

# The Frail'BESTest. An Adaptation of the "Balance Evaluation System Test" for Frail Older Adults. Description, Internal Consistency and Inter-Rater Reliability

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**Introduction:** The Balance Evaluation System Test (BESTest) and the Mini-BESTest were developed to assess the complementary systems that contribute to balance function. These tests include functional tasks involving several high-level exercises to assess the balance function, which may be even more difficult in case of frailty. The Frail'BESTest has been developed to make it possible to include frail older adults in systemic assessment. In this first paper, the objective is to present the Frail'BESTest and to describe the usefulness and complementarity of each system and to test the inter-rater reliability of the score measurements in two health centers.

**Methods:** In the first center, 192 frail and non-frail older patients were enrolled to test I) the contribution of each system, II) internal consistency, and III) the threshold and ceiling effects. The scores of 32 patients from center 1 and 32 patients recruited in another center (center 2) were used to measure the inter-rater reliability of the measurements by means of Kendall's tau coefficients.

**Results:** The internal consistency was moderate to good for five systems and limited for "biomechanical constraints". The distribution of the Frail'BESTest was more centered than that of the Tinetti and Mini-Motor tests. The Kendall's tau showed strong concordance in center 1 for all systems and only for 4 on 6 systems in center 2.

**Discussion:** Completing a systemic evaluation, the therapist may prioritize the patient's needs identifying the most challenging systems. This paper presents the Frail'BESTest and confirms the psychometric properties at a first step level.

**Keywords:** frailty, geriatric assessment, systemic evaluation, motor evaluation, psychometric properties

## Introduction

The BESTest (Balance Evaluation System Test) was validated in 2009 by Horak et al as an innovative diagnostic tool for therapists, using a systemic approach to patient balance. The BESTest helps to prioritize rehabilitation by identifying disabilities and classifying them into complementary systems called sections.<sup>1</sup> Though the BESTest is a relevant test, the time to completion makes it difficult to implement in current care. The MiniBESTest was therefore developed and validated as a shorter version of the original.<sup>2</sup> The BESTest and Mini-BESTest have been validated in various populations, including patients with Parkinson's disease,<sup>3-5</sup>

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multiple sclerosis,<sup>6,7</sup> kidney disease,<sup>8</sup> strokes,<sup>3,9-11</sup> knee osteoarthritis<sup>12,13</sup> and older adults.<sup>14-16</sup>

However, although these tests do not present important floor or ceiling effects,<sup>17</sup> they include functional tasks involving several challenging exercises to assess balance, such as sit-to-stand or back-to-sit transfers without armchairs or rise-to-toes without support. These exercises are very hard to do for most frail older adults. Indeed, frailty<sup>18-21</sup> entails significant fatigability and a considerable reduction in physical performance. The frailty state is associated with a decrease of physical and/or cognitive abilities, functional reserves and resistance to stressor events which can lead to increased physical inactivity, disability, biological disturbances, risk of fall, and hospitalizations.<sup>20,21</sup> Frail older adults have various deficiencies and are unable to compensate adequately to maintain an optimal functional level.<sup>20</sup> Typical deficiencies involve the sensorial system, the visual system,<sup>22</sup> articular and associated proprioceptive impairments,<sup>23</sup> and sarcopenia. Alteration of the proprioceptive system mainly contributes to slower execution of movements<sup>23</sup> whereas sarcopenia is a loss of muscle mass contributing to a deficit in strength and in muscle power.<sup>24</sup> Most of these deficiencies are associated with the functional level of frail patients.<sup>25</sup> There is considerable evidence that deficits of balance and gait abilities can have consequences on functional activities of daily life associated with an increased risk of fall and risk of becoming dependent.<sup>26,27</sup> In geriatric practice, balance is often assessed with functional tests<sup>28</sup> to objectively quantify the patient's capacities. However, these functional tests do not give a lot of information about the balance deficits. A systemic approach like the BESTest could help, prioritizing the rehabilitation objectives by identifying the different deficiencies.

In furtherance of tests adapted for frail older adults, such as the Mini-Motor Test<sup>29</sup> and the Backward Disequilibrium Scale,<sup>30</sup> we have designed an adapted version of the BESTest that will make it practical for use in frail older adults: The Frail'BESTest. The modified test respects Horak's systemic approach, which was to identify the disorders underlying balance control. Therapists can therefore directly manage therapeutic intervention for different types of balance deficiencies. Overall, six sub-systems have been addressed: A: anticipations, B: reactions, C: locomotion, D: sensorial orientation, E: biomechanical constraints and F: asymmetric gait. The organization of each system, the instructions and the evaluation criteria are described in the methods section.

The aim of this paper was to define the Frail'BESTest, to assess its psychometric properties, to describe the usefulness and complementarity of each system, to measure the distribution of scores in a sample of patients and to measure the inter-rater reliability of the measurements in two health centers. For the sake of clarity, a second paper will focus on the concurrent validity, the responsiveness, and the predictive capacities of the Frail'BESTest, as well as its ability to detect frailty.

## Materials and Methods

### Description of Frail'BESTest Items

The test is shown in [Figure 1](#), and the instructions and evaluation criteria for all the assessed items are presented in [Table 1](#).

[Table 2](#) compares the items of the BESTest with the items of the Frail'BESTest. It clearly indicates when a test is maintained, adapted or removed, and each choice is justified. We limited the scoring scale, offering only a binary choice. This is in response to the needs of therapists who are in search of a tool that is (1) informative about the systems involved in the motor impairment and (2) easy and quick to complete.

The "anticipation" section is composed of five tests: two are focused on the diagnosis of anticipatory postural adjustments (APA) (ie Motor programming; Massion et al 1992, for a review)<sup>31</sup> and three are focused on the diagnosis of potential deficiencies in motor planning processes.<sup>32,33</sup> Both APA tests allow the therapist to detect potential impairments in postural anticipation by detecting the consequences of non-optimal movement preparation. APA testing is found in the BESTest,<sup>1</sup> but the difficulty level has been adjusted for frail older adults. As explained in [Table 1](#), the evaluator is asked to assess how well the patient prepares for the movement, not the patient's ability to do the actual task. For example, in the "rise to toes" task, the patient takes the therapist's hands and then has to raise his/her heels off the floor several times. If the patient initially tips back, pulling the therapist's hands, an APA deficiency is probable, since the patient does not move his/her center of mass forward before contracting the soleus muscles in a concentric mode in order to rise.<sup>34</sup> APA testing is overridden in a context of frailty: we know that most falls occur when frail older adults are coordinating their posture and movement.<sup>35</sup> For the motor planning tests, the therapist assesses the sequence of movements: making sure that the different phases of the whole

Frail-BESTest									
Patient : Birthday: Therapist: Date :		<b>A. Anticipations</b>		YES	NO	<b>E. Biomechanical constraints</b>		OK	Not OK
		Rise to toes		1	0	Effort adaptation		1	0
		Alternated reach on a step		1	0	Lower limbs muscle power		1	0
		Half-turn preparation		1	0	Ankle range of motion		1	0
		Sit-to-Stand		1	0	Foot quality state		1	0
Back-to-sit		1	0	TOTAL (A)					
Gait-Speed = <span style="border-bottom: 1px solid black; display: inline-block; width: 100px;"></span>		<b>B. Reactions</b>		YES	NO	Directional instability		1	0
		Postural Adaptation		1	0	Functional Reach Test		1	0
		Fall avoidance reaction		1	0	TOTAL (E)			
		TOTAL (B)							
<b>F. Gait symmetry</b>		<b>C. Locomotion</b>		OK	Not OK	TOTAL (A+B+C+D+E+F)			
		Gait speed in dual task		1	0	/ 26		Observations :	
		Gait speed modulation		1	0				
		Half-Turn quality		1	0				
		Cervical rotation		1	0				
Go down to the floor		1	0						
Rising from the floor		1	0						
TOTAL (C)									
<b>D. Static postural control (sensory orientation)</b>		<b>D. Static postural control (sensory orientation)</b>		OK	Not OK				
		Feet with /Open eyes/firm surface (Polygonal)		1	0				
		Feet apart/closed eyes/firm surface (Visual)		1	0				
		Feet apart/Open eyes /foam surface (Podal)		1	0				
		TOTAL (D)							
<b>F. Gait symmetry</b>		YES	NO						
Gait symmetry		1	0						
Weight bearing pain		0	1						
Strenght deficit		0	1						
TOTAL (F)									

**Figure 1** English version of the Frail'BESTest.

movement are respected for optimal execution (for example, tilting the trunk forward before pushing on the lower limbs to stand up).

The “locomotor tests” are relatively similar to the BESTest, and include the “sit on the floor and stand up” task, classified in the biomechanical constraints section in the BESTest.<sup>1</sup>

The “static postural control” section, similar to the “sensorial orientation” of the BESTest, is focused on three main compensations classically observed in geriatrics: visual-dependency (difficulty with eyes closed),<sup>36,37</sup> polygonal dependency (difficulty reducing the support surface) and podal-dependency (difficulty on a foam surface).<sup>38,39</sup>

The “asymmetric gait” section targets a potential decreased step length and helps the therapist to find the subsequent causes: muscular deficiency, reduced range of motion or nociceptive inputs.

The “bio-mechanical constraints” section assesses various common types of movement limitations. The items are designed to test for a potential deficiency in muscle power,<sup>25,40</sup> a limited range of motion in the ankle,<sup>41</sup> a poor adaptation to effort,<sup>42</sup> a reduction of the stability limits (adapted Functional Reach Test)<sup>43</sup> and a directional preference in instability.<sup>30</sup>

## Context, Methods and Participants

In the first center, 192 frail and non-frail older patients were enrolled to test I) the contribution of each system, II) internal consistency, and III) the threshold and ceiling effects. The scores of 32 patients from center 1 and 32 patients recruited in another center (center 2) were used to measure the inter-rater reliability of the measurements by means of Kendall's tau coefficients.

Our enrolled patients were aged 67 to 95 years (mean  $\pm$  standard deviation =  $84.07 \pm 5.17$  years), and 65.7% female. The local ethics committee of the François Mitterrand hospital approved the experimental protocol, which was carried out in agreement with legal and international requirements (Declaration of Helsinki, 1964). Patients were informed about the research project and gave their written consent before the evaluation. The threshold of  $0.65 \text{ m.s}^{-1}$  in the gait speed test was used to detect the frailty state. The gait speed has been shown as a very good landmark for physical frailty and severe outcomes.<sup>44–46</sup> However, patients were considered frail after a conscientious examination of their medical files, and the final diagnosis was made by geriatrician according to the clinical features of the syndrome. Patients were recruited from the first geriatric department (center 1)

**Table 1** English Version of the Frail'BESTest: Instructions and Evaluation

System	Test	Consign	Evaluation
A Anticipations	Rise to toes	"Give me your hands, rise on your toes and come back down, 3 times"	I: optimal postural preparation (anterior pelvic shift)
	Alternated foot reaching on a step	"Put your foot on the stair and go back on the floor, and with the other foot, repeat 2 times"	I: optimal postural preparation (lateral pelvic shift)
	Half-Turn preparation	"Please go straight on and turn around in front of this wall"	I: optimal postural preparation (the last foot support is oriented on the turn direction)
	Sit-to-stand	"Please Stand-up"	I: optimal trunk tilt (around 45–60° with vertical line)
	Back-to-sit	"Please sit-down"	I: optimal trunk tilt (around 45–60° with vertical line)
B Reactions	Postural adaptation	"I look for your reaction"	I: Optimal muscular contraction with the anterior muscular plan to counteract the anteroposterior light push
	Fall avoidance reaction	"I look for your reaction"	I: Optimal back step to counteract the anteroposterior heavy push
C Locomotion	Gait speed in dual task	"Please walk on this corridor, I am just behind you"	I: No notable gait-speed decrease, or instability
	Gait speed modulation	"Please try to walk faster, and now slower"	I: Ability to walk faster and slower
	Half-turn quality	This test can be assessed during the part A	I: No more than 4 steps are necessary to finish the half-turn
	Cervical rotation when walking	"Please walk on this corridor, I am on your side ... ok now please turn the head to watch me, and now turn on the other side"	I: The patient turn the head with 45° of cervical rotation without slowdown or instability
	Go down to the floor	"Please sit down on the floor, you can use this chair to help yourself"	I: The patient sit down without human help (physical or verbal), securely
	Rise from the floor	"Please standup from the floor, you can use this chair to help yourself"	I: The patient stand up without human help (physical or verbal), securely
D Sensory orientation	Feet together/eyes open	"Please stay in this stand up position for a few seconds"	I: The patient is able to stay during 15 seconds in the position without important instability
	Feet shoulder width apart/ eyes closed	Please stay in this stand up position for a few seconds"	I: The patient is able to stay during 15 seconds in the position without important instability
	Feet shoulder width apart on a foam surface/eyes open	Please stay in this stand up position for a few seconds"	I: The patient is able to stay during 15 seconds in the position without important instability

(Continued)

**Table I** (Continued).

System	Test	Consign	Evaluation
E Biomechanical constraints	Effort adaptation	No specific consign	I: The patient is not short of breath when he sit down after the gait speed test
	Lower limbs muscle power	Consign of the chair test: "please stand up and sit down successively, I will say when you will stop, you can use the armchairs if you need"	I: The patient is able to stand up and sit down three times in 15 seconds
	Ankle range of motion	No specific consign, patient is sit down, with 90° hip and knee flexion	I: passive and active range of motion of more than 10° in dorsal ankle flexion
	Foot quality state	No specific consign, no shoes	I: no problem on the feet, neither cutaneous nor osteoarticular deformities
	Directional instability	No specific consign, the patient is observed during the others tests	I: no preferential instability in one direction, for example backward, or laterally.
	Anterior stability limit (Functional Reach Test)	Consigns of the FRT (Duncan et al 1990): "Please reach forward as far as you can with your index finger without moving on your feet"	I: The patient is able to reach minimum 26 cm
F Gait Symmetry	Gait symmetry	No specific consigns, gait analysis during the gait speed test	I: Equal longer of each step
	Weight bearing pain	"Do you have pain when you charge one foot?"	I: No pain neither for the right nor for the left foot charge
	Strength deficit	No specific consign	I: The therapist evaluation find no strength deficit linked with the gait asymmetry
	Range of motion deficit	No specific consign	I: The therapist evaluation find no range of motion deficit linked with the gait asymmetry

and a second geriatric department in another region of France (center 2). Data were collected between September 2014–April 2015 in center 1 and between January 2014–September 2015 in center 2. [Figure 2](#) displays the patient's distribution in the two centers (Flow diagram).

For clarity, the 192 patients from center 1 are presented in two subgroups: non-frail and frail patients. Please see patients' characteristics in [Table 3](#).

Patient data were collected to calculate the following: I. system contribution, II. internal consistency, and III. distribution of the scores (see statistical analysis). Another double-blind evaluation was conducted with these patients in order to calculate the inter-rater reliability of the Frail'BESTtest.

In center 1, patients were recruited during their outpatient hospital consultation. The motor assessment was performed by an experienced physiotherapist before any of the other

evaluations conducted in this center. This motor assessment included the Frail'BESTtest, the Tinetti test (Performance Oriented Mobility Assessment)<sup>28</sup> and the Mini-motor test.<sup>29</sup> Tinetti and Mini-motor tests were used as comparators since they were being used by clinicians in the two centers at the time. The Tinetti test has proved its reliability in institutionalized aged adults with interrater reliability coefficients ranging from 0.80 to 0.95 and reported test–retest reliability of 0.72 to 0.86.<sup>47,48</sup> The Tinetti test has also exhibited construct validity with gait speed in people with Parkinson's disease and with the Timed Up and Go in older adults.<sup>49,50</sup> The Mini-motor test<sup>29</sup> has very good inter-rater reliability (Pearson coefficients up to 0.95), with a limited redundancy between items (coefficients were far from 100%). The correlation between the Mini-motor test and the Katz index was significantly negative ( $p < 0.05$ ).

In center 2, the recruited patients were assessed during the first session of a rehabilitation program. The motor

**Table 2** Comparisons Between BESTest and Frail'BESTest Items

Items in the BESTest	Items in the Frail'BESTest	Justification
Base of support	Foot quality state	Essential
Com alignment	Directional instability	Directional instability may be checked in static or dynamic balance
Ankle strength & range	Ankle range of motion And lower limbs muscle power	We choose to prioritize the ankle range of motion and the power of all the lower limb muscles with an adaptation of the chair test
Hip/trunk lateral strength	No	This analytic regional analysis had been removed by the functional analysis of Gait symmetry (Part F), that could highlight an impairment in hip stability
Sit on floor and standup	Go down to the floor and rise from the floor	Essential
Sitting verticality and lateral lean	No	We prioritized the functional reach forward test
Functional reach forward	Functional reach test forward	Essential
Functional reach lateral	No	We prioritized the functional reach forward test
Sit to stand	Adapted sit to stand	Use of hands allowed. We targeted the optimal trunk tilt in the evaluation criteria
Rise to toes	Adapted rise to toes	The patient takes the evaluator's hands. We targeted the optimal postural preparation in the evaluation criteria
Stand on one leg	No	We prioritized the RISE TO TOES and the ALTERNATE STAIR TOUCHING
Alternate stair touching	Adapted alternate stair touching	The evaluator has a hands contact on the iliac bones. We targeted the optimal postural preparation in the evaluation criteria
Standing arm raise	No	We prioritized the RISE TO TOES and the ALTERNATE STAIR TOUCHING
In place response forward	No	We prioritized the Backward reactions
In place response backward	Postural adaptation	Essential
Compensatory stepping reaction forward	No	We prioritized the Backward reactions
Compensatory stepping reaction backward	Fall avoidance reaction	Essential
Sensory integration for balance	Sensory orientation	This test is adapted to assess both the visual-preference (eyes closed) and the foot-preference (foam surface) but we replaced the eyes closed/foam surface condition by the reduced polygon condition (feet together) as it is a frequent compensation.
Incline-eyes closed	No	We prioritized the SENSORY ORIENTATION

(Continued)

**Table 2** (Continued).

Items in the BESTest	Items in the Frail'BESTest	Justification
Gait – level surface	Gait speed test	The GAIT SPEED TEST has to be done along 10 meters before the Frail'BESTest examination
Change in gait speed	Gait speed modulation	Essential
Walk with head turns	Cervical rotation when walking	Essential
Walk with pivot turns	Half-turn quality and half-turn preparation	The HALF-TURN QUALITY is similarly evaluated by the stability and the number of steps and the HALF-TURN PREPARATION is focused on the postural preparation
Step over obstacles	No	We prioritized the other locomotor tests
Timed get up and go	No	We prioritized the other locomotor tests because the simple Timed Up and Go is a dual task for some patients with cognitive dysfunctions.
Timed get up and go with dual task	Gait speed in dual task	We use the GAIT SPEED IN DUAL TASK to compare with the normal GAIT SPEED
	Back-to-sit	This is an important test to spot the motor planning impairments
	Effort adaptation	This test allows to note a dyspnea in case of effort adaptation impairment
	Gait Symmetry and the associated weight bearing pain/strenght deficit/range of motion deficit	<i>This section allows detecting a mechanical problem of pain/strength/range of motion potentially explaining gait asymmetry.</i>

assessment included the Frail'BESTest and the Tinetti test, and was conducted at the beginning of the first rehabilitation session for all of the included participants. All of the patients were previously informed of the aim of the study and gave their written consent. The Frail'BESTest was the only supplementary test done specifically for the study.

In both centers, the exclusion criteria were the inability to stand up with help and the inability to understand basic instructions from the therapist.

## Material

The motor assessments were done either in a large corridor (for gait analysis) or in the physiotherapist's office (for the other evaluations). The Frail'BESTest requires only two specific devices: foam (mean density 55 kg/m<sup>3</sup>) for the "sensorial orientation" section and a 12-cm-high rehabilitation step for the "anticipations" section. Motor assessments were immediately scored by the physiotherapist and entered into a specific computer. For tests of inter-rater reliability, the two physiotherapists from each center scored the patient successively, suggesting a 10-min rest in the middle in order to avoid fatigue. The two

physiotherapists alternated positions (first or second evaluator) for each patient.

## Statistical Analysis

Our aim was to determine the internal consistency of the parameters, the construct validity and the reliability of the Frail'BESTest. Sub-scores were calculated for each of the six systems of the Frail'BESTest, and the total score was obtained by totaling these six sub-scores.

An a priori statistical power calculation was done to determine the expected number of subjects. It was based on a power of 0.90, an alpha of 0.05 and a Kendall's Tau higher than 0.7. Based on this hypothesis 30 subjects are expected to achieve enough statistical power.

## Internal Consistency

Internal consistency is defined by the COSMIN panel as the degree of inter-relatedness among the items of each sub-scores.<sup>51</sup> As all sub-scores came from different dimensions, we tested the hypothesis that items from the same sub-score were closely linked and would evolve together (ie measure the same construct). To test this hypothesis, we evaluated the item-total correlation (correlation of each

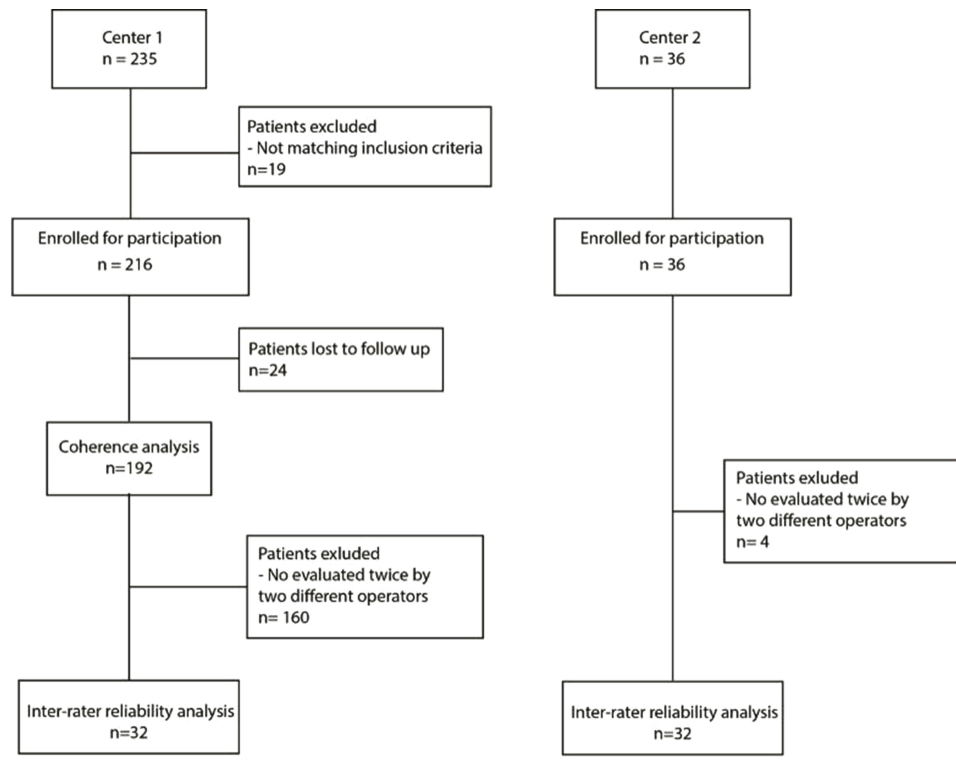


Figure 2 Patient distribution in center 1 and center 2.

item to its sub-score). The Cronbach alpha coefficient and the Kendall’s tau were also used to test the consistency of sub-scores. A Cronbach Alpha and a Kendall’s tau higher than 0.5 were considered acceptable and higher than 0.7 as satisfactory.<sup>52,53</sup>

In a second point, we aim to test the correlation between each domain and the total score. We evaluated the correlation between each sub-score and the total patient score. The relationship between the sub-scores and the total scores was evaluated using both a Kendall’s

Tau and the linearity of the ANOVA. To be part of the scale, we considered an item-total correlation (Kendall Tau) between 0.2 and 0.9. We then plotted the distribution of the Frail’BESTest, the Tinetti Test (considered the gold standard) and the Mini-motor test to seek a potential ceiling effect.

Distribution of the Scores

Distribution was assessed for all three scales (Frail’BESTest, Tinetti and Mini-Motor Test) and it was tested separately for frail and non-frail patients to visualize the homogeneity of the scores in the two samples. Skewness and kurtosis were computed to assess, respectively, the symmetry and the tailedness of the test distributions.

Inter-Rater Reliability

Kendall’s tau was computed to assess the inter-rater reliability of the measurement. A between day test–retest evaluation was performed with a 24-h interval. Evaluators in center 1 received more training for the Frail’BESTest than those in center 2. In both centers, the Kendall’s tau was calculated for total scores and sub-scores (scores for each section) of the Frail’BESTest. The Kendall’s tau was calculated to assess relative reliability using a two-way random effect with an average measure of absolute agreement.

Table 3 Characteristics of the 192 Non-Frail and Frail Patients Enrolled in Center 1

Parameters	Non Frail Mean (SD)	Frail Mean (SD)	P-value
N	82	110	
Male/Female	34/48	31/79	P = 0.065
Age (years)	81.9 (5.4)	85.4 (4.9)	P<0.001
BMI	26.6 (5.1)	26.9 (4.9)	P=0.78
Walking velocity (m/sec)	0.80 (0.12)	0.47 (0.12)	P<0.001
Tinetti score	23.8 (3.3)	16.9 (3.9)	P<0.001
Frail BEST Test score	20.0 (3.7)	13.5 (4.4)	P<0.001
Mini-motor test	18.6 (1.7)	14.8 (3.2)	P<0.001

A Kendall's tau higher than 0.6 was defined as strong and a Kendall's tau higher than 0.8 was defined as very strong.<sup>54</sup>

## Results

Overall, 192 patients were enrolled in center 1 and 32 patients in center 2 (see Figure 2 for flowcharts). Each patient completed all of the items in the scale. Among the 224 patients, 145 were diagnosed as frail according to their gait speed.

The results of the linearity of one-way ANOVAs showed that each system contributes to the total patient scores. Similarly, the linearity coefficient was significant for the relationships between each system and the total score of the Frail'BESTest. The ANOVAs indicated that there is significant linearity between each system and the total score of the Frail'BESTest ( $F > 50$ ;  $p < 0.001$ ).

Internal coherence, tested with the Cronbach alpha coefficient, was moderate to good for five systems (anticipations: 0.784; reactions: 0.636; locomotion: 0.789; sensorial preferences: 0.64; asymmetric gait: 0.698) and limited for the "biomechanical constraints" system (0.478). Item-total correlations were significant for all items and ranged from 0.3 to 0.75, excepted for one item, "System F-Gait symmetry" showed a correlation of 0.98 with its sub-score. Correlations between each sub-score and the total score were ranged between below 0.75 (anticipations: 0.66; reactions: 0.59; locomotion: 0.71; sensorial preferences: 0.56; asymmetric gait: 0.33; biomechanical constraints: 0.60).

The distribution of the scores obtained for each test and expressed as a percentage of the maximum score are provided in Figure 3 (frail patients in the upper portion and non-frail patients in the lower portion). The lower part of the figure (non-frail) and the significant negative skewness indicated that there is a ceiling effect for all scales: most of the patients obtained high-level scores. The medians, first quartiles and third quartiles show that the scores of Mini-motor tests are at the top of the distribution (median = 92.8%), followed by the Tinetti test (median = 77%) and the Frail'BESTest (median = 71.5%). Interestingly, only 13/73 non-frail patients had a score under 50% of the maximum score with the Tinetti test, whereas 21/73 non-frail patients had a score under 50% with the Frail'BESTest. The upper part of the figure (frail patients) reveals that there is no ceiling effect and a very homogeneous distribution of the scores for the Tinetti test (first quartile: 34.6% and third quartile: 61.5%) and the Frail'BESTest (first quartile: 32.1% and third quartile: 57.1%) showed by non-significant

skewness and kurtosis. The distribution to the left side of the curve was more pronounced with the Frail'BESTest (median = 42.9%) compared with the Tinetti test (median = 46.2%).

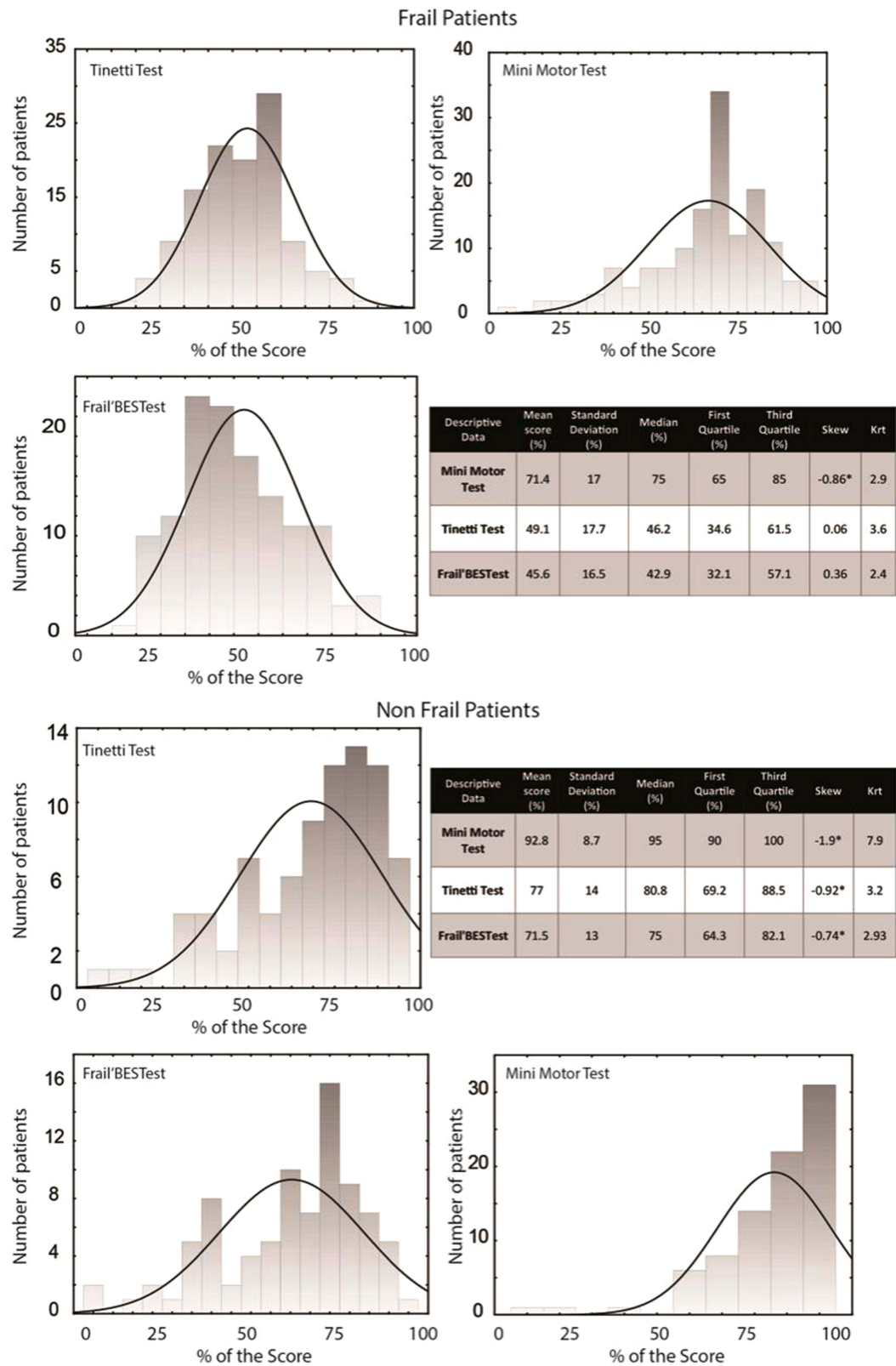
As detailed in Figure 2, inter-rater reliability was studied at both care centers. The results for the Frail'BESTest are presented in graph form in Figure 4A for center 1 (expert physiotherapists and familiar with the Frail'BESTest) and in Figure 4B for center 2 (expert physiotherapists not familiar with the Frail'BESTest). As shown in Figure 4, the Kendall's tau was calculated for these two pairs of evaluators. The Kendall's tau for center 1 was higher than 0.6 indicated a strong concordance for all sub-scores of the Frail'BESTest score. The Kendall's tau in center 2 was strong for 4 on 6 sub-scores of the Frail'BESTest score. Two scores (A and F systems) remain with moderate concordance ( $>0.41$ ) (see Figure 4C).

## Discussion

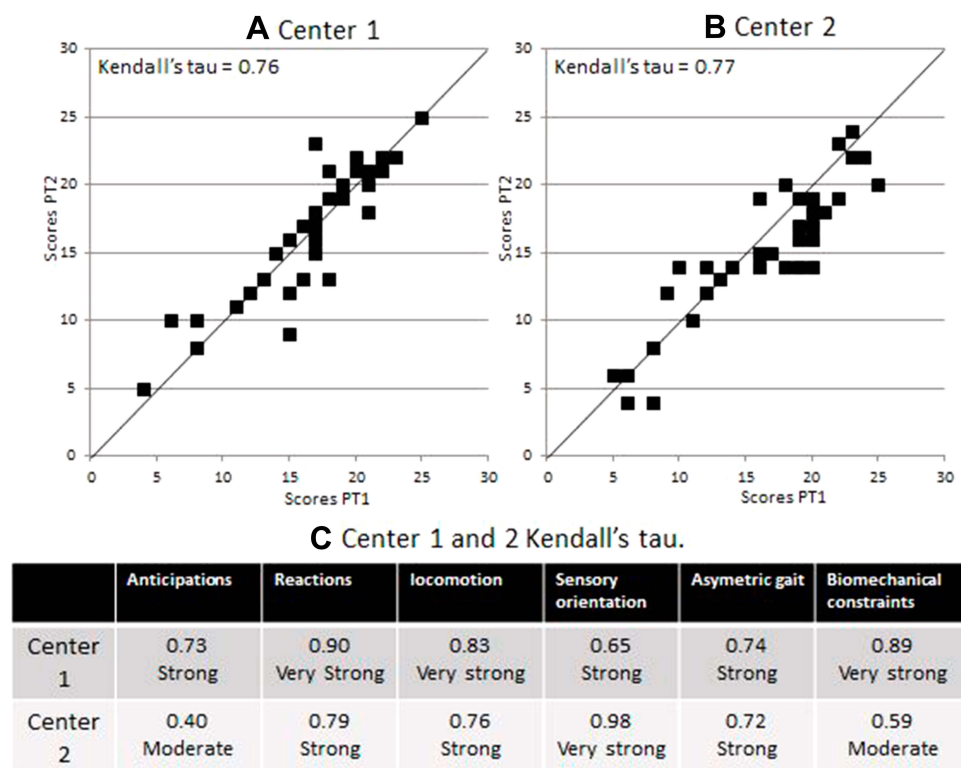
The focus of the present study was to analyze a new Balance Evaluation System Test (BESTest),<sup>1</sup> which is a systemic assessment of balance initially suggested by Horak et al. The modified version, named the Frail'BESTest, was designed for use in frail older adults. In clinical practice, the Frail'BESTest is feasible: an experienced physiotherapist needs eight to 10 min to complete the test with a mild-impaired patient. Completing the evaluation, the therapist may prioritize the patient's needs identifying the most challenging systems. Prioritization is very important in a geriatric context: patient's fatigability involves to choose the most efficient exercises in order to improve the rehabilitation outcomes. We presented the modified version of the scale, and we then conducted a validation analysis. In this paper, we wanted to verify the utility of each system, the complementarity of each system and the inter-rater reliability.

The contribution of each system was found to be good; each system contributed to total patient scores. The linearity F-score of the ANOVA and Kendall's Tau were significant for the relationships between each system and the total score of the Frail'BESTest. Each system demonstrates ability in a specific domain and measures a specific aspect of balance. The mechanisms of age and frailty are complex,<sup>19</sup> so it is important to target different potential affected systems in order to prioritize rehabilitation. The exhaustive exploration of deficiencies initially validated in the BESTest appears to be maintained in the Frail'BESTest but should be confirmed in further studies.

The internal consistency of the systems was satisfactory or acceptable, except for the "Biomechanical



**Figure 3** Distribution of the scores obtained by the 192 patients for each test and descriptive data regarding distribution for the three tests (frail patients in the upper portion and non-frail patients in the lower portion). The black curve represents the theoretical normal curve extracted from the observed distribution. The table indicates means, standard deviations, medians and quartiles of each distribution regarding frailty status. Skew and Kurt report the skewness and kurtosis of each distribution. \*indicates significant parameters.



**Figure 4** Presentation of the interrater reliability of the total Frail-BESTest Score in center 1 (A) and center 2 (B). Kendall's tau coefficients for each system and each center (C).

constraints” system. This issue was partly expected for a measurement of the constraints of both biological and mechanical capacities, and tests from different domains were included in this system. Muscle power, ankle range of motion, or the quality of the foot base of support were part of the mechanical testing, even though the effort has more of a biological aspect (cardio-respiratory limitations). In addition, directional preference could be influenced by a mechanical deficiency such as a peripheral vestibular lesion<sup>55</sup> or a neurological failure (eg a hemiparetic “pusher”<sup>56</sup> or backward disequilibrium<sup>30</sup>). Similarly, the anterior stability limit, measured by the validated “Functional Reach Test”,<sup>43</sup> could be influenced by mechanical deficiencies such as limited ankle or hip range of motion, or by the psychological and neurological factors involved in Psycho-Motor Disadaptation Syndrome, which associates backward disequilibrium and fear of falling, especially falling forward.<sup>57</sup> The internal coherence of the vast bio-mechanical system is low, but it does take into account the heterogeneous characteristic of frail older adults.

There was also an interesting distribution of the Frail’BESTest scores in the 192 patients studied. In non-

frail patients, the three scores showed ceiling effects, though they were less pronounced than in the Tinetti test. Mini-motor test showed a considerable ceiling effect in the non-frail subgroup. However, this result can be considered coherent considering that the Mini-motor test was validated to measure the functional abilities of heavily impaired patients.<sup>29</sup>

In frail patients, the score distribution of the Frail’BESTest seemed to be more evenly distributed than the other scores, with a distribution centered on 42.9% of the total score, against 46.2% for the Tinetti test. Taken together, these results suggest that when compared with the Tinetti test, the Frail’BESTest under-evaluates patient capacities. The potential to progress should, therefore, be higher with this Frail’BESTest; an analysis of responsiveness will assess this assumption in part II of the companion paper.

We tested the inter-rater reliability of the Frail’BESTest in two different geriatric care centers with Kendall’s tau calculations. The first pair of physiotherapists (center 1) obtained a Kendall’s tau of 0.76 (total score) and the second pair (center 2) a Kendall’s tau of 0.77. There was no difference in reliability when considering the total

score of the Frail'BESTest. However, Kendall's tau coefficients were different when calculated within the systems in each center. As shown in Figure 4C, Kendall's tau coefficients were "moderate" in center 2 for system A (Anticipations) and for system E (Biomechanical constraints) rather than "strong" or "very strong" in center 1. In both centers, the physiotherapists were geriatric rehabilitation experts with more than 3 years of experience. The difference could probably be explained by the exposure to the Frail'BESTest in the first center, where the scale was used daily for 3 months before the start of the study. In the second center, the physiotherapists were experienced in geriatric rehabilitation but not as familiar with the tool. Taken together, these Kendall's tau coefficients show a very good overall inter-rater reliability for the Frail'BESTest. Considering the sub-scores obtained for each system, the results are satisfying in center 1, but the poor reliability observed in center 2 for two systems shows that a trainable period is necessary to use the Frail'BESTest with a strong reliability between operators.

One limitation of this study is the heterogeneity of the patients included. However, this heterogeneity gave us the opportunity to measure the performance of the Frail'BESTest in a large sample of patients with different motor and cognitive capacities. It could be interesting to compare the Frail'BESTest with other similar tools used in different geriatrics departments, long-term care facilities. Another limitation could be the frailty diagnosis used in the inclusion. Indeed, the gait speed was mainly used to diagnose frailty. As mentioned in the methods, gait speed is a very interesting test to spot the frailty state. However, other signs should complete the clinical examination in order to confirm the diagnosis, as the other Fried criteria.<sup>18</sup>

The use of a binary choice for scoring the Frail'BESTest could probably be considered another limitation for physical assessment. However, we decided on a pragmatic approach, making the duration of the test compatible with the everyday practices of therapists. This may have resulted in some inaccuracy in the motor evaluation.<sup>58</sup> The motor evaluation section of the Frail'BESTest should, therefore, be assessed more thoroughly and compared with longer and previously validated tests. Moreover, we only tested the inter-rater reliability in this study. Another work should test the intra-rater reliability to complete the analysis. The next step consists on determine the concurrent validity, the responsiveness and the predictive capacities of the Frail'BESTest in terms of detection of frailty and the occurrence of falls.

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## Disclosure

The authors report no conflicts of interest in this work.

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