresses both aspects of appropriate and effective patient care in the daily work of the clinical physiotherapist, targeting both the diagnostic and the therapeutic areas of this work.

2.1. The objective of Study 1 (S1) is to develop the Hungarian version of the Berg Balance Scale via cross-cultural adaptation and to assess its clinimetry in patients living in an institutional setting. The BBS is a widely applied and valid measure of static and dynamic balance (as two aspects of postural control) that has not been adapted and validated in Hungarian.

2.2. The objective of Study 2 (S2) is to put the FES-I questionnaire into clinical practice to assess fear of falling and to identify the risk groups for falls in old age (in the frame of a cross-sectional epidemiology survey).

2.3. The objective of Study 3 (S3) is to assess the possible effects of a multimodal exercise programme on gait (originally designed to improve physical fitness) in elderly participants compared to their inactive peers. S3 employs a retrospective study design.

3. Methods

3.1. Methods of S1 - Development of the Hungarian BBS and assessment of its clinimetrics

Phase 1: Translation and cultural adaptation

In this phase, a Hungarian BBS was developed. First, the original English version of the BBS was independently translated into Hungarian by two translators producing T1 and T2 Hungarian versions. One of the translators was a bilingual physiotherapist with 5 years of experience in geriatric physiotherapy; the other was a professional translator. In the first consensus meeting, the two translated scales were compared, and a preliminary Hungarian version was created. This version was back-translated into English by two native English translators who were blinded to the original English version of the BBS. The translators and two investigators with experience in geriatric physiotherapy compared the original BBS and back-translated English versions to develop a pre-final Hungarian version. This pre-final Hungarian version of the BBS was piloted in a group of 16 older adults by four physiotherapists with 4–5 years of experience in geriatric physiotherapy. Participants for pilot testing were recruited from the target population living in the institution where the study on evaluating the psychometric properties (i.e. Phase 2) was conducted. Their median age was 73.5 years, (12 women and four men with diseases specific to the target group. Physiotherapists and patients were interviewed regarding the comprehensibility of task-related instructions, the scoring terms, and any suggestions for rephrasing for clarity.

Phase 2: Evaluation of psychometric properties

In Phase 2, a total of 150 individuals aged ≥60 years living in a long-term care institution located in Budapest, Hungary were recruited. The inclusion criteria were as follows: ability to walk with or without walking aid, spoke Hungarian as a native language, and having cooperative behaviour. The exclusion criteria were as follows: use of a wheelchair, amputation of the lower limb, having undergone total hip arthroplasty or hemiarthroplasty in the previous 3-month period, as well as Parkinson’s disease and/or severe cognitive impairment. A total of 89 participants randomly selected from the total sample were re-assessed to examine reliability using the following method. Code numbers were assigned to all 150 participants that were later paired with a list of computer-generated random numbers between 1 and 150. Then, the random numbers were organised in ascending numerical order, and the first 89 participants were included in a subsample for the retest. Two physiotherapists (Rater A and Rater B), who had 5 and 7 years of experience, respectively, in geriatric physiotherapy working at long-term care institutions, examined the participants separately. Rater A performed the first BBS, while Rater

B performed the second measurement two hours later the randomly selected participants. After a 7-day period, Rater A performed the BBS again on the same randomly selected participants.

Measurements

First, the socio-demographic data of participants, including age and sex, as well as health-related data, including body weight, height, history of chronic diseases, use of walking aids, and fall history, were collected from the nursing documentation. A person who had fallen at least once in the past 12 months was considered a faller. After the BBS measurement, the functional mobility and status in activities of daily living (ADLs) were assessed. Functional mobility was assessed using a widely applied measure, the TUG_{single} test. The task during TUG_{single} was to stand up from an armchair with a seat height of 46 cm at the "Go" signal, walk at a comfortable but safe pace for three metres, come back and sit back on the chair. The functional status of the participants in ADL was assessed with the Katz index. This index shows the level at which an individual can perform basic everyday ADLs, including bathing, dressing, using the toilet, transferring, bowel and bladder control, and feeding, using a dichotomous scoring (0=dependent [i.e. with supervision, direction, personal assistance, or total care]; 1=independent [i.e. with no supervision]). A total score of 6 points indicates better functional status in ADL.

Statistical analyses

Continuous data were presented as means and standard deviations as well as quartile values; discrete data are presented as numbers and percentages. The distribution of our data based on skewness and kurtosis made parametric tests feasible.

Psychometric characteristics (reliability and validity domains) of the HU-BBS were tested.

To evaluate the floor and ceiling effects, the number of participants achieving the highest and lowest possible scores was determined. The presence of floor and ceiling effects was defined as at least 15% participants reaching the maximum or minimum scores, respectively.

Reliability was determined through internal consistency as well as intra- and inter-rater reliability. The internal consistency was assessed by calculating Cronbach's alpha value considering the factor structure of the HU-BBS. Values between .7 and .95 were considered acceptable.

To examine the relative reliability, the intra- and inter-rater reliabilities were determined by calculating the intraclass correlation coefficient (*ICC*) in a two-way random effects ANOVA model. To examine the absolute reliability, first the standard error of measurement (*SEM*) for repeated measurements was determined. Then, the *SEM* was used to calculate the minimally detectable change at 95% confidence level ($MDC_{95\%}$) using the $2.77 \times SEM$ formula. In addition, Bland–Altman plots were used to visualise the level of agreement between the inter-rater and test-retest measurements by plotting the difference between the HU-BBS scores against the means of the related HU-BBS scores. The 95% limits of agreement were estimated as $\pm 1.96 \times SD$ of the mean difference scores.

Construct validity of the HU-BBS was assessed through convergent, discriminant, and known-group validity. For convergent validity, associations between the HU-BBS score and functional status in ADL (measured with Katz index), functional mobility (measured with TUG_{single} test), as well as age, were analysed by calculating Pearson's correlation coefficient (r). The predefined hypotheses were that the HU-BBS would show a strong positive correlation (≥ .70) with Katz index and a strong negative correlation (≥ .70) with the TUG_{single} test and age. The discriminant validity was assessed by comparing the HU-BBS scores between women and men. The predefined hypothesis was that their HU-BBS scores would not be different. The known-group validity was demonstrated by determining the difference in the HU-BBS between older adults who had fallen and those who had not, using an independent samples t-test. We hypothesised that the HU-BBS score would be lower among people who had fallen at least once in the previous year.

Considering the number of items in the BBS and the recommendation we followed that the sample size should be at least ten times the number of items, but at least 100, we included 150 elderly people in the study. For reliability, 89 older adults were chosen to achieve the expected *ICC* of .70 with a power level of .80 and significance level of .05 and considering a dropout rate of 10%. All the calculations, except those for intra-and inter-rater reliabilities, were based on the data from the first measurement.

Statistical analyses for all three studies were performed with the predictive analytics software IBM SPSS Statistics (Version 19). Similarly, the level of significance was set at $p < .05$ in all three studies.

3.2. Methods of S2 - Investigating the fear of falling among community-living older adults: putting the FES-I questionnaire into practice

Data collection

A total of 204 participants aged 60 and over were recruited who were able to walk with or without a walking aid. We excluded those who were living in institutional settings, such as nursing homes, or who had a sensory or cognitive communication disability that would have made them unable to complete the personal data sheet and questionnaire.

The questions on the personal data sheet were used to obtain data on demographic characteristics (age, sex, and marital status), medication (medicines taken regularly), and health status (diabetes mellitus, osteoporosis, cardiac, respiratory, lower limb musculoskeletal, neurological (Parkinson's disease, stroke) diseases affecting mobility).

Measurements were made after data collection acquired through a self-administered questionnaire and physical measurements at the recruitment site (club hall, secular or religious community centres, churches, parishes). The personal data sheet also included the earlier validated Hungarian short FES-I questionnaire. To assess functional mobility, the TUG_{single} test was used.

Statistical analysis

For descriptive statistics of the sample, mean and standard deviation as well as quartile values, absolute and relative frequencies were calculated. Data normality was determined based on the skewness of the distribution and the results of the Shapiro-Wilk test. The continuous data obtained for the following variables were dichotomised as follows: [1] fear of falling (FoF) (0 = not perceived or normal if total score <10; 1 = abnormal if total score ≥10); [2] fall history (0 = no history of falls (labelled 'non-faller'); 1 = if at least one fall in the past year (labelled 'faller') A fall was defined as an event during which the individual unexpectedly and unintentionally fell from a higher level to the ground or a lower; [3] functional mobility measured by TUG_{single} test (0 = age-appropriate; 1 = if it took more than 12 seconds to complete the movement sequence); [4] medication use (0 = if taking up to 3 of the following medicines regularly: benzodiazepines, antidepressants, antipsychotics, diuretics, antiarrhythmics, non-steroidal analgesics; 1 = if taking more than 3 medications).

To compare our data, we used a two-sample t-test for data with a continuous normal distribution and a z-test for our observational data. We then used binomial logistic regression ('enter' method) to analyse the relationship between the dependent variable (FoF) and the independent variables (factors hypothesised to be related to FoF: age, sex, number of chronic diseases, functional mobility, previous falls, regular medication). The relationship between FoF and the independent variables was assessed by calculating an odds ratio (OR), which indicates whether or how strong the relationship is between the factor and FoF. The significance of the relationship was assessed using the 95% confidence interval (CI); a result was considered significant if it did not include the value 1. The explanatory power of the multivariate model was characterised by Nagelkerke's R^2, which indicates the percentage of the variance of the dependent variable explained by the model with independent variables.

3.3. Methods of S3 - Assessing the effects of a multimodal exercise programme on gait parameters

Data collection

A total of 57 community-dwelling people were recruited in the study. The inclusion criterion was the ability to walk without an assistive device. Exclusion criteria were either neurological or vestibular disorders or surgery either on the lower limbs or spine in the past two years.

Participants considered to be *physically active older people* (n=20) were defined by their age (60 years or older) and by their participation in a geriatric exercise programme for at least six months. Consequently, age-matched older individuals (n=20) recruited through an advertisement in a local newspaper were considered as *inactive older people* if they had not participated in any exercise programme in the previous six months. Age matching meant that the maximum age difference between participants in the physically active and physically inactive groups was allowed to be 5 years. Another group was used to control for age-related changes in gait parameters. This was a group of *physically inactive young people*, defined as subjects aged 35 years or younger who had not participated in any activity programme in the previous six months (n=17).

Measurements concerning the degree of variability of gait parameters were made by calculating the *coefficient of variation (CV)*; it is the ratio of the standard deviation to the mean expressed as percentage ([SD/mean]×100). The higher the value of the ratio, the greater level dispersion around the mean is expressed. Treadmill *gait analysis* made by Zebris FDM-T treadmill system (Zebris Medical GmbH, Germany) was employed to measure step length, step time, step width, and double support ratio as gait parameters. Subjects walked continuously on the treadmill for two minutes at a constant speed of 1.11 ms^{-1}. Based on the scientific literature, this speed corresponds to the average gait speed of the given elderly population. They were asked to walk in their own regular footwear. To assess *gait automaticity*, two versions of the TUG test were taken by the participants. Each of them underwent a TUG_{single} and a $TUG_{cognitive}$ in random order. During the $TUG_{cognitive}$, the TUG test was asked to be performed while counting backwards from a random starting point of 20 to 100 in threes. The automaticity index was calculated to measure the impact of the *cognitive task* on functional mobility using the formula as follows: $TUG_{single}/TUG_{cognitive}$ x100 (%). Evaluating the index, the closer the automaticity index was to 100%, the better the performance of the dual task was considered, i.e., the cost of the cognitive task on the automaticity of walking was lower.

Intervention

The 60-minute ***multimodal (geriatric) exercise programme*** is a combination of aerobic, strengthening, flexibility, and balance exercises, with a five-minute warm-up and cool-down period each. The exercises were performed under the supervision of a physiotherapist (with considerable expertise in physiotherapy for older people). This multimodal geriatric exercise programme was complemented by a Nordic Walking (NW) exercise programme. The maximum possible intensity of NW was moderate, i.e. the individual had no difficulty speaking while walking or the Borg rating perceived exertion was 12–14.

Statistical analysis

The mean and standard deviation as well as quartile values of the data were chosen to describe the sample. For exploring differences among the three groups, one-way independent ANOVAs were preliminarily planned to be conducted. Since the assumption of homogeneity was violated for gait variability data, the Welch's adjusted F statistics (or Welch's ANOVA) were used to determine the differences between groups and a non-parametric post-hoc test with Games-Howell method was used to perform multiple pair-wise comparisons between the relative values of the groups.

4. Results

4.1. Study 1

Phase 1: Translation and adaptation

Forward translation and the preliminary version

During the forward translation stage, some minor linguistic differences have arisen. Regarding item 3, since the meaning of safely and securely in Hungarian is the same, only one word was used in the sentence as follows: 'képes biztonságosan ülni 2 percig' (literal translation: able to sit safely for 2 min). Concerning items 8 and 9, 'inch' was converted to cm as follows: 10 in to 25 cm; 5 in to 12 cm; 2 in to 5 cm; 1–2 in to 2–5 cm.

Backward translation and the pre-final version

During the backward translation stage, some comprehension problems have emerged. These problems were resolved by the Expert Committee. Concerning items 10 and 11, there was a difficulty with the meaning of the term 'turn'. It was unclear whether 'turn' referred to turning of the trunk only, while the feet remained on the floor or whether it meant that small steps should be taken. Considering the aim of these two tasks and the results of the Greek, Turkish, and Brazilian studies, the instructions for these items were modified. In item 10, the following phrase was added at the end of the first sentence: 'anélkül, hogy a lábát felemelné a talajról' (literal translation: without lifting your foot off the floor). In item 11, the following phrase was added at the end of the first sentence: 'kis lépésekkel' (literal translation: taking small steps). Furthermore, the terms 'supervision' and 'assistance' required clarification. In our study, like in the Brazilian study, supervision was defined as 'standing close to the subject without touching them,' while assistance was defined as 'touching or giving a firm external support to avoid falls.' After resolving the aforementioned minor comprehension problems, a pre-final version of the BBS was created. During piloting, no confusing terms or difficulties in understanding were reported: hence, the pre-final Hungarian version was considered as the final Hungarian version of the BBS.

Phase 2: Assessment of the psychometric properties of HU-BBS

There were no floor or ceiling effects because only five participants (3%) obtained the highest total score of 56 points, while none of the participants achieved the lowest score.

Internal consistency

Cronbach's alpha coefficient was .929 for the first factor, .915 for the second factor, and .943 for the whole scale.

Inter- and intra-rater reliability

Of the 89 people originally selected, 81 completed the re-tests. The analyses of inter- and intra-rater reliability indicated excellent reliability (Table 1).

Table 1. Results of reliability analyses

n=81	*ICC*	95% CI	*SEM*	$MDC_{95\%}$
Inter-rater reliability	.988	.982 – .993	0.889	2.46 points
Intra-rater reliability	.984	.976 – .991	1.046	2.89 points

According to the Bland–Altman analysis, the mean inter-rater difference was 0.284, with 95% limits of agreement ranging from −2.193 to 2.744. Two outliers (2.47%) were identified. The mean intra-rater difference was 0.259, with 95% limits of agreement ranging from −2.657 to 3.162. Four data points (4.93%) lay outside this range.

Construct validity

The HU-BBS showed a strong positive correlation with the functional status in ADL, a strong negative correlation with the TUG test, and a moderate negative correlation with age (Table 2).

Table 2. Correlations between the BBS scores and functional mobility and status in ADL and age

	BBS scores	
	r	*p* value
TUG_{single} test	- .824	< .0001
Katz index	.833	< .0001
Age	- .606	< .0001

The HU-BBS score did not differ between women and men (mean ± *SD* for women: 42.5 ± 8.06 points vs mean ± *SD* for men: 44.93 ± 8.41 points; $p = .104$). There were no significant differences between sexes for fall and medical history except for osteoporosis, which was more frequent in female participants.

The HU-BBS score was significantly lower for older adults who had fallen than for those who had not (mean ± *SD* = 36.91 ± 5.36 points; vs mean ± *SD* = 50.54 ± 3.48 points; $p < .0001$).

4.2. Study 2

FoF was common for a total of 61 people (31%; male: n=9; female: n=52). Given that 91% of the sample was female, binary logistic regression analysis was also performed adjusting for sex. Since sex had no significant effect, there was no significant difference between the raw and sex-adjusted regression parameters of the multivariate models. Significant association between the number of chronic diseases in old age and FoF has been revealed. Each additional disease more than doubles the probability of having an abnormal FoF. A significant association between functional mobility and FoF was also confirmed. If for an older person it takes longer than the population threshold of 12 seconds to complete the TUG_{single} test, they are more than nine times more likely to develop FoF. The effects of having fallen within the previous year and of taking medicines more than three of the active ingredients examined were not found to be significant. Our sex-adjusted model with factors showing a significant association explains almost 70% of the variance of the dependent variable (Nagelkerke's $R^2 = .695$).

4.3. Study 3

Based on the results of Welch's adjusted F-statistics and, where appropriate, the Games-Howell method, the following statements were made.

There was a statistically significant difference in *step length variability* between the groups ($F(2, 28.01)=30.947$, $p < .001$). The results of the post hoc test showed that the inactive older group had significantly higher step length variability compared to both the active older group ($p = .007$) and the young group ($p < .001$). Simultaneously, there was also a significant difference between the active older group and the young group ($p < .001$).

There was also statistically significant difference between the groups in terms of *step time variability* ($F(2, 27.25) = 12.406$, $p < .001$). The post hoc test showed that the inactive older group had significantly higher step time variability compared to both the active older group ($p = .002$) and the young group ($p < .001$). Conversely, the difference between the active older group and the young group was not statistically significant ($p = .172$).

Regarding *double support ratio variability*, there was a statistically significant difference between the groups ($F(2, 29.37)=7.204$, $p = .003$). According to the results of the post hoc test, the variability of the double support ratio was significantly higher in the inactive older group compared to both the active older group ($p = .036$) and the young group ($p = .001$). The difference between the active older group and the young group, however, was not statistically significant ($p = .206$). For *step width variability*, the Welch's ANOVA showed no difference between groups ($F(2, 32.26)=0.957$, $p = .338$). In terms of *Cognitive Automaticity Index (CAI)*, a statistically significant difference among groups ($F(2, 54)=7.881$; $p = .001$) was revealed. Post hoc tests verified that the CAI in the inactive older group was significantly lower compared to the active older group ($p = .006$) and the young group ($p = .003$). Conversely, no significant difference was proved between the active older group and the young (inactive) group ($p = .998$).

5. Conclusions

Physiotherapists can play a key role in helping older people to maintain their functional abilities, so that they can live independently for as long as possible and at the highest possible level. This key role of physiotherapists is threefold: developing valid and reliable diagnostic tools, implementing diagnostic tools with sound clinimetrics already assessed, and assessing interventions that are proven to be effective for improving postural control. Valuable diagnostic tools can help physiotherapists to identify individuals at risk of functional decline at an early stage, and effective therapeutic procedures can help to successfully improve declining abilities, making the compression of functional decline and thus successful ageing possible.

5.1. Conclusions from S1

The BBS is a widely used measurement tool for comprehensively assessing the balance of older adults in various settings. Owing to its ease of use, it can be applied not only among older adults, but also among people with various diseases and health conditions. Our study shows that the Hungarian version of the BBS, like those of other languages, has good clinimetrics. After testing on our sample of institutionalised older people, this instrument has relative and absolute reliability indices akin to those other culturally adapted versions. Based on the investigation of its construct via discriminant, convergent, and known-group validity, it was found to be a valid tool as those of other cross-culturally adapted versions. Therefore, the HU-BBS can be recommended for use in assessing balance in Hungarian people not only in everyday clinical practice, but also in single- and multi-centre scientific studies, which might allow comparison of data cross-culturally.

5.2. Conclusions from S2

Fear of falling is considered abnormal when it causes older people to avoid activities they would otherwise be able to do. As a result of a self-perpetuating mechanism, their physical condition is rendered to be poorer, their muscles weaken, their balance control deteriorates, and eventually they lose their ability to care for themselves and become institutionalised. To prevent this self-perpetuating vicious circle from developing, persisting, and worsening, it is particularly important to identify elderly people who are overwhelmed with unreasonable concerns of falling during their daily activities in a timely manner and to involve them in an adequate prevention programme. The short FES-I questionnaire, which is simple and quick to fill out and validated in Hungarian, is particularly useful for screening older people with multiple chronic conditions. By means of the short FES-I we can identify those who are in the need of further detailed screening, a thorough examination. Based on the results, when identified, they can more easily and quickly be involved in targeted interventions.

5.3. Conclusions from S3

The most common and fundamental activity of independent daily living is safe gait. Previous studies have already proved the beneficial effects of diverse exercise programmes on gait safety improvement among older people. Our study demonstrated that the beneficial effects of the multimodal exercise programme employed on gait parameters is similar to those other multimodal exercise trainings, Jaques-Dalcroze eurhythmics, traditional tai chi, or dance-like movements which are already widely used to improve gait safety. Owing to the preferences of the older people influencing their adherence to an exercise programme, it is of high importance that diverse exercise programmes aiming at improving gait safety should be available for this population. The multimodal exercise programme applied in our study certainly enriches the range of available effective geriatric exercise programmes. Successfully delaying functional decline starts with identifying individuals at higher risk as early as possible. Multimodal programmes have been found to be effective in improving gait parameters that are not only associated with the risk of falling but are also determinants of functional capacity. In the light of the above, we recommend both the widespread use of HU-BBS and FES-I for screening elderly patients in clinical settings and the wider availability of multimodal programmes for the elderly with a similar design to the exercise programme used in this study. These can make a valuable contribution to successful ageing.

6. Bibliography of the candidate's publications

6.1. Publications that formed the basis of the dissertation

Simon, **A.**, Gyombolai Zs., Kubik A. Zs., Báthory, Sz., Jónásné Sztruhár I., Fábián G. & Kovács, É. (2023) Cross-cultural validation of the Berg balance scale to assess balance among Hungarian institutionalised older adults *Disability and Rehabilitation*, DOI: 10.1080/09638288.2023.2232717
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IF: 1.432

6.2. Publications in the field of geriatric physiotherapy care as first and co-author.

Kovács, É. & **Simon, A** (2023). Az eleséstől való félelem a geriátriai betegek körében: narratív áttekintő közlemény. [Fear of Falling among Geriatric Patients: a Narrative Review.] *Nővér, 36*(6), 12–18. https://doi.org/10.55608/nover.36.0027 Hungarian
Simon, A., Vass, Z., Farkas, V., Gyombolai, Z., & Kovács, É. (2020). Az ülő életmóddal kapcsolatos tényezők idősotthonban élő, járásképes idős személyek körében. [Factors associated with sedentary lifestyle among older people with the ability to walk, living in nursing homes] *Orvosi Hetilap OH*, *161*(28), 1175–1180.
https://doi.org/10.1556/650.2020.31765 Hungarian
IF: 0.540
Erdős, R.L., Jónásné Sztruhár, I., **Simon, A**., & Kovács, É. (2020). Factors associated with postural control in nursing home residents: Oral presentation at the 13th Conference of the Hungarian Medical Association of America – Hungary Chapter (HMAA-HC) at 30–31 August 2019, in Balatonfüred, Hungary. *Developments in Health Sciences*, *2*(4), 104–107. https://doi.org/10.1556/2066.2019.00005
Kovács, É., Sztruhár, I. J., Mészáros, L., Gyombolai, Z., **Simon, A**., & Farkas, V. (2019). Comparative analysis of functional mobility among Hungarian community-living and institutionalized elderly individuals. *Developments in Health Sciences DHS*, *2*(2), 46–50. https://doi.org/10.1556/2066.2.2019.007