

Estimating VO_{2peak} in 18–90 Year-Old Adults: Development and Validation of the FitMáx©-Questionnaire [Corrigendum]

Meijer R, van Hooff M, Papen-Botterhuis NE. *Int J Gen Med.* 2022;15:3727–3737.

The authors have advised that the Bland-Altman analysis presented in the published article requires a methodological clarification.

During subsequent research involving individuals with long-COVID in an ongoing study, they observed a consistent underestimation of cardiorespiratory fitness (CRF) expressed in oxygen uptake during maximal exercise (VO_{2peak}) by the self-reported questionnaires, as indicated by the raw data. However, the Bland-Altman analysis used in the validation study suggested overestimation of CRF—an inconsistency that warranted further examination.

Upon re-evaluating their methodology, they identified the root cause of this discrepancy: the direction of subtraction used in the analysis. Specifically, they subtracted the questionnaire-derived predictions from the CPET (gold standard) values (CPET – prediction). While this is mathematically valid, the conventional approach in Bland-Altman analysis is to subtract the gold standard from the prediction (prediction – CPET), allowing for a clearer interpretation of bias direction.^{1,2} Adopting the conventional subtraction method provided results that aligned with the raw data, showing an underestimation of CRF, particularly in higher-performing individuals.

In response to these findings, they have updated the Bland-Altman plots to reflect the conventional subtraction approach and revised the accompanying labels to explicitly indicate the direction of subtraction.^{1,2} These revisions enhance the clarity and transparency of their analysis while aligning with standard practices in Bland-Altman methodology. Moreover, they made small clarifications to the statistical model they used and removed a redundant sentence in the interpretation of the limits of agreement.

Page 3727, Abstract, Results section, the text “Bias between predicted and measured VO_{2peak} was -0.24 (-9.23–8.75; 95% limits of agreement) $mL \cdot kg^{-1} \cdot min^{-1}$ ” should read “Bias between predicted and measured VO_{2peak} was 0.24 (-8.75–9.23; 95% limits of agreement) $mL \cdot kg^{-1} \cdot min^{-1}$ ”.

Page 3730, first paragraph, line 3, the text “We performed stepwise selection with 10-fold cross-validation with 100 repeats, retaining 20% of the data at each loop for validation” should read “We performed stepwise selection using 10-fold cross-validation with 100 repeats, implemented with the `repeatedcv` method from the `caret` package in R. This means that for each repetition, the data was split in 10 equal-sized folds. Of this 10, each one was sequentially excluded and used to evaluate the model fit, obtained on the remaining 9 folds”.

Page 3731, Table 1, the updated table should read as follows.

Table 1 Participant Characteristics in the training and testing set, displayed separately

Variable	Training Set (70%; n=531)		Testing Set (30%; n=228)	
	Male	Female	Male	Female
n	390	141	170	58
<i>Anthropometrical data</i>				
Age (yr)	59 (49–68)	57 (46–69)	60 (49–67)	61 (49–71)
Height (cm)	180 (175–184)	165 (160–172)	180 (174–184)	164 (160–168)
Weight (kg)	82.4 (74.4–91.1)	70.4 (61.8–82.3)	82.7 (75.0–89.9)	67.2 (60.5–75.9)
BMI (kg·m ⁻²),	25.4 (23.6–28.1)	25.8 (22.3–29.8)	25.4 (23.5–27.8)	25.0 (22.7–27.9)
FEV ₁ (L)	3.6 (2.9–4.3)	2.5 (1.8–3.0)	3.6 (2.9–4.3)	2.4 (1.7–3.1)
FVC (L)	4.7 (3.9–5.4)	3.1 (2.5–3.8)	4.7 (3.8–5.5)	3.0 (2.4–3.8)
COPD, GOLD classification				
None	355 (91.0%)	121 (85.8%)	158 (92.9%)	49 (84.5%)
GOLD I	10 (2.6%)	1 (0.7%)	2 (1.2%)	7 (12.1%)
GOLD II	17 (4.4%)	13 (9.2%)	5 (2.9%)	2 (3.4%)
GOLD III	5 (1.3%)	5 (3.5%)	5 (2.9%)	0 (0%)
GOLD IV	3 (0.8%)	1 (0.7%)	0 (0%)	0 (0%)
Use of β-blocker				
Yes, n (%)	86 (22.1%)	31 (22.0%)	34 (20.0%)	6 (10.3%)
No, n (%)	304 (77.9%)	110 (78.0%)	136 (80.0%)	52 (89.7%)
<i>CPET data</i>				
Reason CPET/department				
Health check, n (%)	88 (22.6%)	15 (10.6%)	45 (26.5%)	11 (19.0%)
Cardiac, n (%)	208 (53.3%)	43 (30.5%)	84 (49.4%)	7 (12.1%)
Pulmonary, n (%)	84 (21.5%)	71 (50.4%)	34 (20.0%)	34 (58.6%)
Oncologic, n (%)	8 (2.1 %)	10 (7.1%)	7 (4.1%)	6 (10.3%)
Other reason, n (%)	2 (0.5%)	2 (1.4%)	0 (0%)	0 (0%)
Maximal workload (W)	266 (161–347)	123 (79–180)	251 (130–350)	113 (76–161)
Exercise time (min)	9.4 (8.5–10.3)	9.0 (7.8–10.5)	9.7 (8.2–10.6)	9.6 (8.1–10.8)
VO _{2peak} (ml·kg ⁻¹ ·min ⁻¹)	34.6 (21.9–43.3)	20.8 (16.3–27.9)	32.3 (20.0–43.3)	22.0 (17.1–26.7)
VO _{2peak} reference* (ml·kg ⁻¹ ·min ⁻¹)	33.1 (29.2–37.4)	22.5 (17.7–27.9)	33.8 (28.3–38.3)	21.6 (18.4–27.6)
HR _{peak} (beat·min ⁻¹)	158 (139–172)	151 (129–171)	162 (138–176)	160 (137–171)
RER (VCO ₂ /VO ₂)	1.2 (1.1–1.2)	1.1 (1.1–1.2)	1.2 (1.1–1.2)	1.1 (1.1–1.2)
<i>Questionnaire data</i>				
VO _{2peak} DASI (ml·kg ⁻¹ ·min ⁻¹)***	34.6 (25.4–34.6)**	25.0 (20.2–33.8)	34.6 (24.5–34.6)**	28.0 (20.1–34.6)
VO _{2peak} VSAQ (ml·kg ⁻¹ ·min ⁻¹)	31.3 (17.6–39.3)	18.6 (12.6–25.7)	33.5 (16.2–40.3)	16.9 (13.6–23.1)
VO _{2peak} FitMáx (ml·kg ⁻¹ ·min ⁻¹)			34.3 (21.7–43.6)	21.6 (17.9–26.8)
Δ Time CPET and questionnaire (days)	1 (0–8)	0 (0–7)	1 (0–6)	1 (0–5)

Notes: Results are displayed as n (%) or median (IQR). No statistical significant differences were found between the testing and training set. Missing information, number of subjects: FEV₁, 9; FVC, 9; Estimated VO_{2peak} DASI, 242; VSAQ, 6 (in training set). *The prediction model for VO_{2peak} of the Fitness Registry and Importance of Exercise National Database (FRIEND) is recommended by the American College of Sports Medicine as international reference value.^{9,39} **DASI shows a ceiling effect in the study results. ***DASI results were collected in a subset of the total study population (n=517).

Abbreviations: cm, centimeters; COPD, chronic obstructive pulmonary disease; FEV₁, forced expiratory volume in 1 second; FRIEND, Fitness registry and importance of exercise national database; FVC, forced vital capacity; HR, heart rate; kg, kilograms; kg·m⁻², kilograms per square meter; L, liters; min, minutes; ml, milliliters; n, number of subjects; yr, years; W, watts.

Page 3732, Validation Prediction Model section, first paragraph, 3rd sentence, the text “Bias of the FitMáx was $-0.24 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, which is smaller than the DASI ($3.32 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and VSAQ ($3.44 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)” should read “Bias of the FitMáx was $0.24 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, which is smaller than the DASI ($-3.32 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and VSAQ ($-3.44 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)”.

Page 3732, Validation Prediction Model section, second paragraph, last sentence, the text “The density plots on the y-axis of the FitMáx indicate that most of the results from the subjects are within the 95% LoA” should be deleted.

Page 3733, Figure 2, the updated figure is as follows.

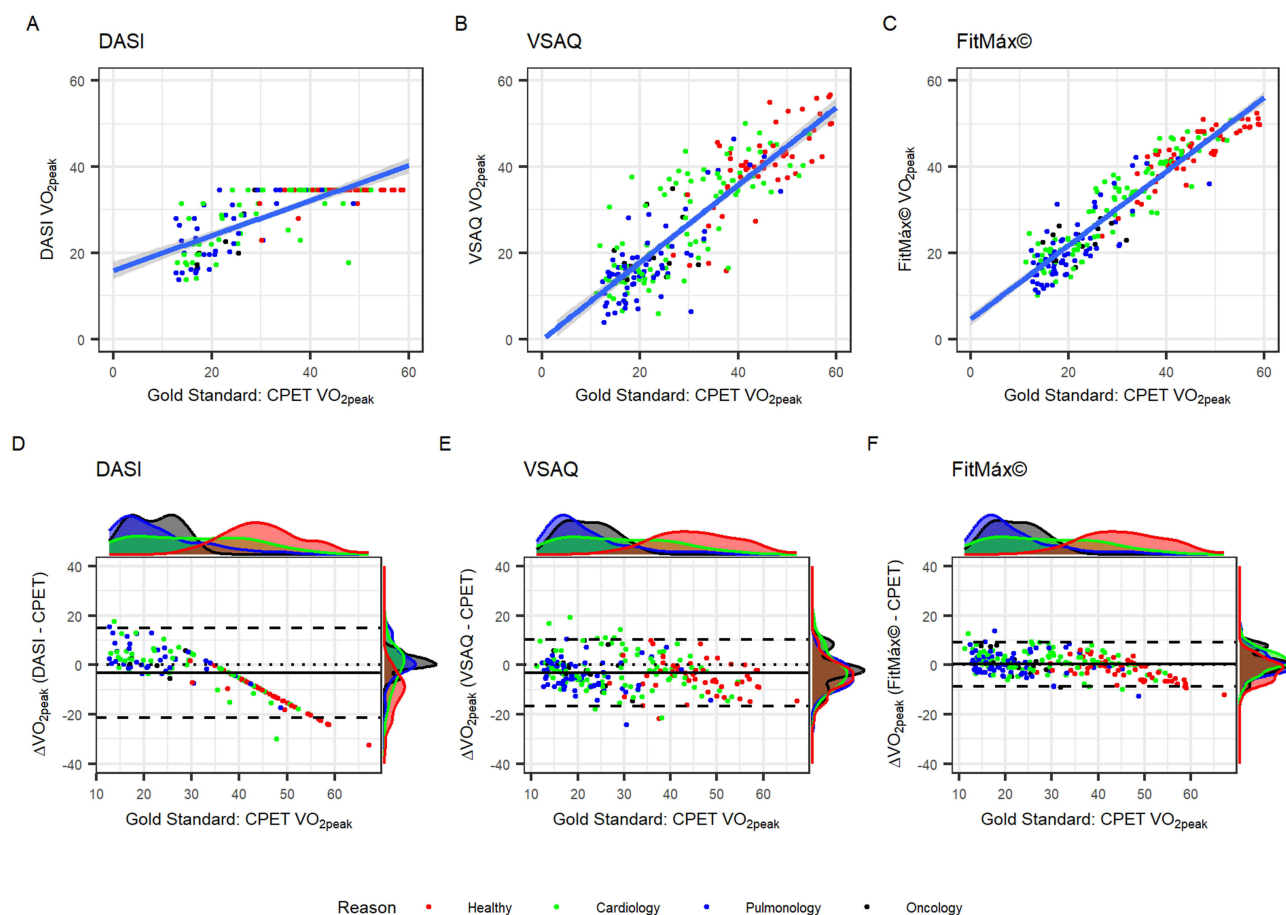


Figure 2 Scatterplots (A–C) show the relationship between predicted (FitMáx, DASI, and VSAQ) and measured $\text{VO}_{2\text{peak}}$ (in $\text{ml min}^{-1} \text{kg}^{-1}$). Each plot includes a solid line representing the best-fit linear regression (least squares); Bland-Altman plots (D–F) for DASI, VSAQ, and FitMáx illustrate the agreement between predicted and measured $\text{VO}_{2\text{peak}}$ (also in $\text{ml min}^{-1} \text{kg}^{-1}$), with a solid line for the mean bias, dashed lines for the limits of agreement (± 1.96 SD), and a dotted line indicating zero bias. Histograms positioned above and to the right of each axes display the distribution of values per CPET indication. Colors indicate the reason for the CPET visit.

Page 3733, Table 3, the updated table should read as follows.

Table 3 Statistics validation of the prediction model including walking, stair climbing and cycling capacity separately.

Model	n	Bias (lb – ub)	r (lb – ub)	R ²	SEE	ICC (lb – ub)
LM FitMáx	228	0.24 (-8.75–9.23)	0.94 (0.92–0.95)	0.88	4.14	0.93 (0.91–0.95)
LM walk	228	0.19 (-12.00–12.37)	0.88 (0.85–0.91)	0.78	5.40	0.87 (0.84–0.90)
LM stair climb	228	0.66 (-11.08–12.41)	0.89 (0.86–0.92)	0.79	5.25	0.88 (0.85–0.91)
LM cycle	228	0.14 (-9.57–9.86)	0.93 (0.91–0.94)	0.86	4.49	0.92 (0.90–0.94)
LM walking + stair climbing	228	0.42 (-10.71–11.55)	0.90 (0.88–0.92)	0.82	5.05	0.90 (0.87–0.92)
VSAQ	228	-3.44 (-16.98–10.11)	0.87 (0.83–0.90)	0.75	6.75	0.87 (0.83–0.90)
LM FitMáx*	150	0.32 (-8.48–9.13)	0.94 (0.92–0.95)	0.88	4.01	0.94 (0.91–0.95)
DASI	150	-3.32 (-21.44–14.81)	0.75 (0.68–0.80)	0.56	4.62	0.62 (0.51–0.71)

Abbreviations: LM, linear model; lb, lower bound; ub, upper bound. *Corrected for missing values of the DASI in the testing set.

Page 3735, Abbreviations section, line 3, the text “FRIENDS” should read “FRIEND”.

The authors recognize the importance of rigorous and transparent reporting in scientific research and sincerely apologize for any confusion caused by the initial presentation of these analyses.

References

1. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet*. 1986;1(8476):307–310.
2. Kroutheyr JS. Why Bland-Altman plots should use X , not $(Y+X)/2$ when X is a reference method. *Stat Med*. 2008;27(5):778–780.

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