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Journal of Sport and Health Science 8 (2019) 267–272

www.jshs.org.cn

Original article

Determination of functional fitness age in women aged 50 and older

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Received 17 May 2016; revised 7 October 2016; accepted 13 November 2016
Available online 23 January 2017

Abstract

Background: The construction of useful and attainable indicators of fitness assessment deserves special attention in clinical practice. We aimed to construct an indicator of the functional fitness age (FFA) of women aged 50 and older by an equation using fitness outcomes and its correlation with chronological age (CA) and to analyze the external validity of our results by comparing our sample to others.
Methods: Participants ($n = 459$, age: 70.3 ± 7.9 years, mean ± SD) were evaluated using the Senior Fitness Test battery. We applied a multiple regression and a subsequent Holt's exponential smoothing to analyze the outcomes.
Results: We obtained a statistically significant expression of $F(6, 452) = 328.384$; $p < 0.0005$ in which the coefficients of the equation explain 81% of variability ($R^2_{corrected} = 0.813$). The equation correlates fitness assessment in women aged 50 and over with regards to CA: FFA = 40.146 + 0.350 × CS (stand) − 0.714 × AC (rep) − 0.110 × ST (step) − 0.177 × CSR (cm) − 0.101 × BS (cm) + 8.835 × FUG (s) where CS means chair stand test, AC means arm curl test, ST means 2-min step test, CSR means chair sit-and-reach test, BS means back scratch test, FUG means 8-foot up-and-go test. We compared this index with percentiles distribution from our sample and from other studies.
Conclusion: We suggest the use of FFA as a valid indicator of fitness in adult and senior women as well as a useful motivational tool to undertake exercise programs.

Keywords: Disability; Elderly; Exercise; Fitness assessment; Health outcomes; Senior Fitness Test

1. Introduction

Time is a standardized pattern in which humans situate numerous events that are interpreted unambiguously and universally. Associating the aging process to time enables referencing, positioning, and assessing the state that any organism or object is in. Biological age is a concept that can be understood as a progressive decrease in viability and increased vulnerability in the body over time, which ultimately leads to death.[1] Several authors have set algorithms related to biological age;[2–7] others established procedures for obtaining relevant indicators of aging in long-lived species;[8] and others even advise the use of these indicators (e.g., fat-free mass percentage, grip strength, expiratory volume, cognitive and neuropsychological data) compared to other traditional indicators.[9,10]

The estimated spirometric lung age (i.e., the age of the average healthy individual who would perform similar to them on spirometry) provides feedback that has been shown to improve the likelihood of smokers quitting smoking.[11–13] In relation to fitness and aging, several authors described the so-called fitness age score to intuitively evaluate the individual's corresponding physical fitness age.[14–18] Kimura et al.[14] recently determined 5 relevant fitness tests in relation to the fitness age score (i.e., 10 m walking time, functional reach, one leg stand with eyes open, vertical jump, and grip strength) with a 7-year longitudinal study by applying the methods described by Ingram et al.[8]

Delimiting the concept of fitness to the elderly, we deem it more appropriate to use the term functional capacity,

Peer review under responsibility of Shanghai University of Sport.
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https://doi.org/10.1016/j.jshs.2017.01.010
Cite this article: Latorre-Rojas EJ, Prat-Subirana JA, Peirau-Terés X, Mas-Alòs S, Beltrán-Garrido JV, Planas-Anzano A. Determination of functional fitness age in women aged 50 and older. *J Sport Health Sci* 2019;8:267–72.

understood as the ability to efficiently carry out basic activities of daily living that people should do to take care of themselves and live independently and autonomously.[19]

Under this perspective, Rikli and Jones[20–24] build on the construction and validation of the Senior Fitness Test (SFT) battery, a set of tests resulted to be relevant for the functional fitness in the elderly and that has been used in other studies.[25–26] The SFT battery assesses lower body strength (30 s chair stand test (CS)), upper body strength (arm curl test (AC)), aerobic endurance (6-min walk test or the 2-min step test (ST) when space limitations), lower limb flexibility (chair sit-and-reach test (CSR)), and upper limb flexibility (back scratch test (BS)).

Kimura et al.[14] test battery for elder populations includes the vertical jump test, an osteoarticular and muscular demanding task that we consider less appropriate than the 30 s CS test for senior people because of risk of injury.[27]

A standardized method for assessing functional fitness age (FFA) in adult and senior women has not yet been established. This study aims (1) to obtain an indicator of the FFA of women aged 50 and over by an equation using the SFT outcomes and its correlation with chronological age (CA) and (2) to analyze the external validity of our results by comparing our sample to others.

2. Materials and methods

2.1. Participants

The sample was obtained from a total of 757 people attending 22 supervised exercise programs offered by the Lleida City Council (i.e., 1 h for 2-day weekly of calisthenics, Tai-Chi, and aquatic exercise) from September to May. Four hundred and fifty-nine (61%) met the following inclusion criteria: (1) female gender; (2) 50 or older at the time of starting the study; (3) not suffering from any physical or mental illness that would prevent them from performing any of the tests; (4) able to walk independently without the assistance of devices such as canes or walkers; and (5) accepting and signing the informed consent to participate in the study. Participants were required to state that they had no medical contraindications for physical activity programs and to hold medical insurance. Participants underwent a supervised exercise program for 6 months by the time of data collection, ranging from an estimated weekly metabolic consumption (measured in metabolic equivalent value (MET)) of 336 MET-min (calisthenics) to 360 MET-min (Tai-Chi) to 660 MET-min (aquatic exercise).[28,29] No other information regarding other dimensions of physical activity behavior (e.g., transportation, occupational) were available to determine if the sample was compliant with the minimum recommendations on physical activity for health by the World Health Organization (600 MET-min a week).[30] The study was conducted according to the Declaration of Helsinki and the Medical Ethical Committee of the Hospital Arnau de Vilanova, Lleida, approved the protocol and the study.

2.2. Measurements

The SFT battery was used for data collection due to a scarcity of equipment and facilities and so we could compare our results with other studies. Fitness test administrators participated in a training seminar to be familiar with the SFT battery and be compliant with the protocols set by Rikli and Jones.[24] The battery included CS, AC, ST, CSR, BS, 8-foot up-and-go test (FUG), and a measurement of body mass index (BMI) as weight per height squared. Data collection took place when the subjects participated in the 1-h exercise workout in March, 6 months after the exercise programs started. Data collection continued for 5 weeks to include all participants who met inclusion criteria. Participants were advised to avoid any extended physical activity during the day before the test.

2.3. Statistical analysis

We obtained percentiles in strata of 5 years of age from 50 to 87 (except for the last group which was from 85 to 87). Then, we applied a multiple regression model using the include method to establish the FFA by means of the SFT battery outcomes and data, that is, CS, AC, ST, CSR, BS, FUG, and BMI. The following application conditions were checked: sample size, metric variables, normality, linearity, absence of multicollinearity, normality of residuals, independence of residuals, and homoscedasticity.[31,32] We conducted Holt's exponential smoothing equation to predict the FFA. The statistical software package SPSS Version 17.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses.

3. Results

3.1. Fitness outcomes

Table 1 shows the correlation coefficients between the participants' age, BMI, and results on SFT battery outcomes. Table 2 shows descriptive statistics by age group and the effect size (ES) between 2 contiguous age groups.

3.2. Functional fitness age equation

The estimated regression model was statistically significant, $F(6, 452) = 328.384$, $p < 0.0005$. The goodness of fit for the model is $R^2_{\text{corrected}} = 0.813$. Among the fitness outcomes, FUG had the greatest influence on FFA ($\beta = 0.689$), while BS ($\beta = -0.052$) and CSR ($\beta = -0.074$) were the 2 fitness components with a lowest influence on FFA. BMI was removed from the equation given its small contribution (<1%) (Table 3).

The multiple regression equation for predicting FFA is as follows:

$$\begin{aligned}\text{FFA} = {} & 40.146 + 0.350 \times \text{CS}(\text{stand}) - 0.714 \times \text{AC}(\text{rep}) \\ & - 0.110 \times \text{ST}(\text{step}) - 0.177 \times \text{CSR}(\text{cm}) - 0.101 \\ & \times \text{BS}(\text{cm}) + 8.835 \times \text{FUG}(\text{s})\end{aligned}$$

The analysis of the relationship between CA and FFA indicated that both increase simultaneously and are directly proportional. We also observed that only 4% of participants ($n = 20$) were outside the 95% confidence interval (Fig. 1).

The age difference (year) was calculated as age_dif = FFA − CA. The mean score was 0.0173 years (±9.19, minimum = −23.14, and maximum = 37.92) (Fig. 2).

Table 1
Correlation coefficients between the Senior Fitness Test battery outcomes and participants' age and BMI ($n = 459$).

	M	SD	Min	Max	Correlation coefficients						
					BMI	CS	AC	ST	CSR	BS	FUG
Age (year)	70.3	7.9	50.0	87.0	0.126**	−0.299**	−0.290**	−0.354	−0.199**	−0.308**	−0.569**
BMI (kg/m^2)	27.9	3.5	20.5	39.0		−0.080	0.021	−0.093*	−0.052	−0.428**	0.219**
CS (rep)	16.7	4.0	6.0	32.0			0.571**	0.564**	0.318**	0.196**	−0.543**
AC (rep)	16.8	3.1	9.0	27.0				0.536**	0.360**	0.191**	−0.450**
ST (step)	94.5	18.2	51.0	140.0					0.330**	0.212**	−0.542**
CSR (cm)	0.7	8.9	−25.0	22.0						0.270**	−0.334**
BS (cm)	−0.1	8.7	−23.0	18.0							−0.368**
FUG (s)	5.2	0.9	3.3	10.0							

* $p < 0.05$, ** $p < 0.005$.
Abbreviations: AC = arm curl test; BMI = body mass index; BS = back scratch test; CS = chair stand test; CSR = chair sit-and-reach test; FUG = 8-foot up-and-go test; Max = maximum; Min = minimum; rep = repetition; ST = 2-min step test.

Table 2
Senior Fitness Test battery scores for age groups ($n = 459$).

		CS (rep)			AC (rep)			ST (step)			CSR (cm)			BS (cm)			FUG (s)		
Age (year)	*n*	M	SD	ES*	M	SD	ES*	M	SD	ES*	M	SD	ES*	M	SD	ES*	M	SD	ES*
50–54	18	20.78	4.90	—	20.72	2.87	—	112.83	13.87	—	3.89	7.91	—	5.00	6.44	—	4.25	0.60	—
55–59	25	19.08	4.00	0.35	17.84	3.26	1.03	109.28	18.55	0.26	2.32	13.48	0.20	1.88	7.18	0.49	4.51	0.62	0.14
60–64	59	17.42	4.08	0.43	16.97	2.87	0.27	98.69	20.64	0.57	1.85	8.91	0.04	3.58	6.06	0.24	4.70	0.52	0.32
65–69	97	16.94	3.99	0.12	17.47	2.99	0.18	94.64	15.27	0.20	2.95	8.20	0.12	1.85	7.48	0.29	5.07	0.61	0.74
70–74	99	16.37	3.36	0.15	16.44	3.10	0.36	95.37	14.03	0.05	0.09	8.45	0.35	−0.75	9.03	0.35	5.32	0.74	0.42
75–79	109	16.28	3.62	0.03	16.48	2.81	0.01	91.73	18.55	0.26	−0.10	8.17	0.02	−2.06	9.17	0.15	5.60	0.87	0.40
80–84	41	14.66	3.95	0.45	15.29	3.05	0.43	79.80	17.12	0.64	−4.00	8.88	0.48	−5.49	10.09	0.38	6.42	1.01	1.03
85–87	11	14.36	4.46	0.08	15.18	2.93	0.04	83.45	15.81	0.21	−2.82	9.28	0.13	−6.09	7.66	0.06	6.50	1.13	0.08

* Effect size compared to the previous age group.
Abbreviations: AC = arm curl test; BS = back scratch test; CS = chair stand test; CSR = chair sit-and-reach test; ES = effect size; FUG = 8-foot up-and-go test; rep = repetition; ST = 2-min step test.

Table 3
Multiple regression coefficients and constant.

	Non-standardized coefficients		Standardized coefficients		
	B	SE	*β*	*t*	*p*
Constant	40.146	5.819		6.899	0.000
CS	0.350	0.120	0.089	2.907	0.004
AC	−0.714	0.186	−0.130	−3.831	0.000
ST	−0.110	0.033	−0.123	−3.312	0.001
CSR	−0.177	0.064	−0.074	−2.746	0.006
BS	−0.101	0.065	−0.052	−1.542	0.124
FUG	8.835	0.603	0.689	14.661	0.000

Abbreviations: AC = arm curl test; B = non-standardized beta coefficient (slope line); BS = back scratch test; CS = chair stand test; CSR = chair sit-and-reach test; FUG = 8-foot up-and-go test; ST = 2-min step test.

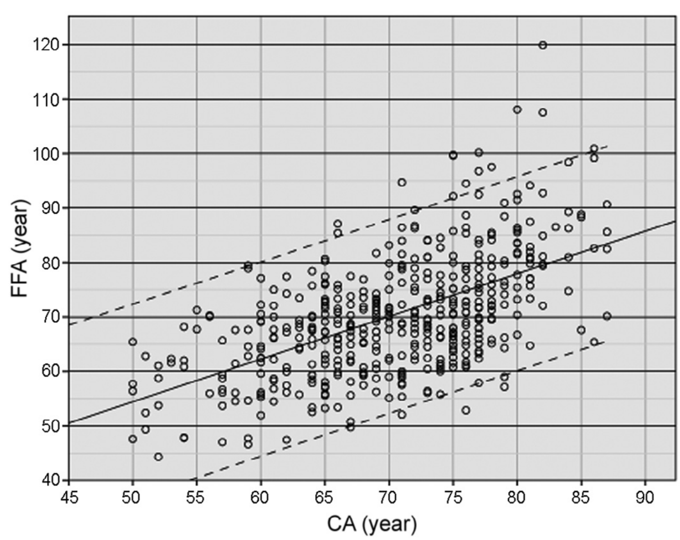

Fig. 1. Relationship between FFA and CA resulting from the multiple regression equation for predicting the FFA. Discontinuous lines show the 95% confidence interval. CA = chronological age; FFA = functional fitness age.

3.3. *Equation adequacy compared to percentile values*

We obtained percentiles of each SFT outcome for women in Lleida according to the CA (in 5-year strata). Each participant had a global score, that is, the mean value of the percentiles from the 6 fitness tests. Fig. 3 represents this global score and its relationship with the age_dif.

There is a significant linear association ($R^2 = 0.66$, $p < 0.005$) and an inverse proportionality between age_dif and the global score of percentiles. That is, a smaller mean value in the percentiles relates to a more positive difference between FFA and CA (less functional fitness than predicted by CA). Otherwise, participants who obtained better ratings in the global score showed lower FFA than CA (greater functional fitness that predicted by CA).

4. Discussion

4.1. *Indicators of functional fitness—FFA equation and percentiles*

Our cross-sectional analysis determined the fitness condition of 459 women. We then proceeded to calculate 2 indicators of functional fitness: FFA and the global score of average percentiles. Each indicator provides accessible and understandable

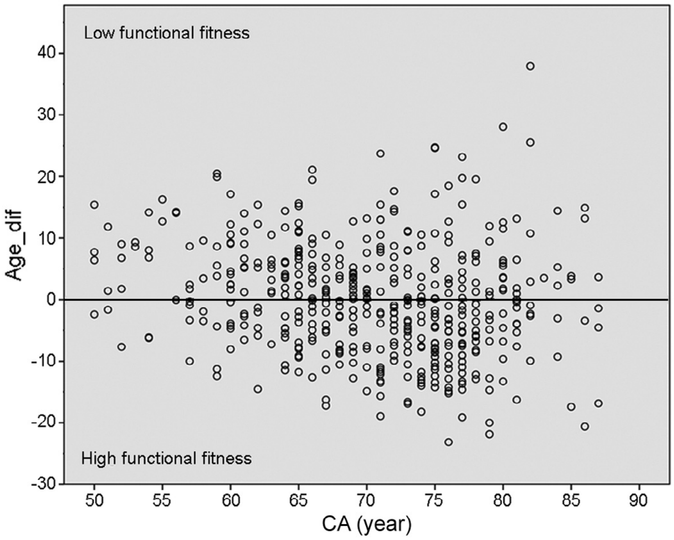

Fig. 2. Functional fitness according to age_dif (FFA – CA) compared to CA only. Participants placed under the line with a value of 0 on the *y*-axis have good physical fitness because their age_dif value is negative; therefore, their FFA is lower than their CA. In other words, their functional fitness levels are like younger women's fitness. On the other hand, participants above the horizontal red line have less functional fitness than what would be expected chronologically, that is, higher FFA than CA. CA = chronological age; FFA = functional fitness age.

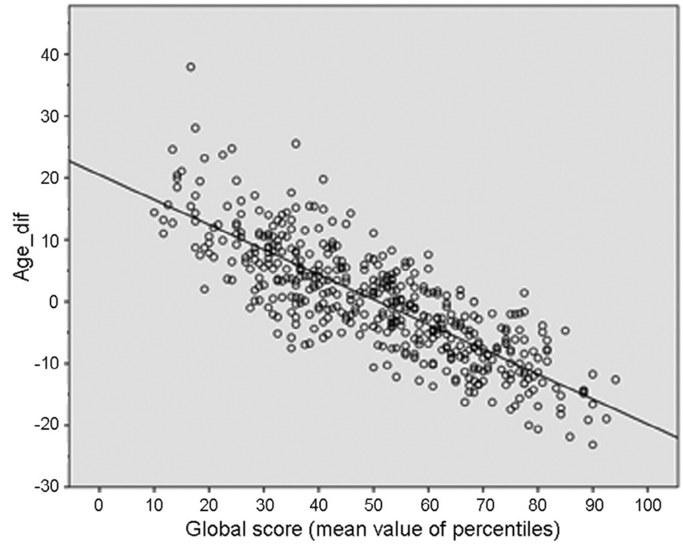

Fig. 3. The relationship between age_dif (functional fitness age – chronological age) and the mean value of percentiles from each of the Senior Fitness Test battery outcomes.

information for practitioners in clinical practice. The age_dif shows the disparity between someone's expected fitness condition according to the CA. The indicators age_dif and the global score are not equal but they are strongly related ($R^2 = 0.66$), as can be seen in Fig. 3.

The substantial difference between FFA and the global score of average percentiles is that the global score (mean score) assumes equal weight to each test, whereas each test outcomes weights differently for the FFA calculation, as indicated by the coefficients obtained from the regression analysis model (Table 3).

The 50th percentile reflects the expected score for the CA. As an example (Fig. 4), a 70-year-old woman showing the following scores: CS = 22, AC = 17, ST = 120, CSR = 3, BS = 10, FUG = 4.88 would result in an FFA of 64.08 years, almost 6 years younger.

In our findings, the FUG weights the greatest amongst all to calculate the FFA. This is in line with other previous research where walking[33] or gait speed[34] showed the greatest relation with risk of premature mortality.

4.2. Comparison of fitness outcomes with other populations

Our cross-sectional data showed decreasing performance in each test over time (Table 4). Fitness decline of our sample of 459 women was similar to that of other populations reported elsewhere, despite differences in sample size.

4.2.1. Leg strength

Our results of the CS showed a decrease of 29.74% of leg strength from the age of 50 to 80–87 years old. Other studies suggest a 1.5% decrease of strength when comparing the age of 45 and 60 years.[1,35] Samuel and Rowe[36] indicated that there is a 20.0% decrease of strength performance when comparing the age range of 60 to 80 and above. Goodpaster et al.[37] indicated that the yearly decline from the age of 80 is 2.6%. Núñez Roca et al.[38] showed a decrease of 30.0% in leg strength from the range of 55–64 years to 64 years and above. Generally, the decrease of leg strength of our sample was lower compared to other studies (Table 5).

CA = 70 years

FFA = 40.146 + 0.350 × CS – 0.714 × AC – 0.110 × ST – 0.177 × CSR – 0.101 × BS + 8.835 × FUG = 64.08 years

	Score	%	Median
CS (rep)	22	90	17
AC (rep)	17	50	17
ST (step)	120	95	95
CSR (cm)	3	60	0.78
BS (cm)	10	95	-0.03
FUG (s)	4.88	70	5.29
Global score (mean)		77	

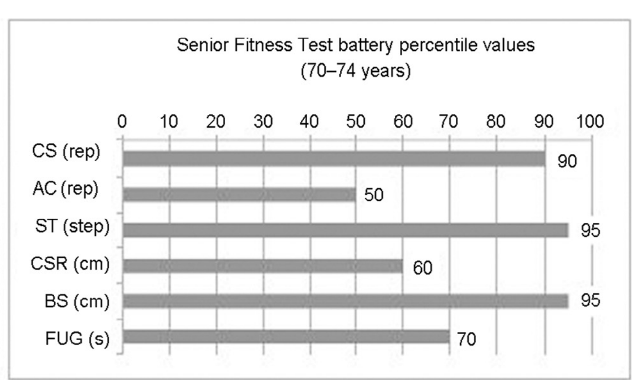

Fig. 4. FFA report example. AC = arm curl test; BS = back scratch test; CA = chronological age; CS = chair stand test; CSR= chair sit-and-reach test; FFA = functional fitness age; FUG = 8-foot up-and-go test; rep = repetition; ST = 2-min step test.

Table 4
Percentage of performance decline of the Senior Fitness Test battery outcomes ($n = 459$).

Age (year)	n	BMI[a]	CS	AC	ST	CSR[b]	BS[b]	FUG[b]
50–54	18	100	100	100	100	100	100	100
55–59	25	2.48	−8.18	−13.90	−3.15	−40.36	−62.40	6.12
60–64	59	2.41	−16.17	−18.10	−12.53	−52.44	−28.40	10.59
65–69	97	5.08	−18.48	−15.69	−16.12	−24.16	−63.00	19.29
70–74	99	6.13	−21.22	−20.66	−15.47	−97.69	−115.00	25.18
75–79	109	6.58	−21.66	−20.46	−18.70	−102.57	−141.20	31.76
80–87	52	6.09	−29.74	−26.30	−28.58	−196.40	−212.40	51.59

[a] Positive values refer to fitness decline.
[b] Test results range from positive to negative values.
Abbreviations: AC = arm curl test; BMI = body mass index, BS = back scratch test; CS = chair stand test; CSR = chair sit-and-reach test; FUG = 8-foot up-and-go test; ST = 2-min step test.

4.2.2. Arm strength

Arm strength measured with the arm curl test (AC) was the fitness condition that decreased the least, with a net loss of 26.30%. As other researchers concluded, there is a further decline in lower body strength than in upper body strength.[21,38,39]

In our study, the participants aged more than 64 years averaged 18% less repetitions than those younger than 64, while Núñez Roca et al.[38] found a loss of 21.58% in arm strength.

Strength decline is faster as people become older. The breakpoint of Lleida participants where strength reduction begins to accelerate is around 70 years.

4.2.3. Aerobic endurance

Participants results on the aerobic endurance fitness test, the ST showed a similar percentage of decline than other studies, although absolute scores showed that Lleida women scored 10 steps more per year than the Hong Kong (China) and U.S. samples.[21,40]

4.2.4. Lower limbs flexibility

Comparing our CSR results with other studies from Hong Kong (China),[40] Brazil,[41] and the USA,[21,41] Hong Kong samples consistently show better results in absolute terms. However, the decline in lower limb flexibility begins earlier in Lleida women (70–79 years compared to 80 years) compared to the Brazilian and U.S. samples, whose decline is more gradual.

4.2.5. Upper limbs flexibility

Comparing the results of upper limbs flexibility using the BS, the Hong Kong (China) sample shows better results than the Lleida and the U.S. population.[21,40] The age group of 80 and above in Lleida has a decrease in upper limbs flexibility greater than the sample from Hong Kong (China). The U.S. sample, however, shows the worst results and a more pronounced decline with time.

Table 5
Comparison of the decrease in leg strength (%).

Age group comparison	Lleida population	Other populations	
	Decline	Decline	Reference
45 *vs.* 60	1.1	1.5	Spirduso et al.;[1,a] Siff and Verkhoshansky[35,a]
55–64 *vs.* 64+	26.0	30.0	Núñez Roca et al.[38,b]
60 *vs.* 80+	18.2	20.0	Samuel and Rowe[36,a]
80 *vs.* 80+	2.4	2.6	Goodpaster et al.[37]

[a] Leg strength was measured with a dynamometer, isometric strength.
[b] Leg strength was measured with a counter-movement jump test, explosive strength.

4.2.6. Agility

Our participants' scores of agility measured with the FUG showed a similar percentage of decrease as other studies.[21,40,41]

5. Conclusion

We consider the SFT battery an appropriate set of tests to assess FFA) in elderly women due to low technical difficulty and safety of the tests (i.e., low physical demand). Using the SFT battery we created an equation to determine the FFA and, when compared to the CA, may provide relevant information for practitioners to set exercise programs. The fitness outcomes of our sample were similar to other populations. The outcomes of a physical fitness test may indicate what capacity is low compared to normative values. However, we suggest that the indicator of FFA and the difference between FFA and CA (age_dif) is easy to understand for a general population. It may be also a motivation shift to start an exercise program or to adapt a current one to more specific fitness capacities, like the estimated spirometric lung age (i.e., the age of the average healthy individual who would perform similar to them on spirometry) has been shown to improve the likelihood of smokers quitting smoking. Individual scores for each outcome may provide relevant information to individualize exercise programs aimed at improving lower health-related fitness capacities. Longitudinal studies including exercise programs to improve health-related fitness may use the FFA indicator (and age_dif) and focus on participation adherence or health-related outcomes (e.g., number of injuries, risk of falls, cardiovascular risk factors, cognitive performance).

Our study evaluated active women participating in exercise programs. They may suffer from medical conditions but none of the conditions limited their participation in exercise programs. Future research should focus on other populations, such as men or other age groups. The determination of FFA for patients of different medical conditions may even correlate with morbidity and self-perception of quality of life.

Acknowledgments

The authors give special thanks to the Institut Municipal d'Activitats Esportives (IMAE), the Lleida City Council, the Universidad Santo Tomás Aquino of Colombia, and the National Institute of Physical Education of Catalonia (INEFC) for their support, and Tina Buchmann (Translations and Language Services).

Authors' contributions

EJLR performed the SFT measurements; JAPS and APA conceived of the study, participated in its design and coordination; XPT and SMA drafted the manuscript; APA and JVBG performed the data analysis and helped to draft the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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