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Title of the paper

Validity of a simple sit-to-stand method for assessing force-velocity profile in older adults.

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1 ABSTRACT

2 **Background:** Lower limb muscle strength is an important determinant of physical function in older adults.
3 However, its measure in clinical settings is limited because of the requirement for large-scale and costly
4 equipment. A new simple protocol based on sit-to-stand test (STS) is developed to measure force velocity
5 (F - v) and power velocity (P - v) profile in the community-dwelling older adults. **Objective:** The objective
6 of this study was to assess the validity of this new methodology for measuring F - v and P - v profile compared
7 to the gold standard isokinetic BIODEX. **Participants:** 46 older people aged 65-85 years ($M = 73.7$; $SD =$
8 7.7). **Methods:** F - v and P - v profiles were assessed in participants on their dominant leg. The concurrent
9 validity of STS was tested using Spearman's rank correlation coefficient and Passing Bablok: maximal
10 power output P_{max} , optimal velocity and force V_{opt} and F_{opt} , maximal force at null velocity F_0 , maximal
11 unloaded velocity V_0 and coefficient of F - v (S_{FV}) and P - v equation (a_{poly} , b_{poly}). **Results:** No
12 proportional difference for F_0 and b_{poly} and a low significant correlation for P_{max} ($r = 0.314$), S_{FV} ($r =$
13 0.229), a_{poly} ($r=0.335$) and b_{poly} ($r= 0.226$) whereas the other parameters were non correlated
14 significantly. **Conclusion:** STS method is moderately reliable on force and power parameters whereas
15 further improvements are needing for velocity parameters. However, its feasibility, portability and lower
16 cost compared to other methods makes it very affordable in clinical context and will allow easy
17 investigation of aging population.

18 **Keywords:** Force-velocity relationship, simple method, clinical evaluation, sit-to-stand, ageing

20 1 INTRODUCTION

21 The "power-force-velocity" approach is based on force and power-velocity (F - v and P - v) relationships
22 characterizing maximal mechanical capabilities of lower limbs' neuromuscular systems [1,2]. For now,
23 individual F - v profile is widely used in sport performance as it give an optimal individual F - v profile that
24 maximizes lower limb ballistic performance which allows individual determination of force or velocity

25 deficit. These profiles could be very interesting to replicate in geriatrics and aging research as measures of
26 muscle function could allow to screen for an age-related loss of muscle strength and power. Indeed, a loss
27 of muscle function is related to frailty [3], risk of disability [4], and morbidity in older people, all of which
28 can lead to a loss of independence in older people.

29 To date, Gold Standard for measuring muscle function in clinical practice and research settings is isokinetic
30 dynamometry [5]. Nevertheless, those systems that measure force and velocity with accuracy are very
31 expensive and time-consuming which limit their spread in clinics. The recent technological progress
32 involving wearable sensors opens the field of possibilities and allows to replace those costly systems with
33 convenient, simple and accurate analysis of the biomechanical kinematic variables. Samozino et al [6]
34 developed their own simple method for having power-force-velocity profiles which can be determined from
35 a series of 2 to 6 loaded vertical squat jumps. In geriatrics, a more adapted exercise is the sit-to-stand (STS)
36 test which is widely used to assess muscle strength [7,8]. Although time to complete STS is the primary
37 measure of function, leg velocity and muscle power also contribute to understanding physical performance
38 but require more sophisticated, time-consuming and expensive assessment tools such as force plates [9]
39 and/or motion capture system. To avoid those systems, many studies have attempted to evaluate STS
40 movements with either single or multiple accelerometers, both embedded and in smartphones, placed over
41 different regions of the human body [10,11,12]. Rojas et al [13] characterize velocity profile during STS
42 transitions with an embedded smartphone placed on L2/L3 vertebrae region while Lepetit et al [14] used a
43 single magneto-inertial measurement unit fixed on the chest to quantify velocity, acceleration and kinematic
44 data. All these studies only measure one parameter over leg power, force and velocity which does not allow
45 the assessment of $F-v$ and $P-v$ profiles. To our knowledge, the only study that combines everything is Ruiz-
46 Cardenas et al [15]. They developed an App technology to objectively measure time, velocity and leg power
47 during a single STS test. The App was designed for analysing STS via highspeed video recording (240
48 frames-per-second) allowing the calculation of time between two frames selected by the user and
49 subsequent calculation of mean vertical velocity and vertical power relative to body weight.

50 Nowadays, the spread of technology enable the development of simple method by only using smartphones
51 or simple devices. Recently, an open library for real-time multi-person key point detection was proposed
52 by Carnegie Mellon University named OpenPose. It is a real-time system to jointly detect 130 human body,
53 hand and facial key points on single images. In addition, its computational performance on body key point
54 estimation is invariant to the number of detected people in the image with high accuracy. OpenPose is freely
55 available for all kinds of free non-commercial use [16]. This library enable to have every single joint of the
56 body, angular velocities of the joint, and lower limb forces. In our knowledge, yet, no study has used
57 OpenPose to calculate lower limb force and velocity on STS.

58 As STS has already proved its worth as an effective tool for assessing F-v profiles in clinical geriatric and
59 as OpenPose seems to be a promising one also, combining the two could result in an effective simple
60 method. In this context, the aim of this study was to propose and validate a new simple protocol for
61 determining the F - v and P - v profiles in the hope of using it to detect decline in physical abilities in older
62 adults. The concurrent validity of this method was tested by comparison to reference isokinetic protocol.
63 We hypothesized that force and power variables will be moderately correlated, velocity variables will be
64 poorly correlated with linear association between them reflecting a sufficient concurrent validity.

65 **2 MATERIALS AND METHODS**

66 **2.1 PARTICIPANTS**

67 A total of 109 community-dwelling older adults aged between 65 and 85 years old were recruited. Exclusion
68 criteria were pathologies that prohibit a maximal strength test, such as severe cardiovascular disease,
69 artificial hip or knee, acute hernia, infection, or tumour. All participant gave written informed consent.
70 Thirty acquisition were not well recorded during STS due to some improper Openpose detection caused by
71 the camera angle, leading to missing data at some velocities (0, 5 or 10kgs). Also, Grubbs test [17] detected
72 33 recurrent outliers (abnormal STS parameters) resulting in their removal. Finally, 46 participants (6men,

73 40women) were included in this study (mean age = 73.7 +/- 7.7 years; mean height = 161.8 +/- 8.2 cm;
74 mean weight = 61.5 +/- 11.4 kgs; mean BMI = 23.5 +/- 4.2 kgs/m²).

75 **2.2 EXPERIMENTAL PROTOCOL**

76 Participants were drawn from the *Frailty* project, which aims to identify multidisciplinary markers of aging.
77 Approval of the study protocol was obtained (*n*^o 2015-A01188-41). The protocol consists of evaluating *F-v*
78 *v* profiles with Biodex dynamometer system 4 (Biodex Medical Systems, Inc., Shirley, NY) and with STS
79 simple method. The side of healthy or dominant leg for *F-v* profile evaluation was chosen to fit with the
80 unilaterality of BIODEX. Thus, hip and knee prosthesis, knee arthrosis and other pathologies were avoided.
81 The protocol included two standardized tests in the following order: STS protocol and Biodex protocol.
82 During each test, participants were clearly instructed by the test leader to perform with maximal effort.

83 **2.2.1 Sit-to-stand protocol**

84 The tool used was an adjusted chair without backrest. The seat height was visually adjusted to allow the
85 participant to start with a 90° knee angle. A visual line was also placed on the ground to limit feet's
86 displacement during the test. Participants were initially seated on the chair with their back in an upright
87 position wearing their own shoes (in an ecologically situation) (Figure 1). Then, they were instructed to
88 stand up as fast as they can with their arms folded across their chest in 3 conditions: with no additional load,
89 with 10kgs load and with 5kgs. All trials were performed using the same chair and with similar ambient
90 conditions. They repeated it 3 times to assure to reach maximal velocity during STS and the best of the 3
91 trials was taken. Resting time between the 3 conditions was sufficient to prevent participant from fatigue.
92 A camera was positioned to follow STS movement on their dominant leg unless there was a medical
93 contraindication.

94

95 **2.2.1.1 Analysis procedure and data recording to sit to stand protocol**

96 Acquisitions were recorded with an Ipad (30hz, 1280x720p). The videos were processed on Python with
97 OpenPose library [16]. This library can detect multiple people in real time which is the first time a library
98 can jointly detect key points on human body, face, and foot. The protocol setup was to collect measurements
99 from iPad, to retrieve key points by applying OpenPose “Body25 model” on videos, to preprocess
100 (denoising, calculating kinematic parameters) and finally to calculate $F-v$ and $P-v$ profiles. To determine
101 the time point for starting and ending the movement during STS test, plateau were detected on knee flexion
102 extension kinematics. A 0° plateau corresponded to the end of the STS (full extension and a 90° to the start
103 of the movement. The starting point of the STS was determined when a plateau at 90° on knee flexion
104 kinematics was detected. The ending point was defined when full extension of knee was achieved in an
105 upright stance corresponding to a 0° plateau. All the $F-v$ and $P-v$ parameters were calculated for one leg to
106 allow comparison with the unilateral single joint BIODEX. With OpenPose, the coordinates (X, Y) over
107 time for shoulder, hip and knee were taken allowing the calculation of their velocities. The associate thigh
108 and body force (eg reaction force) for one leg were calculated as followed as well as power P:

109 $F_{thigh} = 0.1416 * p * g$

110 $F_{upper_body} = 0.6028 * (p + charge) * g$

111 *With g the gravitational force (9,81 N/kg), p the weight of the participant (kg), charge could be 0, 5 or*
112 *10kgs depending on the wearing jacket and 0.1416 and 0.6028 were taken from the anthropometric De*
113 *Leva’s table [18].*

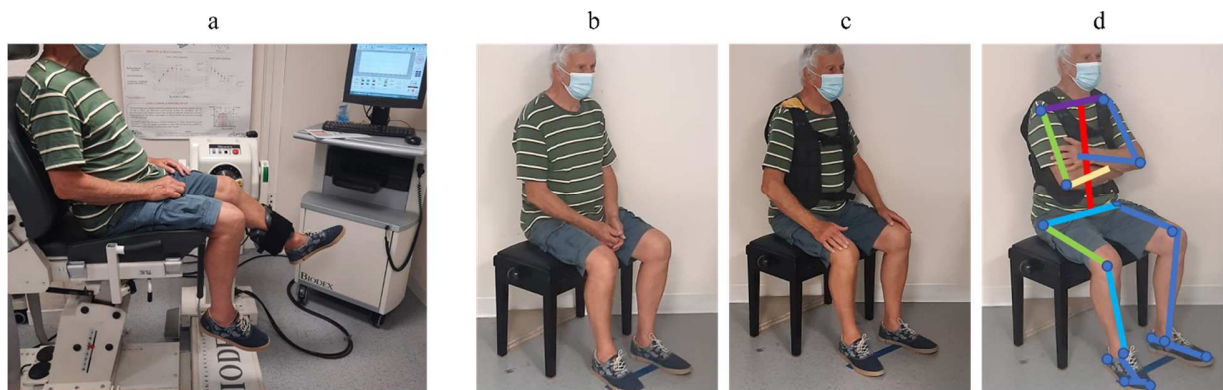
114 $P = M_{upper_body} * v_{upper_body} + 2 * (M_{thigh} * v_{thigh})$

115 *with M_{upper_body} the net moment joint ($F_{upper_body} * d$), M_{thigh} as $F_{thigh} * d$ and v the angular velocity*
116 *of the upper body and thigh respectively.*

117

118 **2.2.2 Isokinetic protocol**

119 Measurements were performed unilaterally on the same side of STS protocol. Participants were seated on
120 a backward- inclined (5°) and adjustable chair, which is part of the dynamometer (Figure 1). A strap was
121 applied across thigh and hips and shoulders were stabilized with safety belts to avoid additional movements.
122 The rotational axis of the dynamometer was aligned with the transversal knee-joint axis and connected to
123 the point of force application at the distal end of the tibia (i.e. 5cm above the lateral malleolus) using a
124 length-adjustable rigid lever arm. Range of motion was set from a knee joint angle of 90° to 160°, with a
125 full extended leg corresponding to a 180° knee angle. Participants were evaluated at six different velocities:
126 180°/s, 150°/s, 120°/s, 90°/s, 60°/s, 30°/s to reach an accurate F - v profile. Before starting the evaluation,
127 participants performed repetitions to familiarize with knee extension movement and to warm-up.



128
129 *Figure 1: Isokinetic BIODEX positioning of the participant (a) and STS protocol at 0kgs (b), 10kgs (c) and 5kgs with OpenPose*
130 *skeleton fitting specific body point (d).*

131 **2.2.2.1 Analysis procedure and data recording for isokinetic protocol**

132 Sampling was performed at 100 Hz using an electronic interface card (Biodex Medical Systems Inc.,
133 X2151, Shirley, NY, USA). The evaluation on the six different velocities allows to obtain a set of
134 parameters such as the ratio between agonist and antagonist muscles as well as curves representing F - v and
135 P - v relationships.

136 Force (F) – velocity (V) relationship was described by a first order linear equation:

137
$$F = S_{FV} \cdot V + F_0$$

138 with S_{FV} and b_{linear} the coefficients of the polynomial relation. Note that $F0$ is a force corresponding to
 139 the theoretical moment at 0° /s velocity value. The velocity value which corresponds to 0 Nm was the
 140 maximum theoretical velocity (V_{MAX}).

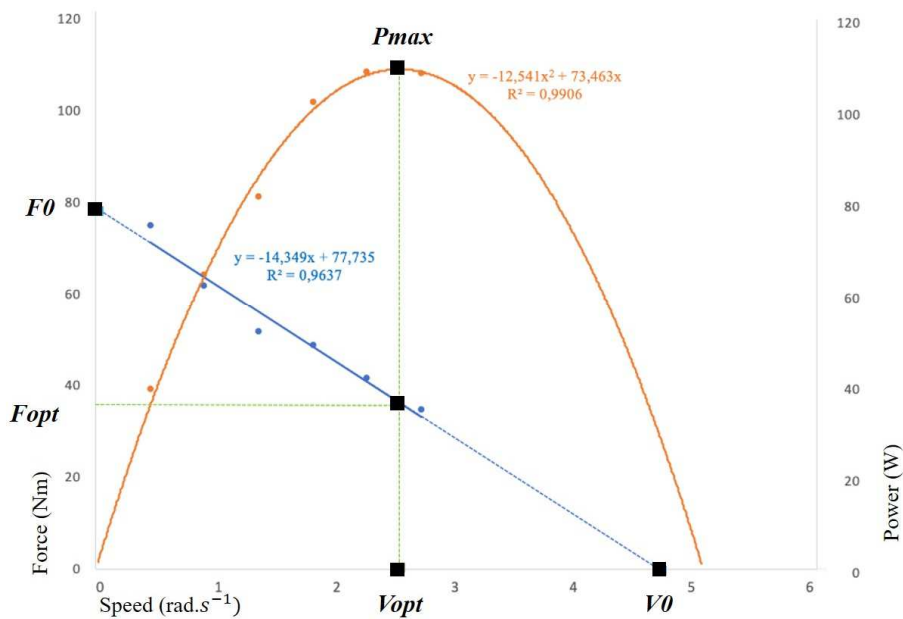
141 Power (P) - velocity (V) relationship was described by a second order polynomial equation:

142
$$P = a_{poly} \cdot V^2 + b_{poly} \cdot V$$

143 with a_{poly} and b_{poly} coefficients of the polynomial relation (Figure 2).

144 Maximum power (P_{MAX}), and optimal velocity (V_{OPT}) were determined from this equation as:

145
$$V_{OPT} = -\frac{b_{poly}}{2 \cdot a_{poly}} \text{ and } P_{MAX} = -\frac{b_{poly}^2}{2 \cdot a_{poly}}$$



146

147 *Figure 2: Force-velocity (F-v) and power-velocity (P-v) profiles*

148 **2.3 DATA ANALYSIS AND STATISTICAL CALCULATION**

149 All statistical method comparison was made on $F-v$ and $P-v$ parameters which are P_{max} , F_{opt} , V_{opt} and
 150 $V0$. We also compared coefficient of $F-v$ and $P-v$ equation which are a_{poly} and b_{poly} defined as the
 151 quadratic and linear coefficient respectively of $P-v$ equation and S_{fv} and $F0$ defined as the slope and the

152 constant of the linear F - v equation. All data were screened for normality using the Shapiro Wilk test.
153 Concurrent validity between STS and BIODEX was assessed by determining Spearman's rank correlation
154 coefficient (r). The following correlation classification was used: negligible $r=0-0.10$, low $r=0.10-0.39$;
155 moderate: $r = 0.40-0.69$; high: $r = 0.70-0.89$; very high: $r = 0.90-1.0$ [19]. Passing-Bablok regression was
156 used to assess the linear association between parameters that succeed to CUSUM test ($p>0.05$) [20]. All
157 statistical tests were regarded as significant at $p<0.05$ with a Benjamini-Hochberg correction for multiple
158 associations and statistical analyses were performed using XLSTAT (Addinsoft, New York, USA).

159 3 RESULTS

160 Mean \pm Standard deviation for both STS and BIODEX methods for mean force, velocity and power output
161 are presented in Table 1. Spearman's rank correlation showed no to very low ($r= -0.024-0.226$) and non-
162 significant ($p=0.08-0.77$) for most of the parameters except for P_{max} ($r = 0.314$), S_{fv} ($r = 0.229$), a_{poly}
163 ($r=0.335$) and b_{poly} ($r=0.226$) (Table 1). Finally, for all parameters except for S_{fv} , p-value of the CUSUM
164 test was more than 0.05 (Table 1) concluding in a linear relation between the two methods. We were thus
165 able to use Passing Bablok regression analysis presented in Figure 3.

166 The intercept value in Table 2 is a measure of systematic differences between the two methods. The 95%
167 confidence interval containing the value 0 means no systematic difference between the two methods which
168 is not the case for P_{max} , V_{opt} , F_0 , V_0 , S_{fv} and a_{poly} . Then, it is concluded that the difference between
169 STS and the reference BIODEX method differs at least by a constant amount. For F_{opt} and b_{poly} , the
170 confidence interval is respectively $[-111.9; 0.3]$ and $[-123.1; 1.04]$ concluding in no systematic difference
171 between STS and BIODEX.

172 The slope coefficient in Table 2 is a measure of proportional differences between the two methods. The
173 95% confidence interval for the slope including 1 means no proportional difference is found. For P_{max} ,
174 F_{opt} , V_{opt} , V_0 , S_{fv} and a_{poly} , any of the confidence interval contains 1 concluding in a proportional

175 difference between the two methods whereas for $F0$, and b_poly , no proportional difference between the
 176 two methods was found.

177 *Table 1: Mean \pm Standard deviation and concurrent validity between both methods for mean force, velocity, and power output in*
 178 *one leg.*

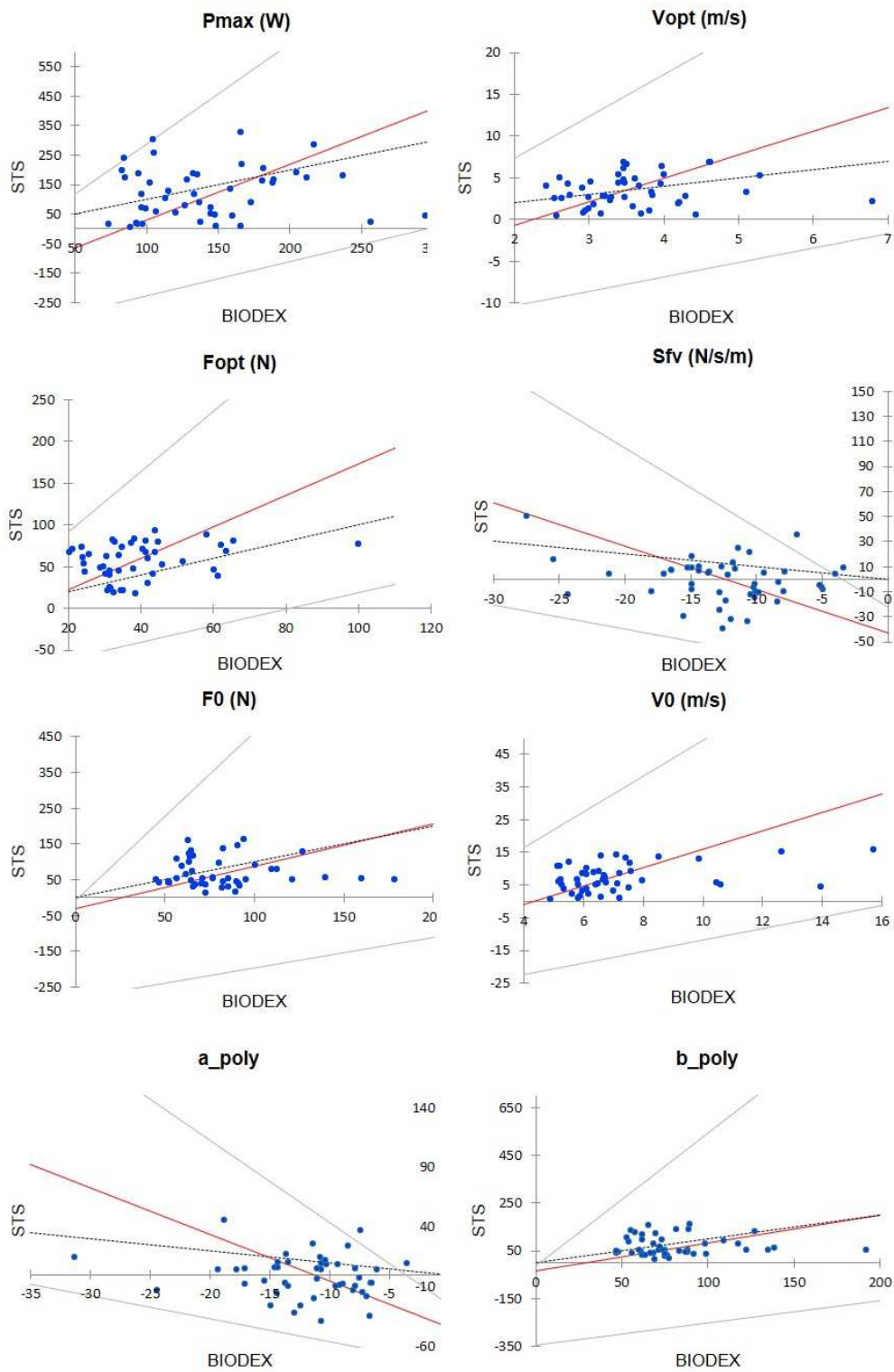
	Biodex (reference measures)	STS	Spearman's r coefficient	CUSUM test for linearity
Pmax (W)	143.9 +/- 49.9	187.5 +/- 147.3	0.314*	0.124
Vopt (rad/s)	3.6 +/- 0.8	3.3 +/- 3.3	-0.043	0.621
Fopt (N)	39.5 +/- 14.9	36.3 +/- 37.9	0.161	0.05
F0 (N)	83.1 +/- 28.5	62.3 +/- 42.6	0.199	0.387
V0 (rad/s)	7.1 +/- 2.1	6 +/- 7	-0.024	0.109
S_{fv}(N.s. m^{-1})	-12.7 +/- 5.1	-4.4 +/- 11.6	0.229*	0.021**
a_poly	-12.7 +/- 5.1	-4.1 +/- 11.7	0.335*	0.05
b_poly	81.7 +/- 28.7	61.8 +/- 43.3	0.226*	0.621

Pmax: Maximal power output against different loading conditions
Vopt: optimal velocity to reach maximal power
Fopt: optimal force to reach maximal power
F0: the theoretical maximal force at null velocity,
V0: the theoretical maximal velocity at which lower limbs can extend during one extension under zero load
 S_{fv} : slope of the F-v relationship
a_poly, b_poly: coefficient of the P-v relationship
 * Significant correlation ($p < 0.05$) ($p_value < B-H$ adjusted p_value)
 ** non-linear relation between the two methods ($p < 0.05$) (Passing Bablok not applicable)

179 *Table 2: Passing Bablok model coefficient for Pmax, Vopt, Fopt, F0, V0, S_{fv} , a_poly and b_poly*

	Intercept value (95% confidence interval)	Slope coefficient (95% confidence interval)
Pmax (W)	-182 [-408 ; -45.1]	2.4 [1.5 ; 4.2]
Vopt (rad/s)	75.4 [0.7 ; 8.08]	-20.9 [-1.6 ; 0.4]
Fopt (N)	-42.9 [-111.9 ; 0.3] a	2.3 [1.1 ; 4.1]
F0 (N)	-50.7 [-155.2 ; 0.7]	1.4 [0.7 ; 2.8] b
V0 (rad/s)	42.3 [5.1 ; 19.3]	-5.8 [-2.3 ; -0.13]
S_{fv} (N. s. m^{-1})	23 [47.8 ; 9.3]	2.2 [1.1 ; 4.4]
a_poly	22.6 [41.1; 12.2]	2.4 [1.4 ; 3.2]

b_poly	-73.4 [-123.1 ; 1.04] a	1.7 [0.7 ; 2.4] b
a No systematic difference between the two methods b No proportional difference between the two methods		



180

181 *Figure 3: Passing Bablok regression analysis of the two methods, STS and the reference BIODEX, for Pmax, Vopt, Fopt, F0, V0,*
 182 *Sfv, Fmax, a_poly and b_poly. Scatter diagram with regression line and confidence bands. Identity line is dash*

183 4 DISCUSSION

184 The objectives of this study were to assess the concurrent validity of a new method to assess F - v
185 and P - v profiles in older adults based on STS protocol comparing it with the well-known isokinetic protocol.
186 Results obtained highlighted a linear relationship between most of the F - v and P - v parameters between the
187 two methods, no proportional difference for $F0$ and b_{poly} and a low significant correlation for $Pmax$ ($r =$
188 0.314), S_{fv} ($r = 0.229$), a_{poly} ($r=0.335$) and b_{poly} ($r=0.226$) whereas the other parameters were non
189 correlated significantly. Results are, thus, encouraging showing a fairly low concurrent validity for
190 parameters of force, power and slope of F - v and P - v relationship (S_{fv} , a_{poly} and b_{poly} respectively).

191 Spearman's rank correlation was significant but quite low for $Pmax$ ($r = 0.314$, $p = 0.017$), S_{fv} ($r =$
192 0.229 , $p=0.065$), a_{poly} ($r=0.335$, $p=0.012$) and b_{poly} ($r=0.226$, $p =0.065$) whereas incongruent and non-
193 significant correlation were found for the other parameters. Impellizzeri et al. also found a quite low
194 correlation for peak force by comparing a jump test with an isokinetic leg extension ($r = 0.48$, $95\%CI: 0.26-$
195 0.66) [21]. But when compared to a more similar test (pneumatic leg extension), the correlation is stronger
196 ($r=0.83$, $95\%CI = 0.7-0.91$) [21,22,23]. In view of these results, results are consistent with the literature and
197 the difference between the two protocols, BIODEX and STS, may strongly impact on the agreement
198 between F - v and P - v parameters. Indeed, when one method (BIODEX) recruited one leg in a closed
199 kinematic chain (isolate knee joint), the other (STS) recruited two legs in open kinematic chain (multiple
200 joints participating to the movement). Studies have demonstrated that mechanical output in leg multi-joint
201 movement is different from that in a single- joint exercise [24]. However, even if methods are quite
202 different, the agreement in $Pmax$, thus the STS calculation, is quite consistent with previous results which
203 highlight the capacity of the STS method to determine the mean peak force in community-dwelling older
204 adults. Indeed, the range of magnitude of $Pmax$ between BIODEX and STS were very similar ($M= 143.9W$,
205 $SD= 49.9W$; $M=187.5 W$, $SD=147.3W$ for BIODEX and STS respectively). The $187.5W$ found during the
206 STS was for one leg which gave approximately $375W$ for the entire power developed by the two legs during
207 the STS movement. This value was compared to other studies that used different methods for $Pmax$

208 calculation to check the consistency of this study's protocol. Regarding the range of magnitude, the study's
209 P_{max} appeared to be very closed to the 400W value found in other studies highlighting the consistency of
210 this value [25,26].

211 The high variability in P_{max} represented by a SD of $\pm 147.3W$ (more than 75% of variability)
212 should also be noticed as, for other studies using STS test, the variability was lower (around 40% in P_{max}
213 variability) [27]. The high variability obtained here, which is also extended to all STS parameters, can be
214 partly attributed to the STS design protocol used in this study. Indeed, a reasonable variability was found
215 for BIODEX parameters when the range of movement was individually adjusted allowing participants to
216 start with a precise 90° knee angle. Also, when Alcazar et al [27] used a standardized armless chair (0.49
217 m height), a 40% variability was found. In this study, knee angle was not precisely measured even if the
218 start position during STS was visually corrected by the investigator. The starting position visually adjusted
219 was at 85° as a mean in all the participants which highlight that the visual placement at 90° is not perfect.
220 To improve precision, future studies should use the video recording and Openpose to directly correct knee
221 angle and re-adjust chair height to allow participant to begin STS with a precise 90° knee angle which can
222 be done in live. The high STS variability is also explained by the protocol itself where the STS parameters
223 were very dependent to the patient stand up velocity whereas for the BIODEX, the patient had to simply
224 follow the pace and the fixed velocity. This contributes to more technical variation in STS execution leading
225 to a high intra-variability thus a lower reliability.

226 The high variability is also participating in the lower reliability results found especially in velocity
227 parameters (V_{opt} and V_0) where no proportional and systematic difference was found in Passing Bablok.
228 Several studies in young and older adults have also reported lower agreement values for V_0
229 [28,29,30,31,32]. This could be attributable partially to the STS method itself to assess F-v profiles. Indeed,
230 while the F-v profile was assessed by using multiple point (i.e. 6 velocities), the STS was using three points
231 (0, 5, 10kgs). Janicijevic et al [32] have recently shown a low concurrent validity of the two-point method,
232 which is quite similar to the three-point, for V_0 and F_0 . When moving from multiple-point methods (usually
233 4 to 6 velocities or loads) to a two-point method (or a three-point), the extrapolation between the two-points

234 to construct $F-v$ and $P-v$ slopes is wider than the multiple points providing a larger range of force and
235 velocity data thus a large extrapolation error risk [32]. Also, the model used to fit the $F-v$ relationship was
236 the linear model over all the sample (from 0 to 100% of $F0$) which was largely used in other studies [6,33].
237 This can be debatable as the linear equation was found to exceptionally fit the $F-v$ shape only between 45
238 to 100% of $F0$ [34]. Many models have been proposed to fit the $F-v$ relationship with a hyperbolic equation
239 as Hill et al proposed [35] when others demonstrated that the relationship was deviated from this rectangular
240 hyperbola at forces close to the maximal isometric force and that a double-hyperbolic equation was better
241 [36]. It is understandable that the misconception of the shape of the $F-v$ relationship can lead to serious
242 errors in the estimation of several parameters derived from linear equations, such as $F0$ and $V0$. However,
243 despite this questionable choices, the shape of the STS $F-v$ and $P-v$ equation (Sfv and a_poly respectively)
244 was found to be correlated ($r=0.229-0.335$) while other studies found inconsistent results for them ($p>0.05$)
245 [30,32].

246 Although results are similar to previous works, this method presents some limitations. First,
247 participants were filmed in a side view bounding Openpose on one side to calculate kinematics. This could
248 have increase the risk of losing data or abnormal recording if the subject was not well detected. When
249 missing data appeared, it results in extrapolation when calculating $F-v$ parameters that could partially
250 explained the incongruent correlation obtained [28,29]. An improvement could be to place the participant
251 at 45° to the camera to allow Openpose to refer to both right and left sides in order to improve detection
252 thus reliability on calculation. Another limit is that absolute fixed loads were used (5 and 10kgs) instead of
253 relative to body weight to simplify the protocol. It appeared not to correspond to some patients which were
254 removed from the study as the hypothesis of reducing velocities with heavier loads was not always
255 respected. It was for only 30% of the participants but to reduce exclusion, a real time feedback on movement
256 velocity should be given during STS to be sure the hypothesis is well respected [37]. Finally, the study
257 design did not allow for a test-rest reliability on STS but previous results seem promising. Indeed, many
258 studies have tested reliability of a STS power test which appears to be excellent ($ICC=0.96$) [22,23]. Future
259 studies should, therefore, test reliability on other $F-v$ parameters than power. It is therefore likely that the

260 observed limited validity in the F-v parameters especially in velocity parameters are caused by extrapolation
261 error and the combination of technical/instrumental and biological variations that could be easily rectified.

262 However, for a measurement tool to be widely accepted, factors such as feasibility, safety, and cost
263 are just as, if not more, important than measurement properties. Several tools have been used to assess *F-v*
264 and *P-v* profiles in older adults but are very expensive and time-consuming. Indeed, an isokinetic ergometer
265 is feasible with older adults but will take long time (at least 20mn for warm up and protocol) and is
266 overpriced (around 80 000\$). A method based on loaded and unloaded squat jump was developed by
267 Samozino et al [6] to assess *F-v* and *P-v* profiles with low-cost materials. It has shown to have sufficient
268 validity and reliability but there remains safety and feasibility concerns, especially in low functioning older
269 adults. This study was, to our knowledge, the first to propose and validate STS protocol to assess *F-v* and
270 *P-v* profiles in older adults and follows in the footsteps Balachandran et al [22] who succeed to develop
271 STS power test in older adults. This method is portable, quicker (around 10mn for the all protocol) and less
272 expensive (estimated at less than 300\$) than the existed methods.

273 As a conclusion, we found better correlation in variables of force and power but not significant in
274 velocities and we shared the same conclusion with better results as other studies that have reported lower
275 or no reliability values for *VO*, *Pmax* or *Sfv* [30,32]. The simple computation method proposed here might
276 offer an inexpensive and easy alternative to assess and individualize *F-v* profiles without the need of
277 expensive technologies in community-dwelling older adults. Future research should investigate if the
278 method is consistent to detect frailty among older adults or future fallers based on *F-v* and *P-v* profiles.

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