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Original article

The 3 Minute Step Test is a validated field test to evaluate the functional exercise capacity in children aged 6 to 12

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ABSTRACT

Background. – Field tests are useful to assess the functional exercise capacity. The 6 minute walking test (6MWT) is the most common field test even if alternatives are needed. The main aim of the study was to verify if the 3 minute step test (3MST) is a valid tool to measure the functional exercise capacity and can surrogate the 6MWT in healthy children from 6- to 12-years-old.
Methods. – This randomized cross-over trial recruited 30 healthy children from 6 to 12 years. One 6MWT and two 3MST ($3MST_1$ and $3MST_2$) were performed randomly on 3 consecutive days. The variables were the distance (6MWT), the number of steps (3MST) and the cardiorespiratory parameters.
Results. – The distance walked during 6MWT was very strongly correlated to the number of steps during the 3MST ($3MST_1$: rho = 0.833; $P < 0.001$ and $3MST_2$: rho = 0.868; $P < 0.001$). Heart rate (HR) was lower than the theoretical maximal HR at the end of both tests. The change in HR and perceived fatigue were significantly higher after the 3MST. A learning effect was observed in the 3MST (+8 steps; $P < 0.001$).
Conclusions. – The 3MST is validated and can be a surrogate for the 6MWT in healthy children population between 6 and 12 years old. A training test is required in these children.

1. Introduction

The level of physical fitness during childhood and adolescence is associated to the risk of obesity, cardiovascular diseases, and the musculoskeletal and mental health. It can be assessed by the functional exercise capacity [1]. Moreover, various physical exercise programs improved the functional exercise capacity in paediatric patients with obesity or chronic cardiac or respiratory diseases, such as cystic fibrosis, asthma or bronchopulmonary dysplasia [2–5]. As recommended by the American Thoracic Society and the European Respiratory Society (ATS and ERS, respectively) in the statement about pulmonary rehabilitation, the evaluation of the functional exercise capacity is mandatory in this context [6].

The cardiopulmonary exercise test is the gold standard to assess the physical capacity [1]. However, taking into account the barriers related to the cardiopulmonary exercise test, field tests are useful because they are simpler to carry out and imply less cost. Out of these, the 6 minute walking test is the most common (6MWT) [7,8]. It was previously validated in children [9]. Moreover, its psychometric properties were verified and it offers predicted values [7,10].

Nevertheless, the required long hallway, the inability to walk and the necessity for some hospitalized patients to stay in a room are barriers for this test. Some other field tests have therefore been proposed such as the step tests and the sit-to-stand-test (STST) [11–18]. Conversely to the STST, little attention was paid to the step test in children [17]. The step test measures how many times someone can step on and off a stair in a fixed time. A study failed to validate the 6 minute step test (6MST) as a surrogate to the 6MWT in children from 6 to 12 years old and the authors concluded that the first one was more demanding [13]. By reducing the duration of this test, we hypothesized that the correlation between the number of steps that an individual can perform and the distance walked during the 6MWT could be improved. This is supported by the results of a study performed in stable patients with Chronic Obstructive Pulmonary Disease showing that the 3 minute step test (3MST) was an alternative to the 6MWT [14].

Abbreviations: ATS, American Thoracic Society; ERS, European Respiratory Society; 6MWT, 6 minute walking test; STST, sit-to-stand-test; 6MST, 6 minute step test; 3MST, 3 minute step test; BMI, body mass index; SpO2, pulsed oxygen saturation; HR, heart rate; MCID, minimal clinically important change score.

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The purpose of this study was to verify if the 3MST is a valid tool to measure the functional exercise capacity in healthy children from 6 to 12 years old. The secondary aim of the study was to analyse if there is a learning effect when the 3MST is performed.

2. Methods

2.1. Subjects

Children between 6 and 12 years old were recruited in the Axular Lizeoa school of San Sebastian (Gipuzkoa, Spain), between the 13th and 15th of January, 2020. The inclusion criteria were to be student of primary education and to be between 6 and 12 years old. The exclusion criteria were to have a diagnosis of obesity, neurological, pulmonary or cardiac disease, or to have a motor disability, based on a parents questionnaire.

The experiment was previously approved by the Institutional Medical Ethics Committee (BE403201317636). Before each experiment, a written informed consent form was obtained from the parents, based on the Good Clinical Practice guidelines from the declaration of Helsinki.

2.2. Design of the study

It was a randomized cross-over study, performed on three consecutive days. From all the eligible volunteers, 30 were recruited randomly using a list of random numbers generated with computer (Microsoft Excel). To guarantee the homogeneity of the sample regarding the age, children were recruited depending on the school year, half of the sample was picked from the 1st, 2nd and 3rd school years, and the other half from 4th, 5th and 6th. For the validation, children performed one 6MWT and one 3MST ($3MST_1$). To verify the learning effect, the children performed a second 3MST ($3MST_2$). The first day 50% of the children performed the 6MWT (Group 1), and the others the 3MST (Group 2). The second day they made it inversely and the third day all children performed the 3MST for the second time. The statistical analysis was blinded.

2.3. Field Tests

All the field tests were carried out by the same examiner.

2.3.1. 6MWT

The 6 minute walking test was performed in a straight, unobstructed and flat corridor, following the instructions of the ATS's protocol for adults [19], that was validated in children by Li et al. [9]. Subjects were instructed to walk as far as possible for 6 minutes between two marks separated by 30 metres. During the test, standardized sentences were pronounced.

2.3.2. 3MST

The 3 minute step test was carried out by stepping on and off a 20-cm single step device as many times as possible during 3 minutes, without handles, using the protocol outlined by the ATS for adults in 6 minute step test and Reychler et al.'s paper [13,20].

2.4. Variables

The main variables were the number of steps (3MST) and the distance in metres (6MWT). These outcomes were measured with a manual track counter for the number of laps and a measuring tape, and a manual track counter, for the 6MWT and the 3MST respectively. The walked distance was expressed in percentage of the predicted value based on Vandoni et al.'s equation [21]. The anthropometric parameters were collected with a questionnaire previously completed by the parents. The Body Mass Index (BMI) [weight (kg)/height (m)^2] was calculated. Pulsed oxygen saturation (SpO_2) and heart rate (HR) were measured with a finger pulse oximeter (Beurer, PO 40, Germany) and the fatigue was quantified using the EPInfant scale [22]. These outcomes were recorded before and after each test. The change of this last 3 parameters were calculated by the difference between the initial and final values and represents the demands related to the tests. Theoretical maximal HR was calculated with the specific equation for children (208–0,7 $\times$ age) [23]. From this, the percentage of predicted maximal HR was calculated.

2.5. Statistical analysis

A representative sample (n) of 25 individuals was previously determined, accepting an alpha risk of 0.05 and a beta risk of 0.2 in a two-sided test, with a correlation coefficient of 0.6. It has been anticipated a drop-out rate of 20% [24]. Thus the sample size was fixed to 30.

For the statistical analysis, SPSS 25.0 software (IBM Corp., Armonk, NY, USA) was used. Descriptive statistics were performed. Kolmogorov-Smirnov test was passed to all quantitative variables to verify the normality of the distribution. The comparisons of quantitative normally distributed variables were performed with the Student's T-test. The chi-squared test was used to investigate the association between qualitative variables.

The concurrent validity of the 3MST was verified by the correlation between the number of steps and the walked distance during 6MWT. It was calculated by the Spearman's correlation coefficient. The other outcomes similar between the two tests were compared with paired Student's T-test, and correlated together. All the correlations were expressed by absolute values and interpreted as very weak (< 0.00–0.19), weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79), or very strong (0.80–1.0).

To verify reliability between the first and second 3MST, the Interclass Correlation Coefficient (ICC) was calculated using a two-way mixed effect model for absolute agreement. The ICC was expressed by absolute value and 95% confidence interval. The reliability was interpreted from the ICC as poor (ICC < 0.50), moderate (ICC from 0.50 to 0.75), good (ICC from 0.75 to 0.90) or excellent (ICC > 0.90). The learning effect was calculated by the Bland and Altman method. Bias in the number of steps during the 3MST with 95% confidence of interval and limits of agreement were estimated.

The influence of different outcomes on the number of steps was verified by correlating this number with anthropometric data. The Spearman (rho) or Pearson (r) coefficients were used as appropriate. These correlations were similarly expressed and interpreted than for the validation. For all the analysis, a P-value lower than 0.05 was considered as significant.

3. Results

Out of the 134 children that were eligible for the study, 30 were randomly recruited. All the subjects completed all the 3 tests (Fig. 1). Demographic parameters of the children are displayed in Table 1. There were no differences between the individuals from Groups 1 and 2. The walked distance was 649.8 ± 76.7 metres (107.8 ± 8.47% of the predicted value) and the number of steps was 124 ± 30.

3.1. Concurrent validity

The correlation between the number of steps during 3MST and the walked distance was very strong ($3MST_1$: rho = 0.833; $P < 0.001$ and $3MST_2$: rho = 0.868; $P < 0.001$) (Fig. 2). The cardiorespiratory variables and the fatigue are illustrated in Table 2. The initial HR,

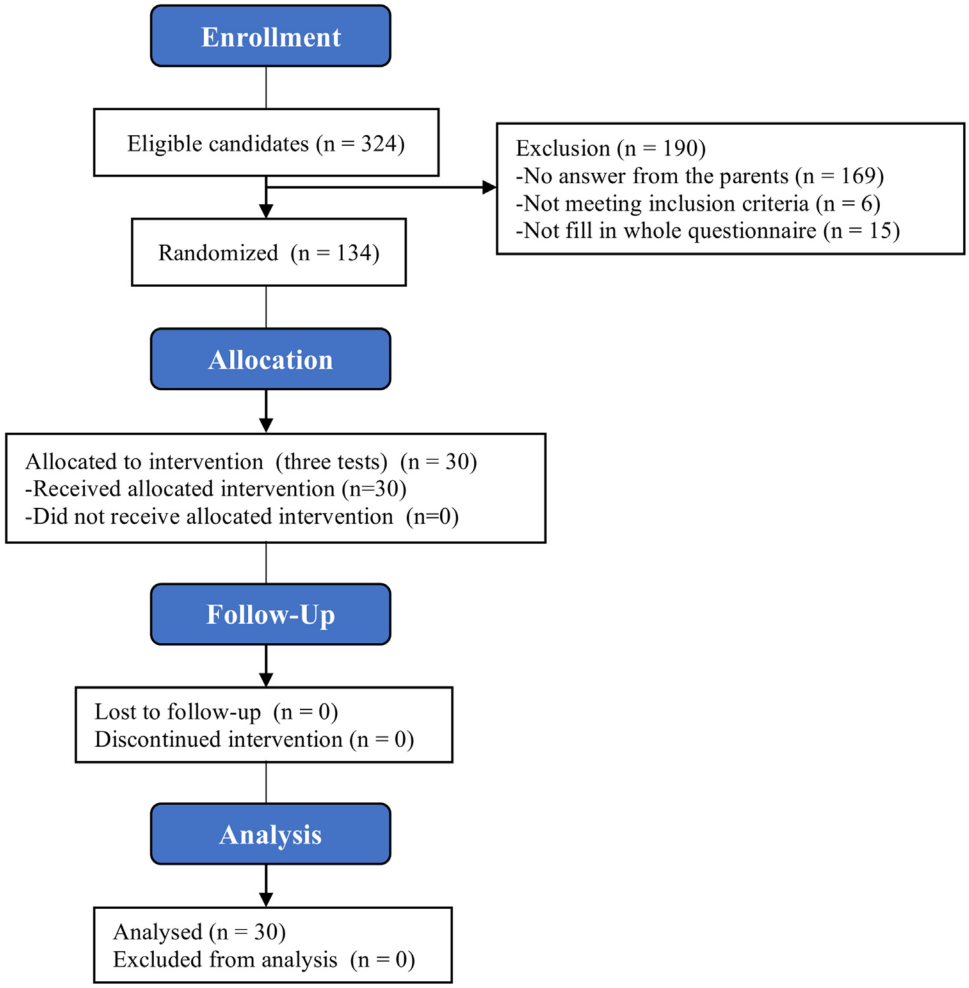

Fig. 1. Consort flow chart of the study.

Table 1
Demographic data of the children ($n = 30$).

Variable	Total	Group 1	Group 2	*P*-value
Sex (girl), *n* (%)	15 (50)	7 (46.7)	8 (53.3)	0.715
Age (years), mean (SD)	8.6 (1.8)	8.6 (0.5)	8.5 (0.5)	0.922
Weight (kg), mean (SD)	31.1 (9.4)	31.7 (2.5)	30.5 (2.4)	0.733
Height (m), mean (SD)	1.35 (0.1)	1.36 (0.0)	1.34 (0.0)	0.740
BMI (kg/m^2), mean (SD)	16.7 (2.3)	16.9 (0.6)	16.5 (0.6)	0.702
HR (bpm), mean (SD)	91 (11.6)	90 (2.2)	92 (3.7)	0.622
SpO_2 (%), mean (SD)	98.1 (0.8)	98.4 (0.1)	97.9 (0.3)	0.074
Physically active (yes), *n* (%)	29 (96.7)	14 (93.3)	15 (100)	0.309

SD: standard deviation; BMI: body mass index; HR: heart rate; SpO_2: pulsed oxygen saturation; physically active: children who made physical exercise out of school; group 1: children who performed the 6MWT on the first day; group 2: children who performed the 3MST on the first day.

Table 2
Cardiorespiratory results of the field tests.

Variable	6MWT	$3MST_1$	$3MST_2$	*P*-value*	*P*-value**
HR_i (bpm)	94 (15.0)	93 (14.7)	91 (11.6)	0.315	0.400
HR_f (bpm)	128 (17.1)	147 (22.3)	153 (26.0)	**<0.001**	0.071
$_{dif}HR$ (bpm)	34 (20.4)	54 (25.4)	62 (29.0)	**<0.001**	0.012
SpO_{2i} (%)	98.3 (0.8)	98.1 (1.2)	98.1 (0.8)	0.378	0.798
SpO_{2f} (%)	97.8 (1.2)	97.6 (1.2)	97.4 (1.3)	0.177	0.502
$_{dif}SpO_2$ (%)	0.9 (0.7)	0.9 (0.9)	1.0 (1.0)	0.876	0.889
$Fatigue_i$ (0–10)	0.67 (0.7)	0.73 (1.2)	0.80 (1.2)	0.536	0.645
$Fatigue_f$ (0–10)	3.70 (2.1)	4.13 (2.2)	4.50 (2.4)	**0.010**	0.373
$_{dif}Fatigue$ (0–10)	3.0 (2.2)	3.4 (2.1)	3.7 (2.4)	**0.022**	0.337

Results are mean (standard deviation). 6MWT: Six Minute Walking Test $3MST_1$: First 3 Minute Step Test; $3MST_2$: Second 3 Minute Step Test; SD: Standard Deviation; SD: Standard Deviation; HR: Heart Rate; SpO_2: Pulsed Oxygen Saturation; i: initial; f: final; dif: difference = |f-i|; Values in bold mean are statistically significant ($p < 0.05$).

* 6MWT vs. $3MST_2$.

** $3MST_1$ vs. $3MST_2$.

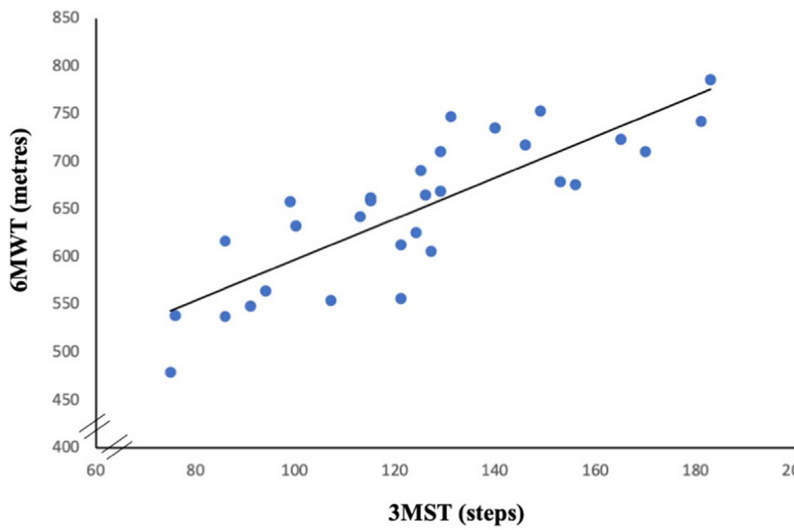

Fig. 2. Relationship between the second 3 Minute Step Test (3MST2) and the 6 Minute Walking Test (6MWT).

SpO_2 and fatigue were similar before the 3 tests. No desaturation was observed after any of the tests. At the end of all the tests, the HR from all the subjects was lower than the theoretical maximal HR (200–204 bpm). Regarding the change in HR ($_{dif}$HR), and in fatigue ($_{dif}$Fatigue), they were different between the two tests. The 3MST was associated to a higher cardiac demand and fatigue because it generated greater $_{dif}$HR (54 bpm ($3MST_1$) and 62 bpm ($3MST_2$) vs. 34 bpm (6MWT); $P<0.001$) and greater $_{dif}$Fatigue ($P=0.022$). Nevertheless, the correlations between 6MWT and $3MST_1$, or $3MST_2$ for $_{dif}$HR and for $_{dif}$Fatigue were moderate or strong ($3MST_1$: r = 0.581; $P=0.001$ and r = 0.561; $P=0.001$, respectively and $3MST_2$: r = 0.554; $P=0.001$ and r = 0.702; $P<0.001$, respectively).

3.2. Reliability and learning effect

The reliability between the first and the second 3MST was excellent (ICC = 0.944–95%CI = 0.771; 0.979; $P<0.001$). There was an important learning effect as illustrated by the significant bias between these two tests as revealed by the Bland and Altman method (8.3 [IC95% = 4.19; 12.41] and limits of agreement = −13.26; 29.86) (Fig. 3).

3.3. Parameters influencing the number of steps during the 3MST and the walked distance during the 6MWT

The number of steps during 3MST was related to age (rho = 0.774; $P<0.001$), height (rho = 0.557; $P<0.001$), and weight (rho = 0.407; $P=0.026$) but not to BMI (rho = −0.042; $P=0.827$). Similar relationships were found for the two 3MST. The walked distance was correlated to age (r = 0.677; $P<0.001$) and height (r = 0.494; $P=0.006$) but neither to weight (r = 0.195; $P=0.302$) nor BMI (r = −0.136; $P=0.472$). The learning effect between $3MST_1$ and $3MST_2$ was not correlated to any anthropometric outcomes.

4. Discussion

This study demonstrated that the 6MWT and the 3MST are feasible in children from 6 to 12 years old, and that the number of steps performed during the 3MST is very strongly associated to the walked distance during the 6MWT and highly reliable. This means that the 3MST is a valid test to estimate and to follow the functional exercise capacity in children of this age range. However, based on the cardiorespiratory response, the 3MST is twice more demanding than the 6MWT. Besides that, it was noticed that there is a learning effect of 8 steps when the 3MST is performed twice.

The evaluation of the functional exercise capacity is important in clinical practice, because it provides an evaluation of global and integrated responses of all the systems involved during exercise, including the respiratory and cardiovascular systems, systemic circulation, peripheral circulation, blood, neuromuscular units, and muscle metabolism. The tests in which the subject takes his own path, estimate the submaximal functional exercise capacity level. It reflects the demanding level of daily life activities [19].

The functional exercise capacity of the children was normal in our study. In fact, the distance walked during the 6MWT was in the normal range, based on the Italian prediction equation for healthy children from Vandoni et al.[21] This equation was used due to the lack of Spanish studies for reference values.

A significant, but only weak, correlation between the step number during the 6MST and the walked distance during the 6MWT was previously demonstrated in children from 6 to 12 years old [13]. Then, the authors failed to validate this test as a tool to evaluate the functional exercise capacity. It can be explained by the higher metabolic demand that causes stair climbing compared to walking [11,13]. We hypothesized that the 6MST was too long and too demanding compared to the 6MWT and that a shorter version of this test could be more interesting. The correlation between the 3MST and the 6MWT was very strong in our study. That confirms our hypothesis and it means that the 3MST is a valid tool to evaluate the functional exercise capacity in children from 6 to 12 years old.

Cardiorespiratory response was significantly different between both tests, as it was described in other studies [11–13]. As expected, due to the healthy children recruited for the study, desaturation was not observed. Although none of the children reached the theoretical maximal HR during these tests, the 3MST causes more increase in HR than the 6MWT. It means that 3MST is again more demanding than 6MWT, even though the time was reduced by half compared to 6MST. Furthermore, final HR was higher after the 3MST than after 6MST [13]. There are two possible explanations. First, the children were older in our study than in the previous study. As older children have higher exercise capacity, they can go faster and, so HR can also be higher. Second, longer test involves more fatigue, so children can slow down their path, and consequently final HR was lower. A similar result was also observed in adults, although difference is not so pronounced [11,18].

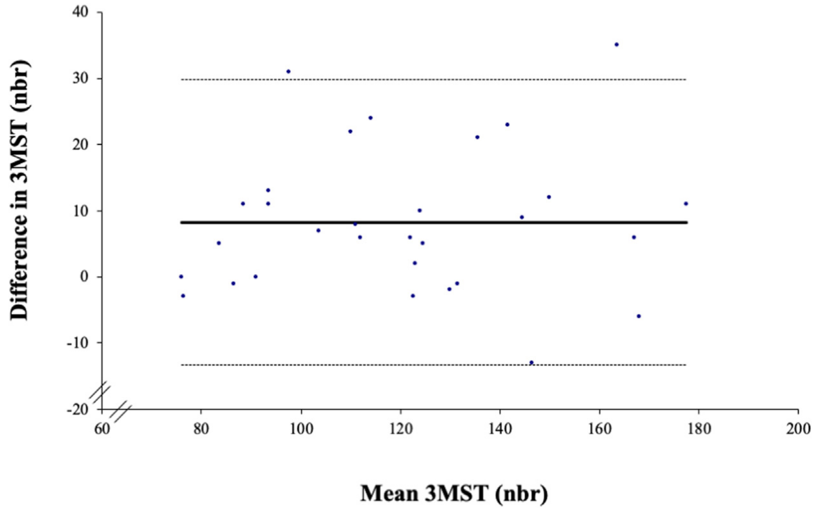

Fig. 3. Learning effect for the 3 Minute Step Test (Bland and Altman method).

The higher HR highlights that the test has higher energetic demand, and this can be explained by the fact that stair climbing requires higher muscle demand than walking on level ground due to the need to overcome the force of gravity [13]. This is confirmed by the higher level of fatigue that was perceived on the 3MST.

To our knowledge, there was no study that analysed the reliability and the learning effect of the 3MST. Our results demonstrated that the reliability was excellent justifying a good reproducibility of this test. No training is required for the 6MWT in children [25], whereas our study demonstrates that there was a learning effect on the 3MST, similarly to the STST [17]. This can be explained by the fact that walking requires less coordination capacity than to climb up and down from a step. Children walk independently at 9 to 15 months of age, while they are not able to easily switch the feet when standing on a stair before 3 years old [26]. After they acquired the skill of walking, gross motor development consists of refinements in balance, coordination, speed, and strength [27].

As it was expected, the age and the height were related both to the step number (3MST) and to the walked distance (6MWT). However, the weight was only related to the number of steps during the 3MST, but not to the walked distance. This absence of correlation is surprising because this relationship was previously observed.[21] It can be explained by the small sample size. The higher energetic demand of the 3MST to struggle against gravity compared to the 6MWT could be the cause of this discrepancy.

Some limitations need to be addressed for this study. First, only healthy children were recruited. It could be argued that, in contrast with healthy subjects, patients could not finish the 3MST due to the related-disease fatigue or the learning effect can be different due to modified intrinsic or extrinsic motivation and functional limitation due to the disease. Extrapolation to patients should be cautious. Second, intrinsic motivation varies with age, increasing until 15 years of age [28], and self-determined motivation was associated to physical activity [29]. Thirdly, the fixed height of the step can be questionable due to its potential influence on the results related to the height of the children.

5. Conclusions

In conclusion, the 3MST is valid and feasible in children between 6 and 12 years old. The strong association between the number of steps during the 3MST and the walked distance during the 6MWT means that the 3MST can be a surrogate in healthy children population to assess the functional exercise capacity. Besides that, a learning effect was observed, justifying the need for a training test. Additionally, there is a need for further studies to assess the responsiveness and the minimal clinically important change score (MCID), and to determine normative data.

Specific contributions

Amaia Iturain Barrón: literature search, data collection, study design, analysis of data, manuscript preparation.

Salvador Quintana Riera: analysis of data, review of manuscript.

Grégory Reychler: analysis of data, review of manuscript.

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Disclosure of interest

The authors declare that they have no competing interest.

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