

Normal reference values for aerobic fitness in cystic fibrosis: a scoping review

Owen W Tomlinson ^{1,2,3} Curtis A Wadey,¹ Craig A Williams^{1,2}

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¹Children's Health and Exercise Research Centre, Department of Public Health and Sport Sciences, Faculty of Health and Life Sciences, University of Exeter, Exeter, UK

²Academic Department of Respiratory Medicine, Royal Devon University Healthcare NHS Foundation Trust, Exeter, UK

³Department of Clinical and Biomedical Sciences, Faculty of Health and Life Sciences, University of Exeter, Exeter, UK

Correspondence to

Dr Owen W Tomlinson;
O.W.Tomlinson@exeter.ac.uk

ABSTRACT

Objective The importance of aerobic fitness ($\text{VO}_{2\text{peak}}$) in cystic fibrosis (CF) is well established, and regular exercise testing is recommended. To standardise $\text{VO}_{2\text{peak}}$, a 'percentage of predicted' ($\%_{\text{pred}}$) derived from normative reference values (NRV), as promoted by the 2015 European Cystic Fibrosis Society Exercise Working Group (ECFS EWG), can be reported. However, the NRVs used in CF and their relative frequency is unknown.

Method A scoping review was performed via systematic database searches (PubMed, Embase, Web of Science, SciELO, EBSCO) and forward citation searches for studies that include people with CF and report $\text{VO}_{2\text{peak}}$ as $\%_{\text{pred}}$. Studies were screened using Covidence, and data related to patient demographics, testing modality and reference equations were extracted. Additional analyses were performed on studies published in 2016–2021, following the ECFS EWG statement in 2015.

Results A total of 170 studies were identified, dating from 1984 to 2022, representing 6831 patients with CF, citing 34 NRV. Most studies (154/170) used cycle ergometry, 15/170 used treadmills, and the remainder used alternative, combination or undeclared modalities. In total, 61/170 failed to declare the NRV used. There were 61 studies published since the ECFS EWG statement, whereby 18/61 used the suggested NRV.

Conclusion There is a wide discrepancy in NRV used in the CF literature base to describe $\text{VO}_{2\text{peak}}$ as $\%_{\text{pred}}$, with few studies using NRV from the ECFS EWG statement. This high variance compromises the interpretation and comparison of studies while leaving them susceptible to misinterpretation and limiting replication. Standardisation and alignment of reporting of $\text{VO}_{2\text{peak}}$ values are urgently needed.

INTRODUCTION

It has been well established that aerobic fitness (as represented by peak oxygen uptake, $\text{VO}_{2\text{peak}}$) is an important biomarker in people with cystic fibrosis (CF). A higher level of aerobic fitness is associated with a higher risk of early mortality or transplant,¹ reduced risk of being hospitalised,² and enhanced quality of life.³ As such, regular exercise testing is recommended^{4–6} for people with CF to monitor changes and guide exercise training interventions to improve fitness.

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Aerobic fitness is a valuable outcome in people with cystic fibrosis and can be presented as a 'per cent of predicted' against a normative reference value to aid clinical decision making.
- ⇒ However, the normative reference values used in cystic fibrosis and how often they are used are unknown.

WHAT THIS STUDY ADDS

- ⇒ This review shows a wide variation in the number, and frequency, of normative values, used to describe aerobic fitness as a 'per cent of predicted' in cystic fibrosis.
- ⇒ Approximately one-third of studies fail to state which normative values they used, which has notable consequences on the interpretation of data.

Cardiopulmonary exercise testing (CPET) is noted as the gold-standard procedure for assessing fitness and establishing $\text{VO}_{2\text{peak}}$ (and where possible, maximal oxygen uptake, $\text{VO}_{2\text{max}}$)⁷ and is typically performed using cycle or treadmill ergometry.⁵ Moreover, there are multiple ways to report $\text{VO}_{2\text{peak}}$ data, whereby this is typically displayed in either: (A) absolute units (mL/min), although this does not account for body size and therefore smaller individuals can be unfairly penalised or (B) relative to body mass (mL/kg/min), although these reports can be biased by body composition, that is, those individuals with larger muscle mass can be unfairly penalised and misclassified as having low fitness. There are several further assumptions and errors in using these approaches,⁸ and therefore precautions should be made prior to their use in reports.

Consequently, presenting data as a 'per cent of predicted' ($\%_{\text{pred}}$)—reported relative to an expected value for a certain age, sex, height and weight—can be used to present data in an intuitive way that can be easily understood by clinicians and patients alike. Using $\%_{\text{pred}}$ in CF is commonplace for scoring values derived from spirometry, such as forced expiratory

Table 1 Normative reference values recommended for use by European Cystic Fibrosis Society Exercise Working Group (ECFS EWG)

Reference	Modality	Equation
Jones <i>et al</i> ²⁶	Cycle ergometry	VO_{2max} (L/min) = $-0.62 \text{ sex (0 male, 1 female)} + 0.046 \text{ height (cm)} - 0.021 \text{ age (years)} - 4.31$
Orenstein ²¹	Cycle ergometry	Female: VO_{2peak} (L/min) = $3.08806 \text{ height (m)} - 2.877$ Male: VO_{2peak} (L/min) = $4.4955 \text{ height (m)} - 4.64$
Werkman <i>et al</i> ⁴⁰	Cycle ergometry	$VO_{2peak} = 216.3 - 138.7 \times \text{sex (0 male, 1 female)} + 11.5 \times W_{peak}$
ACSM ⁴¹	Treadmill	VO_2 (mL/kg/min) = $3.5 + 0.1 \times \text{speed (m} \times \text{min}^{-1}) + 1.8 \times \text{speed} \times \text{fractional grade}$ VO_2 (mL/kg/min) = $3.5 + 0.2 (\text{speed}) + 0.9 (\text{speed} \times \text{fractional grade})$
Bruce <i>et al</i> ⁴²	Treadmill	VO_{2max} (mL/kg/min) = $6.70 - 2.82 \text{ sex (1 male, 2 female)} + 0.056 (\text{duration in seconds})$
Foster <i>et al</i> ⁴³	Treadmill	VO_{2peak} (mL/kg/min) = $14.8 - 1.379 \times \text{time (min)} + 0.451 \times \text{time (min)}^2 - 0.012 \times \text{time (min)}^3$
Pollock <i>et al</i> ⁴⁴	Treadmill	VO_{2peak} (mL/kg/min) = $0.073 \times \text{time (seconds)} - 3.9$

Data obtained from ECFS EWG Statement on Exercise Testing.⁵ Further reference data are recommended by ECFS EWG for treadmills, but these are in the form of percentiles and not an equation to derive a 'per cent of predicted' value.^{45–48}
ACSM, American College of Sports Medicine; VO_{2max} , maximal oxygen uptake; W_{peak} , peak work rate.

volume in one second and forced vital capacity. To facilitate this, normal reference values (NRV) are available for lung function,⁹ and are used routinely in registry reports.¹⁰ The available lung function NRVs are multi-ethnic, derived from ~100 000 patient records in over 30 countries, and are collaboratively developed by multiple international organisations, leading to widespread acceptance as the gold-standard NRV for spirometry.⁹ However, unlike spirometry, there is no universal agreement on the most appropriate NRV to use for CPET, and interpretation of VO_{2peak} .

Recent literature reviews have identified a high volume of NRV available,^{11 12} with 29 sets of NRV dedicated to CPET parameters from 2014 to 2019 alone.¹² These NRV are not wholly focused on VO_{2peak} , and also include reference to work rate, peak heart rate, oxygen pulse and ventilation, among others.^{11 12} This heterogeneity of NRV presents a dilemma for clinicians as it is not clear which is the 'correct' NRV (and parameter) to use. To facilitate this choice, the European Cystic Fibrosis Society Exercise Working Group (ECFS EWG) has published a statement on exercise testing in CF,⁵ detailing protocols and strategies for implementing and interpreting CPET data, including VO_{2peak} . As part of this statement, several sets of NRV have been recommended for use, dependent on exercise modality (table 1). However, since the publication of this statement, it is unclear to what extent these have been adopted for use; and to what extent NRV are generally used in the CF literature base. Recent survey work of CF clinics in the UK has established a wide variation in NRV used for interpreting CPET,¹³ suggesting that this variation in available literature may translate to variable implementation in clinical practice.

Therefore, the purpose of this scoping review was to establish which NRV are used to report VO_{2peak} as %_{pred} in the CF literature and identify how many studies since the publication of the ECFS EWG statement used the recommended NRV.

METHOD

Search strategy

A multifaceted search strategy, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist,¹⁴ was used, with three components:

1. A search using the terms [(cystic fibrosis) AND (vo2* OR vo2max OR vo2peak)] was employed in the PubMed, Embase (Ovid MEDLINE, APA PsycInfo, Embase, HMC Health Management Information Consortium, Social Policy and Practice, Global Health, CAB Abstracts, APA PsycExtra), Web of Science (Science Citation Index Expanded [SCI-EXPANDED], Emerging Sources Citation Index [ESCI], Conference Proceedings Citation Index- Science [CPCI-S], Social Sciences Citation Index [SSCI]), SciELO, and EBSCO (The Allied and Complementary Medicine Database [AMED], Child Development & Adolescent Studies, CINAHL Complete, MEDLINE, SPORTDiscus) databases, from inception to December 2021. Articles were then screened using freely available specialist software (Covidence, Veritas Health Innovation, Melbourne, Australia).
2. Forward citation searches from two key papers in the CF and exercise literature. First, the ECFS EWG Statement from Hebestreit *et al*⁵—the only CF-specific exercise testing document to date—advocates for the aforementioned equations to report normative data. Second, the landmark study of Nixon *et al*¹⁵—the first to establish the association between VO_{2peak} as a per cent of predicted and mortality—thus becoming a cornerstone study in the field with hundreds of citations. Forward citations were obtained from Web of Science, from respective publication dates to December 2021, filtered to only include 'article' and 'early view' studies.
3. A manual search of PubMed, using the term [(cystic fibrosis) AND (exercise)], from inception to December 2021.

All searches and screening were undertaken by a single author (OT). Double-screening was not performed to increase the speed of conducting the scoping review.

Inclusion/exclusion criteria

Articles were included if they satisfied the following: (1) original investigation, (2) partial or complete inclusion of people with CF, (3) inclusion of VO_{2max} or VO_{2peak} data as a directly measured outcome, and (4) VO_{2max} or VO_{2peak} presented as %pred.

Studies were excluded if they were: (1) not original investigation (eg, review, protocol paper, conference abstract), (2) did not include people with CF, (3) did not include VO_{2max} or VO_{2peak} data (ie, only submaximal data), (4) VO_{2max} or VO_{2peak} not presented as a percentage of predicted (ie, only L/min, mL/kg/min). No exclusions were made based on language.

Data extraction

Once studies were screened, identified and selected, full texts were retrieved, and the following data related to the study extracted: study title and year of publication; participant sample (sample size, age, sex and the number of people with CF if part of a larger cohort); testing modality used for determination of VO_{2peak} ; NRV cited and year of publication. In studies that cited a further study for methodology (eg, 'this test was conducted as previously

described by (author)'), the original reference was traced and examined to determine the exact NRV used.

A list of the cited NRV studies was also compiled, with individual equations extracted from each study, alongside the derived population (sample size, age, sex) and the testing modality used to derive VO_{2peak} .

Quality assessment/risk of bias

This scoping review aimed to obtain descriptive data on NRV equations used within the literature base. Therefore, a formal risk of bias (RoB) was not applicable, and no such tool was available. However, a customised RoB approach was designed, verifying whether a study citing an NRV equation was doing so correctly.

This verification process included examining categories of sex, age, modality and date (two categories). Within this process, studies could be awarded 'yes', 'unknown' or 'no' status and be awarded +1, 0, or -1 points, respectively (ie, a study to correctly use all five categories would be awarded five points); akin to 'low', 'moderate' and 'high' RoB seen in traditional scoring models. A full explanation and examples of RoB are provided in online supplemental file 3.

A quasi-random sample of 10% of studies—identified using an online pseudo-randomisation programme (CalculatorSoup, <https://www.calculatorsoup.com>) was

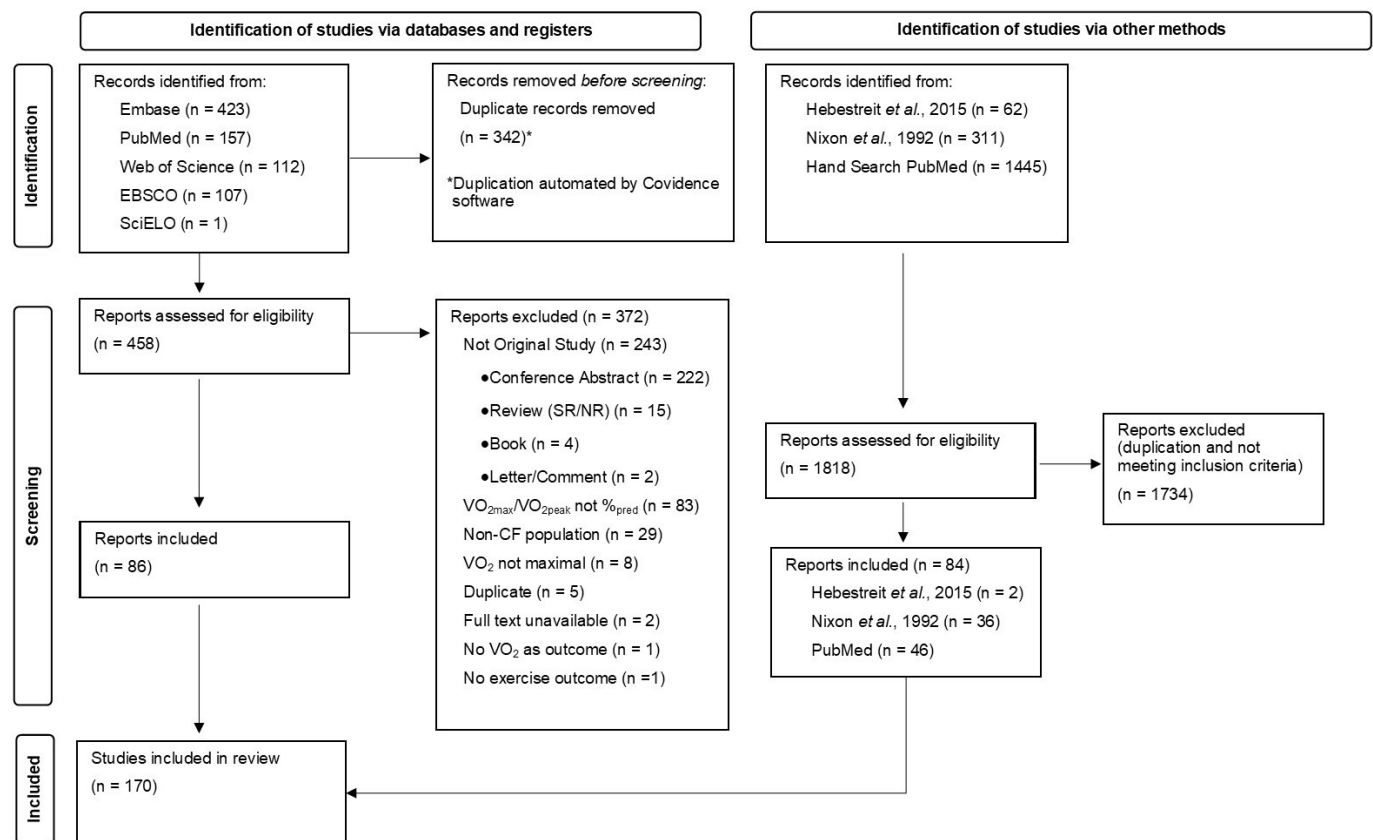


Figure 1 PRISMA flow chart detailing identification and inclusion of studies in scoping review. CF, cystic fibrosis; NR, narrative review; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; SR, systematic review; VO_2 , oxygen uptake; VO_{2max} , maximal oxygen uptake; VO_{2peak} , peak oxygen uptake.

Table 2 Normal reference values identified by scoping review and count of frequency of use

Normal reference value	Pre-EWG (n), 1984–2015	Post-EWG (n), 2016–2022	Total (n)
Binkhorst <i>et al</i> ²⁷	2	0	2
Binkhorst <i>et al</i> ⁴⁹	4	0	4
Bongers <i>et al</i> ⁵⁰	1	1	2
Bongers <i>et al</i> ²²	0	2	2
Cooper and Weiler-Ravell ⁵¹	1	1	2
Cooper <i>et al</i> ⁵²	1	1	2
Edvardsen <i>et al</i> ²⁴	0	3	3
Godfrey <i>et al</i> ⁶³	0	3	3
Hansen <i>et al</i> ²⁵	7	2	9
Jones and Campbell ⁵⁴	3	0	3
Jones <i>et al</i> ²⁶	6	6	12
Jones ⁵⁵	21	2	23
Orenstein ⁵⁶	3	0	3
Orenstein ²¹	8	12	20
Wasserman <i>et al</i> ⁵⁷	3	0	3
Wasserman <i>et al</i> ⁵⁸	1	3	4

Table only includes normal reference values to be cited more than once, with full list of values used in online supplemental file 2. Normal reference values recommended for use by ECFS EWG are bold and italicised. The EWG statement was published in 2015, and therefore studies from 2016 onwards are counted. ECFS EWG, European Cystic Fibrosis Society Exercise Working Group.

independently verified by a second author (CAWa). If any disputes arose, a third coauthor (CAWi) was consulted to resolve conflicts.

Statistical analysis

Analyses compromised absolute frequencies and percentages. Separate and combined analyses related to RoB were undertaken for studies to cite NRV and those that did not. Additional frequencies and percentages were undertaken to identify which NRV recommended by the ECFS EWG is used within the CF literature.

RESULTS

Included studies and study characteristics

Following searches and screening, a total of n=170 eligible studies were identified, with a PRISMA flow diagram¹⁴ provided in figure 1. A full list of studies, with individual characteristics, including sample, exercise modality and NRV used, is provided in online supplemental file 1.

The n=170 studies spanned from 1984 to 2022, covering a total sample of n=6831 people with CF (n=3555 males, n=2711 females, remainder unspecified). Of these studies, n=109 (64%) were published from 1984 to 2015, and n=61 (34%) were published from 2016 to 2022 (post-publication of the ECFS EWG statement). With regard to exercise modality, n=154 used cycle ergometry, n=15 used

treadmill ergometry, n=2 were of unknown modality and n=1 for each of 10m shuttle walk, arm ergometry, and quadriceps exercise, with n=4 studies using more than one modality.

Normal reference values

Of the n=170 studies, 61 (36%) provided no details on the NRV used to present VO_{2peak} data as a percentage of predicted, leaving n=109 studies (64%) to explicitly state which NRV were used. Within these studies, n=34 sets of NRV were used, dating from 1971 to 2019. The mean difference in time between a study and its cited NRV was 18±11 years (median=17 years, range=1–48 years).

Of the n=34 NRV cited, n=18 (53%) were only cited once. Moreover, of the NRV recommended by the ECFS EWG,⁵ these are cited a total of n=32 times (18% of 179 uses of NRV). Within this n=32, a total of n=18 (56%) of these citations were done so since the statement's publication. This n=18 also represented 30% of the n=61 studies published since the ECFS EWG statement. None of the NRV recommended for treadmill testing by the ECFS EWG were cited. The n=16 NRV to be cited more than once is provided in table 2.

Additional analyses for RoB are also performed based on this split of inclusion versus non-inclusion of NRV.

Quality assessment/RoB

From the total of n=170 studies identified, n=179 RoB analyses were performed because n=8 studies used more than one set of NRV. When considering all studies (n=170 studies, n=179 RoB analyses), 50% of studies used NRV that was of an appropriate derivation population for sex, 13% for age, and 18% for modality. Only 8% of studies used an NRV from within the prior 5 years, and 18% from within the prior 10 years. When only considering studies to stipulate the NRV used (n=109 studies, n=118 RoB analyses), 76% used NRV that were of an appropriate derivation population for sex, 20% for age, and 27% for modality. Only 13% used an NRV from the prior 5 years, and 28% from the prior 10 years. A full breakdown for each category RoB is provided in figure 2.

Scores ranged from -3, to +5, with 0 being the most common score (n=79) due to the high number of studies to not report NRV used. Otherwise, the most prevalent scores were -1 (n=42) and +1 (n=23). Only n=3 studies were awarded a score of +5 points, matching their cited NRV for age, sex, modality and time frame (≤5 and ≤10 years). A schematic detailing RoB scores and their prevalence are displayed in figure 3. The full RoB analyses are provided in online supplemental file 3.

DISCUSSION

For the first time, this scoping review has characterised the reference values and equations used to characterise VO_{2peak} as a 'per cent of predicted' in people with CF. Given the inherent value of VO_{2peak} in the clinical management of this disease, the main finding is that approximately one-third of studies do not report the NRV

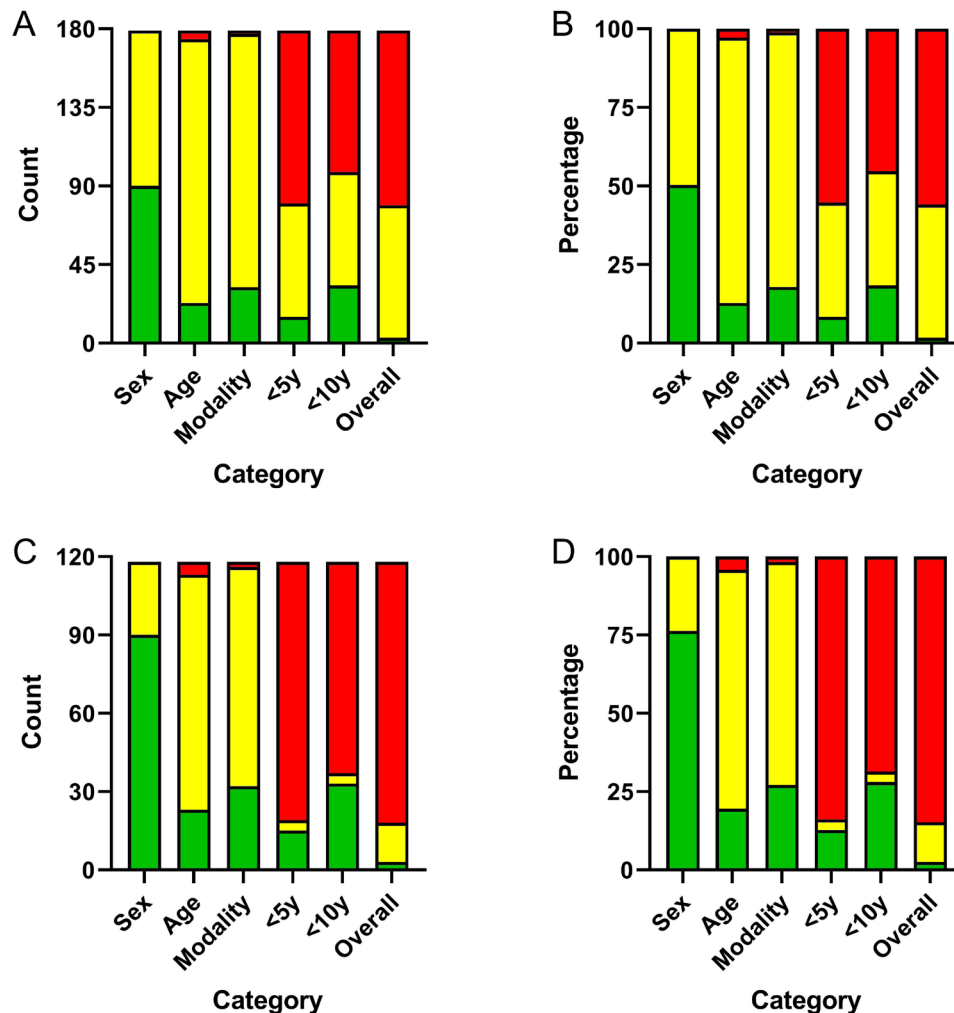


Figure 2 Risk of bias (RoB) assessment for included studies, presented as absolute counts and as percentages. (A) RoB for all studies and analyses, presented as absolute numbers; (B) RoB for all studies and analyses, presented as a percentage; (C) RoB for all studies and analyses to explicitly state NRV used (ie, excluding those who do not state NRV), presented as whole numbers; (D) RoB for all studies and analyses to explicitly state NRV used, presented as a percentage. Red=wrong details/high RoB; yellow=unclear details/moderate RoB; Green=correct details/low RoB. NRV, normal reference value.

used—and the wide range of NRV used (34 in total)—is a cause for concern.

Reporting of values

The lack of reporting in this one-third of studies is concerning, as this under-reporting introduces bias and can misrepresent the data.¹⁶ If, for example, a study consists of adult participants but uses an NRV designed for a paediatric population, this will likely result in inflation of results (ie, scoring better than anticipated) and thus can inadvertently manipulate the data. Without the reporting of the cited NRV, assurances that such practices do not occur cannot be guaranteed. Moreover, the unavailability of methodological details has been noted as a contributory factor to the current replication crisis facing the wider scientific community,¹⁷ and this scoping review found that the CF literature base is not immune from this problem.

Conversely, approximately two-thirds of studies (64%) did indeed provide data on the NRV used to describe

VO_{2peak} as a per cent of predicted, although only 32 studies used NRV suggested by the ECFS EWG. While this large proportion, declaring the NRV, could initially be considered an encouraging statistic, there is a notable range in the volume of NRV used, whereby 34 distinct sets of values are used, most are only used once. A lack of agreement on which NRV to use is reflected in recent survey work,¹³ whereby CF clinics in the UK present with wide variation in NRV used, and a lack of understanding on what constitutes the best set of values to use. There is equally a wide level of variation seen in the NRV recommended for use by leading medical organisations, and their documentation for how to perform CPET in a clinical scenario.^{5 18–20}

Quality of reporting

In addition to the wide range of NRV used, very few studies are using NRV that are recent, and have an appropriately matched derivation population (age, sex, modality and recency); reflected by only three studies in



Figure 3 Number of studies with each risk of bias (RoB) score. Figure details the possible combination of RoB scores (and number of total n=179 analyses with each score). Figure does not state explicit categories themselves (eg, sex, age), but the distribution of possible scores (Y/?/N). This is because equivalent scores can be obtained via multiple categories and methods (eg, a score of +3 can be obtained by four +1 scores and a -1 score, but also via three +1 scores and two 0 scores—all regardless of explicit category).

this review scoring a perfect five points for RoB, as indicated in figure 3. This finding does not mean that other studies are deficient in their respective study designs, as many are high-quality randomised control trials and cohort studies that are well designed and executed, nor that they are deliberately using inappropriate NRV. It will mean, however, that studies are citing NRV that are deficient in their own reporting, and the literature base itself is limited by the number of NRV that robustly report how data is generated. For example, one NRV recommended by the ECFS EWG is that of Orenstein²¹—being cited 20 times by studies in this review. However, on inspection of this work, no information is available on the characteristics of the derivation population and therefore, the studies that cite this work still cannot be assured that they are using an appropriate NRV for their own population—therefore being awarded few points for RoB in this scoping review.

There is notable heterogeneity in how NRV are derived, as shown by the equations in online supplemental file 2, whereby some studies solely use age to derive an NRV^{22–24}, whereas some will incorporate further variables such as height and weight^{5 26}, and further studies will use exercise-derived factors such as heart rate or time to exhaustion.^{27 28} This variance in how NRV are established can have notable impact on NRV selection, particularly if studies are not collating certain types of data, or NRV are not suitable for the population in question.

Implications for clinical practice

This discrepancy in the NRV used in clinical situations can have genuine adverse clinical impacts, as highlighted in a recent case report from Waterfall *et al.*²⁹ whereby a patient underwent exercise testing at two different

hospitals (who used two different sets of NRV) with a delay in medical treatment occurring as a result. In addition, use of multiple NRV can result in alternative interpretations of the same data, as shown by a paper within this review³⁰ who used two sets of NRV to reveal one statistically significant, and one non-significant, result for VO_{2peak} as per cent predicted, despite the underlying raw data being the same. Such manipulation of data is poor practice and has partially occurred by virtue of the number of NRV available. This case therefore indicates the drastic clinical consequences that can occur due to the lack of standardisation and use of differing NRV.

It should also be noted that this lack of consistency in reporting is not limited to VO_{2peak} , and therefore, variables for which NRV exist, such as work rate, heart rate, oxygen pulse, ventilation etc,^{11 12} are all equally likely to be affected by poor and inappropriate reporting as shown in the current work. Moreover, this is not a phenomenon wholly related to clinical groups. For example, interpretation of exercise responses in children can vary on choice of heart rate thresholds,³¹ and can impact on determination of a true VO_{2max} , or potentially submaximal response. For children with clinical considerations, this can have even further negative impacts.

To counter the negative findings within this scoping review—a lack of reporting, and wide variation in data to be reported—the wider exercise and clinical physiology community must take action. Several large NRV studies and databases exist,^{32–35} and therefore, pooling of data has been advocated for by leading organisations,^{18 36} to create a singular and comprehensive set of normative values. Therefore, a Task Force has been established by the European Respiratory Society (ERS; TF-2021–09),³⁷ in collaboration with the Global Lung Initiative (GLI), to create such a database for a range of CPET values, including VO_{2peak} . The GLI has previously created reference values for spirometry⁹ and enhanced interpretation of lung function in CF³⁸ and therefore it is anticipated that a similar, positive, outcome may be found with this new ERS Task Force.

In the interim, it is not clear which is the most appropriate method by which to present VO_{2peak} , not just for people with CF, but for all populations. As previously mentioned, use of absolute values (L/min) or values normalised to body mass (mL/kg/min) can be biased. Therefore, use of allometric scaling (which removes residual effects of body size) may be a viable option, although several scaling exponents are available,³⁹ and are specific to the measured population and have limited transferability. Therefore, until a solution is found, the authors recommend that clinical and research staff to use CPET should be as open with reporting VO_{2peak} as possible to avoid misinterpretation. This includes simultaneously providing data in (A) absolute values, (B) scaled relative to body mass, (C) allometrically scaled for the specific population, and (D) using %_{pred}, but only if an explicit equation provided, and not just a reference, as the data shown in online supplemental file 2 indicates

that a single reference can provide multiple equations, further compounding interpretation of data.

Strengths and limitations

There are several strengths and weaknesses to this scoping review to acknowledge. First, the wide remit for inclusion (ie, CF, and $\text{VO}_{2\text{peak}}$ as $\%_{\text{pred}}$) has led to a notably large number of studies being included, thus enhancing the confidence in the findings. Moreover, referencing the existing ECFS EWG as a source of existing NRV has ensured that this review maintains a high level of clinical relevance. In contrast, as no standardised method for RoB is available for such a scoping review, a customised approach was designed, which will inevitably be open to scrutiny. However, as clinical guidelines recommend that NRV used in studies should match population characteristics and CPET protocols,²⁰ the RoB approach used in this review is deemed an ecologically suitable approach and warrants replication in further clinical groups.

CONCLUSION

In summary, this scoping review has identified wide discrepancies in how $\text{VO}_{2\text{peak}}$ is reported as a 'per cent of predicted' within the CF literature base. A singular, comprehensive, dataset is required by the wider medical and exercise physiology communities, and it is anticipated that ongoing projects using enhanced reporting and collaborative integration of existing databases will address this gap in the near future.

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ORCID iD

Owen W Tomlinson <http://orcid.org/0000-0003-4063-7682>

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Supplemental File 1. List of studies included in analyses.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Hjeltnes et al., 1984 [1]	8M/0F	16.2 (?) 15.5-17.0	Cycle	Astrand & Rodahl, 1977	As exact equation is not known, suitability for sex, age and modality cannot be established.
Edlund et al., 1986 [2]	14M/9F	? 7.0-14.0	Treadmill	ACSM, 1980	As exact equation is not known, suitability for sex, age and modality cannot be established.
Marcotte et al., 1986a [3]	15M/7F	? 16.0-38.0	Cycle	Jones & Campbell, 1982	References provides options for children 8 and above, and adults 20 and above. Not clear how old an individual paediatric data is applicable to and therefore how 18-19 year olds are accounted for. Therefore, only a partial match for age-appropriate risk of bias.
Marcotte et al.,1986b [4]	40M/10F	20 (6) 11.0-38.0	Cycle	Jones & Campbell, 1982	References provides options for children 8 and above, and adults 20 and above. Not clear how old an individual paediatric data is applicable to and therefore how 18-19 year olds are accounted for. Therefore, only a partial match for age-appropriate risk of bias.
Stanghelle et al., 1986 [5]	5M/5F	11.5 (?) 11-12	Cycle	Hermansen, 1973	
Versteegh et al., 1986 [6]	12M/12F	16 (?) 10-22	Cycle	Unknown	Equation not stated in manuscript.
Browning et al., 1990 [7]	7M/4F	21 (1)* 17-29 *SE, not SD	Cycle	Jones & Campbell, 1982	References provides options for children 8 and above, and adults 20 and above. Not clear how old an individual paediatric data is applicable to and therefore how 18-19 year olds are accounted for (also assuming 17 year olds are treated as children). Therefore, only a partial match for age-appropriate risk of bias.
Versteegh et al., 1990 [8]	12M/12F	16 (?) 10-22	Cycle	Unknown	Equation not stated in manuscript.
Heijerman et al., 1991 [9]	8M/8F	28.7 (5.0) 21-40	Cycle	Jones et al., 1985	
Regnis et al., 1991 [10]	12M/10F	23 (1)* 18-33 *SEM, not SD	Cycle	Unknown	States Jones et al., 1985 (Am Rev Resp Dis, 131:700-708), is used for W _{max} , but not VO _{2max} . Whilst it may be assumed this reference would also be for VO _{2max} , it is not explicitly stated and is therefore listed as 'unknown'.
Heijerman et al., 1992 [11]	6M/4F	28.3 (5.7) 21-40	Cycle	Jones et al., 1985	
Nixon et al., 1992 [12]	57M/51F	17 (?) 7-35	Cycle	Orenstein, in press	<p>This is assumed to be the same reference as Orenstein (1993) as this is stated as ‘in press’ when the manuscript was published in 1992 and thus timelines would be appropriate.</p> <p>However, as this is an assumption and the reference cannot be verified, the agreement with regards to age, sex, and modality cannot be established.</p>

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Williams et al., 1992 [13]	1 (sex unknown)*	37.3 (6.7)* ? Wider sample of all DLTx patients. Age of pwCF unknown.	Cycle	Jones, 1988	<p>*Wider sample of n = 7 of various diseases (all undergoing DLTx).</p> <p>Paper states: "<i>Reference values were derived from Jones and Campbell (9) and Cotes (10)</i>".</p> <p>Cotes is a lung function reference, so authors have assumed exercise data is from Jones, even though it is not explicitly stated which variable was obtained from which reference.</p> <p>Exact equation used from Jones & Campbell (1988) is not known, but sex-specific equations are available. Age and modality of source equation not known from reference.</p>
Freeman et al., 1993 [14]	15M/7F	22.1 (5.1) 15-35	Cycle	Jones, 1988	Reference explicitly refers to pages 306-307 of Jones (1988), which is appendix with tables of equations.
Henke et al., 1993 [15]	19M/14F	23 (7) 12-39	Cycle	Unknown	Equation not stated in manuscript.
Kaplan et al., 1996 [16]	20M/15F	dF508/dF508:* 16.0 (7.3) ? dF508/-: 17.0 (8.7) ?	Cycle	Orenstein, 1993	<p>Age data split into two groups based upon dF508 status.</p> <p>The manuscript states "<i>This result was also normalised to predicted VO_{2max} according to the formula of Orenstein (27)</i>".</p> <p>However, reference #27 is Pate (1990, Endurance Exercise Trainability). Orenstein is actually reference #26.</p> <p>Despite discrepancy in referencing, as Orenstein is explicitly stated, this reference is carried forward for analysis. Although issues with Orenstein, 1993 mean that age and modality are unknown for risk of bias.</p>
Alison et al., 1997 [17]	18M/6F	26 (7.7) 17-44	Cycle	Jones et al., 1985	Only control group had data presented as % _{pred} .
Evans et al., 1997 [18]	0M/1F*	39 (x) (n/a) Wider sample: 49.7 (2.4) 39-57	Quadriceps exercise in MRI machine	Wasserman et al., 1987	<p>*Wider sample of n = 9 (4M/5F), all LTx recipients.</p> <p>Authors acknowledge use of cycle ergometry reference data as a study limitation, stating: "<i>Because there are no predicted VO_{2max} values for quadriceps exercise, the data were expressed as a percentage of predicted cycling VO_{2max} to decrease the confounding effects of age, sex, and height</i>".</p> <p>As several equations are available in Wasserman et al., 1987, it is unclear which is used and therefore age is given 'unknown' for risk of bias, but sex is appropriate as separate equations are given for males and females. Modality is acknowledged as being derived from cycle ergometry in the study, and can therefore be given a 'not appropriate' for risk of bias (despite authors acknowledgment above).</p>
Moorcroft et al., 1997a [19]	52M/35F	19.8 (x) 15-40	Cycle	Jones, 1988	
Moorcroft et al., 1997b [20]	19M/11F	19.8 (1.1)* 16-40	Cycle	Jones, 1988	<p>*Age data presented as Mean (SEM), not mean (SD).</p> <p>Data for n = 30, of a wider n = 92. The n = 30 represents a 're-tested' cohort of patients amongst wider pool. This is the only sub-group that sex data is available for.</p>

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Oelberg et al., 1988 [21]	7M/3F	26.9 (2.5) 18-41	Cycle	Hansen et al., 1984	DLTx cohort. Hansen et al., (1984) reference group is in men aged from 34-74 years, so only a partial match for sex and age for risk of bias.
Pellegrino et al., 1998 [22]	4 (sex unknown)*	? (?) ? Whole sample: 37 (11) ?	Cycle	Unknown	*Wider sample of n = 8 (5M/3F) patients, all are post-DLTx. Equation not stated in manuscript.
Tuzin et al., 1998 [23]	2M/1F*	11.3 (2.3) 10-14 Wider sample: * 9.4 (2.3) 7-14	Cycle	Unknown	*Wider sample of n = 10 (8M/2F). This manuscript reports three separate sets of studies, whereby only one incorporated fitness testing to obtain VO _{2max} (n = 3, 2M/1F). Equation not stated in manuscript.
Boas et al., 1999 [24]	25M/0F	11.6 (2.8) 7-18*	Cycle	Orenstein, 1991	*Age range for whole study sample, including patients with asthma, and control group. Orenstein (1993) states in preface: " <i>This book is a compilation of presentations made at the Standards for Pediatric Exercise Testing Workshop in October 1991 in Scottsdale, AZ</i> ". Therefore, as a 1991 book cannot be identified, it is assumed that the 1991and 1993 reference are the same (particularly as reference page numbers match), and thus the same issues associated with Orenstein (1993) are applicable.
Bradley et al., 1999 [25]	14M/6F	25 (7) ?	Treadmill	Unknown	Equation not stated in manuscript.
McKone et al., 1999 [26]	6M/3F	26.3 (8.3) ?	Cycle	Jones, 1988	Explicitly states equation used: VO _{2max} = 0.83 height ^{2.73} x (1 – 0.007 age) x (1 – 0.25 Sex)
Schwaiblmair et al., 1999 [27]	19* (sex unknown)	SLTx: 49.3 (10.6) ? DLTx: 30.7(9.9) ? HLTx: 28.7 (10.1) ?	Cycle	Wasserman et al., 1994	*Wider sample of n = 103 pts, all recipients of LTx or HLTx. The stated sample of n = 19 for pwCF is a minimum. 23% of 78 LTx patients have CF, equalling n = 18. 4% of 25 HLTx patients have CF, equalling n = 1. There are additional patients with congenital CF within a sample of 14% of 'miscellaneous' LTx patients, but exact number is not known. Reference states pages 1-97 of Wasserman et al., (1994). However, page 97 finishes in middle of chapter on 'protocols for exercise testing', with no reference to any normative equations. In other textbooks from Wasserman, the chapter on 'normal values' covers normative equations. As it is unclear where (and which) the reference equation is from, all sections are unknown with regards to risk of bias.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Boas et al., 2000a [28]	7M/8F	13.4 (?) 8-21	Cycle	Orenstein, 1991	<p>Orenstein (1993) states in preface: "<i>This book is a compilation of presentations made at the Standards for Pediatric Exercise Testing Workshop in October 1991 in Scottsdale, AZ</i>".</p> <p>Therefore, as a 1991 book cannot be identified, it is assumed that the 1991and 1993 reference are the same (particularly as reference page numbers match), and thus the same issues associated with Orenstein (1993) are applicable.</p>
Boas et al., 2000b [29]	6M/6F	12.0 (?) 8-17	Cycle	Orenstein, 1991	<p>This manuscript doesn't state the equation used in the methodology but does in results section.</p> <p>Orenstein (1993) states in preface: "<i>This book is a compilation of presentations made at the Standards for Pediatric Exercise Testing Workshop in October 1991 in Scottsdale, AZ</i>".</p> <p>Therefore, as a 1991 book cannot be identified, it is assumed that the 1991and 1993 reference are the same (particularly as reference page numbers match), and thus the same issues associated with Orenstein (1993) are applicable.</p>
Fink et al., 2000 [30]	1M/0F	28 (x) (n/a)	Unknown	Unknown	Equation not stated in manuscript.
Moser et al., 2000 [31]	8M/14F	10.3 (0.7) 6-18	Cycle	Own Reference Data (unpublished)	<p>Reference equation not provided.</p> <p>The exact statement from the manuscript reads: "<i>Exercise data from 54 healthy children (37 females and 17 males) who had been recently tested under the supervision of one of the authors (D.M.C.) were used to establish normal values for gas exchange responses to exercise</i>".</p> <p>Therefore, as both sexes were included in this reference data, it can be assumed that sex-appropriate data is used for risk of bias purposes. Age can be assumed for risk of bias as it is stated to be derived from children, but the exact age range is not known. Modality data is not known for risk of bias purposes.</p>
Frangolias & Wilcox, 2001 [32]	32M/38F	27.3 (8.7) 17-53	Cycle	Jones, 1988	<p>Explicitly states equation used: $VO_{2max} = 3.20 \text{ height} - 0.024 \text{ age} + 0.019 \text{ weight} - 0.49 \text{ sex} - 3.17$</p> <p>Manuscript explicitly states page 306 of Jones (1988), which directs to Appendix D with aforementioned equation.</p>
Karila et al., 2001 [33]	6 (sex unknown)*	? (?) ? Wider sample: 12 (3.04) 5-17	Cycle/Tread mill	Wasserman et al., 1994	<p>*Wider sample of n = 92 (56M/36F) consisted of multiple conditions, including asthma, spasmodic cough, congenital heart disease, bronchopulmonary dysplasia, and interstitial lung disease, amongst others.</p> <p>Choice of modality was stature dependent, with a minimum stature of 125 cm for cycle ergometry. Total cycle n = 55, treadmill n = 37.</p> <p>Purpose of study was to assess feasibility of implementing individualised workloads, hence difference in modalities.</p>
Pouliou et al., 2001 [34]	9M/9F	24 (13) 14-61	Cycle	Unknown	Equation not stated in manuscript.
Blau et al., 2002 [35]	6M/7F	16 (4) 9-25	Cycle	Unknown	Cites Wasserman et al., (1987) for exercise protocol, but gives no further details on reference equations used for outcome measures.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Hutler et al., 2002 [36]	7M/3F	12.1 (1.7) 9.7-14.3	Cycle	1. Rowland, 1996 2. Orenstein, 1993	1. Rowland reference used for sex & age predicted values. 2. Orenstein reference used for sex & height predicted values. Use of two different equation produces different % _{pred} values within this study, and therefore this ends up with one significant result, and one non-significant result, after an intervention (Table 5, Hutler 2002).
McKone et al., 2002 [37]	7M/1F	26 (1) ?	Cycle	Wasserman et al., 1999	Explicitly states equation used: $VO_{2max} = 0.83 \text{ height}^{2.73} \times (1 - 0.007 \text{ age}) \times (1 - 0.25 \text{ Sex})$ This is the equation from Jones (1988) and would follow with the group of McKone et al., using this in other work within this review. However, the citation is for #28 (Wasserman et al., 1999), and Jones is #27. It is assumed that this is likely a mistake in citations, but all items are given 'unknown' status for purposes of risk of bias, apart from sex, as this is explicitly built into equation given.
Thin et al., 2002 [38]	23M/7F*	Mild CF: 24.3 (6.0) ? Moderate CF: 23.2 (5.5) ? Severe CF: 25.3 (3.2) ?	Cycle	Wasserman et al., 1994	*n = 36 originally recruited, but only n = 30 analysed due to exclusions (e.g., non-identification of gas exchange threshold). Cited chapter is on 'Normal Values'.
Frangolias et al., 2003a [39]	44M/24F	Normal: 27.0 (1.6) ? Osteopenic: 30.6 (1.1) ? Osteoporotic: 37.5 (4.0) ?	Cycle	Jones, 1988	Sample split into 3 groups based upon bone mineral density z-score. Cites Frangolias & Wilcox (2001), which used Jones (1988).
Frangolias et al., 2003b [40]	46M/27F	29.6 (1.0) ?	Cycle	Jones, 1988	Cites Frangolias & Wilcox (2001), which used Jones (1988).

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Klijn et al., 2003a [41]	65 (sex unknown)	10.5 (2.9) 4-18	Cycle & Treadmill	Binkhorst et al., 1986	<12 years = Treadmill ≥ 12 years = Cycle ergometry Manuscript acknowledges modality difference, stating: “ <i>VO_{2peak} as a percentage of predicted (VO_{2peak}%) values were obtained from an age- and gender-matched Dutch reference population, which used the same modes of exercise</i> ”. Source data is conducted in 6-18 year olds, whereas the citing study is in 4-18 year olds, so age is only partially appropriate for risk of bias.
Klijn et al., 2003b [42]	39 (sex unknown)	13.2 (1.8) 9-17	Cycle	Binkhorst et al., 1992	Source data is conducted in 12-14 and 16-18 year olds, whereas the citing study is in 9-17 year olds, so age is only partially appropriate for risk of bias.
Sexauer et al., 2003 [43]	24M/16F	VL: 29 (1.3) 19-42 NVL: 29 (1.2) 19-39	Cycle	Jones, 1988	2 groups based upon presence of ventilatory limitation (VL) or no ventilatory limitation (NVL).
Klijn et al., 2004 [44]	20 (sex unknown)	Training: 13.6 (1.3) Control: 14.2 (2.1) *Whole Group Range: 9-18	Cycle	Binkhorst et al., 1986	Cohort split into two groups – training and control. Mean (± SD) age given for both groups, but age range only given for entire cohort. Source data for cycle ergometry is conducted in 12-18 year olds, whereas the citing study is in 9-18 year olds, so age is only partially appropriate for risk of bias
Moorcroft et al., [45]	48 (sex unknown)	Training: 23.5 (6.4) ? Control: 23.6 (5.5) ?	Cycle & Arm	Jones, 1988	Participants underwent both maximal cycle ergometry and arm ergometry exercise tests. Despite VO _{2peak} (% _{pred}) being stated in methodology, no results are presented. Modality can only be listed as ‘partial’ due to lack of data for arm ergometry, as Jones (1988) is assumed to be cycle ergometry.
Pinet et al., 2004 [46]	8M/4F	33.8 (8.6)	Cycle	Hansen et al., 1984	Source data from Hansen et al., (1984) is conducted in males only, and in 34-74 year olds. Therefore, both sex and age can only be given a ‘partial’ match for risk of bias.
Dodd et al., 2005 [47]	7M/1F	24 (7) ?	Cycle	Jones, 1988	Explicitly states equation used: VO _{2max} = 0.83 height ^{2.73} x (1 – 0.007 age) x (1 – 0.25 Sex) Page range for Jones (1988) cited in reference list includes the appendices.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Fournier et al., 2005 [48]	7M/8F	30.1 (12.5) ?	Cycle	Unknown	Equation not stated in manuscript.
Hebestreit et al., 2005 [49]	11M/7F	15.8 (6.1) 9.8-33.8	Cycle	Orenstein, 1993	
McKone et al., [50]	15* Study 1: 6M/3F Study 2: 7M/2F	Study 1: 26.7 (3.1) ? Study 2: 23.7 (1.5) ?	Cycle	Jones, 1988	*Two studies were run in one paper, with overlap of participants between studies, so an exact breakdown of sex cannot be determined. Explicitly states equation used: $VO_{2max} = 0.83 \text{ height}^{2.73} \times (1 - 0.007 \text{ age}) \times (1 - 0.25 \text{ Sex})$
Moorcroft et al., 2005 [51]	63M/41F	24.6 (7.1) 16-49	Cycle	Jones, 1988	
Dodd et al., 2006a [52]	3M/4F	23 (4.1) 19-30	Cycle	Jones, 1988	Explicitly states equation used: $VO_{2max} = 0.83 \text{ height}^{2.73} \times (1 - 0.007 \text{ age}) \times (1 - 0.25 \text{ Sex})$
Dodd et al., 2006b [53]	13M/9F	22 (5.9) 17-41	Cycle	Jones, 1988	Explicitly states equation used: $VO_{2max} = 0.83 \text{ height}^{2.73} \times (1 - 0.007 \text{ age}) \times (1 - 0.25 \text{ Sex})$
Hebestreit et al., 2006 [54]	35M/36F	20.5 (6.0) 12.2-40.0	Cycle	Orenstein, 1993	
Reinsma et al., 2006 [55]	2M/3F*	31.4 (8.8)** 17-38**	Cycle	Wasserman et al., 2001	*Wider sample of LTx pts = 17M/8F. **Age data for pwCF only. Wider sample = 43 (10), 17-56. All pwCF are DLTx recipients. This study cites Wasserman et al., (2001), yet it appears that a 2001 version of this textbook does not exist. The 3 rd edition (1999) and 4 th edition (2004) are referenced by other studies in this analysis, yet this is the only to mention a copy from 2001. An edition is not provided by the authors in their reference list, and so the exact copy cannot be identified. As the reference cannot be explicitly identified, everything is given 'unknown' status for risk of bias.
Barry & Gallagher, 2007 [56]	7M/8F	25.5 (8.6) ?	Cycle	Jones, 1988	Description of experimental procedures refers to McKone et al., (1999), who utilised Jones (1988). However, no further referencing is made for outcomes measures (i.e., VO_{2max}).
Barry et al., 2008 [57]	15M/0F	23.9 (?) 19-40	Cycle	Jones, 1988	Explicitly states equation used: $VO_{2max} = 0.83 \text{ height}^{2.73} \times (1 - 0.007 \text{ age})$ No sex offset included, as only male participants involved.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Dodd et al., 2008 [58]	25 (sex unknown)*	25.5 (?) 17-52	Cycle	Jones, 1988	<p>*Wider sample of n = 169 (94M/75F), age 27.3 (10.4), 16-52 years, with a sub-sample of n = 25 chosen at random to also undergo CPET for study.</p> <p>Explicitly states equation used: $VO_{2max} = 0.83 \text{ height}^{2.73} \times (1 - 0.007 \text{ age}) \times (1 - 0.25 \text{ Sex})$</p> <p>Page range for Jones (1988) cited in reference list includes the appendices.</p>
Hubert et al., 2009 [59]	23M/11F	19 (?) 15-25	Cycle	Wasserman et al., 2005	Cited chapter is on 'Normal Values', although unclear which is used.
Ruf & Hebestreit, 2009 [60]	39M/36F	Female: 19.8 (6.9) ? Male: 21.8 (6.9) ? *Whole Group Range: 12-41	Cycle	Orenstein, 1993	
Troosters et al., 2009 [61]	35M/29F	Female: 27 (9) ? Male: 25 (6) ?	Cycle	Jones, 1988	
Zavorsky et al., 2009 [62]	3M/9F	9.8 (2.0) ?	Cycle	Cooper & Weiler-Ravell, 1984	
Groen et al., 2010 [63]	8M/5F	15.8 (1.8) ?	Cycle	Binkhorst et al., 1992	<p>Source data is conducted in 12-14 and 16-18 year olds, whereas the citing study has a mean of 15.8 (±1.8) years, so any 15 years olds will not be accounted for and therefore age is only partially appropriate for risk of bias.</p> <p>Study also cites Takken et al., (2007, Int J Sports Med, 28, 580 – 584), which in turn cites Binkhorst et al., 1992. Reason for additional citation unclear.</p>
Gruet et al., 2010 [64]	25M/6F	29.6 (6.0) ?	Cycle	Unknown	Equation not stated in manuscript.
McBride et al., 2010 [65]	33M/31F	9.3 (0.9) ?	Cycle	Cooper et al., 1984	

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Nguyen et al., 2010 [66]	21M/30F	30.2 (?) 16-67	Cycle	ATS/ACCP, 2003	<p>Unclear from paper which equation was used. As issues exist regarding sex-appropriateness of Hansen et al., 1984, a ‘partial’ can only be given for risk of bias.</p> <p>In addition, age can only be ‘unknown’ status as it may be appropriate if Jones et al., (1985) were used, but not if Hansen et al., (1984) were used.</p> <p>Modality can be assumed as both Jones et al., (1985) and Hansen et al., (1984) used cycle ergometry.</p> <p>As ATS/ACCP document itself is the article cited, <5 years is awarded a ‘yes’ (as it is unclear which underlying equation was used to counter this).</p>
Bartels et al., 2011 [67]	35 (sex unknown)*	?(?) ? *Wider sample: 51 (14) ?	Cycle	Unknown	<p>*Wider sample of n= 153 LTx patients (78M/75F), although CF breakdown not known.</p> <p>CF group is a combined CF & Bronchiectasis sample.</p> <p>Equation not stated in manuscript. Study cites ATS/ACCP 2003 for CPET termination criteria, but not reference data.</p>
Dwyer et al., 2011 [68]	10M/4F	27 (7) 18-44	Cycle & Treadmill	1: Jones et al., 1985 (Cycle) 2: Drinkwater et al., 1975 (Treadmill) 3. Froelicher et al., 1974 (Treadmill)	<p>Crossover trial examining effect of different modalities upon sputum expectoration, hence different equations for different modalities.</p> <p>Treadmill data references are sex-specific, hence why two sets of treadmill values given.</p> <p>Data from Froelicher et al., (1974) is in males aged 20-53, so any males aged <20 years will not match equation. As it is not known from manuscript if, and how many, males were <20 years, age can only be given a ‘partial’ match for risk of bias.</p>
Gruber et al., 2011 [69]	186M/158F	Female: 19.9 (8.1) ? Male: 22.0 (7.5) ? Whole Group Range: 7-43	Cycle	Orenstein, 1993	
Hulzebos et al., 2011 [70]	0M/1F	16 (x) n/a	Cycle	Unknown	Equation not stated in manuscript.
Leroy et al., 2011 [71]	4M/14F	32 (12.6) 20-67	Cycle	ERS, 1997	<p>Unknown which exact equations used. As ERS cites several studies, including Hansen et al., (1984) [males only, aged 34-74 years] and Blackie et al., (1989) [aged >55 years only], both sex and age can only be given ‘partial’ appropriateness for risk of bias.</p> <p>All studies cited by ERS used cycle ergometry, so this can be awarded an appropriate match for risk of bias.</p>

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Tejero Garcia et al., 2011 [72]	23M/27F	Female: 23.5 (19.5-27)* ? Male: 25 (19-30)* ?	Cycle	Unknown	* Age data presented as median (IQR). Equation not stated in manuscript.
Traylor et al., 2011 [73]	13M/5F*	23 (7) ?	Cycle	Unknown	*Total n = 18, with Table 2 stating 26% are female. However, 26% of 18 = 4.68, and therefore n = 5 female (and consequently n = 13 male) is assumed. Equation not stated in manuscript.
Vallier et al., 2011 [74]	11M/0F	26.8 (6.9) ?	Cycle	Jones, 1988	Explicitly states equation used: $VO_{2max} = 0.83 \text{ height}^{2.73} \times (1 - 0.007 \text{ age}) \times (1 - 0.25 \text{ Sex})$
Vivodtzev et al., 2011 [75]	4M/0F*	36.5 (10.5)* 20-49 *Wider sample: 47 (13) 20-70	Cycle	Unknown	*Wider population of n = 12 (10M/2F), a mixture of SLTx, DLTx and HLTx recipients. All pwCF were DLTx. Equation not stated in manuscript.
Werkman et al., 2011 [76]	69M/50F	13.8 (1.7) 12-18	Cycle	1: Gulmans et al., 1997 2: Saris et al., 1985	Unclear which equation is referenced for VO ₂ , and which is W _{peak} , as the manuscript states: " <i>Reference values for VO_{2peak} and W_{peak} from healthy children and adolescents were obtained from previously studied Dutch children and adolescents (23,24)</i> ". Reference #23 = Gulmans, et al., (1997) Reference #24 = Saris et al., (1985) Therefore, this statement would imply that VO _{2peak} is from Gulmans et al., but no VO ₂ data or any equation is in Gulmans et al., (only W _{max}). In addition, Saris et al., does not appear to have any equations to actually use. Therefore, both sets of equations given ‘unknown’ status for risk of bias purposes.
Wheatley et al., 2011 [77]	12M/5F	23 (8) ?	Cycle	Hansen et al., 1984	Age range of group is assumed to be 15-31 (± 1SD from mean). Therefore, age is not appropriate for risk of bias. Sex is only partially appropriate as original data is in males only.
Armstrong et al., 2012 [78]	46 (sex unknown)	? (?) ? *Wider sample: 58 (?) 38-63	Cycle	Jones et al., 1985	*Wider sample of n = 183 (50% female), all LTx recipients. Within sample, n = 46 had CF/bronchiectasis.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Bongers et al., 2012 [79]	13M/9F	15.7 (1.5) 11.8-18.7	Cycle	Ten Harkel et al., 2011	As reference data is for males only, sex can only be given 'partial' for risk of bias purposes.
Manika et al., 2012 [80]	11M/6F	23.9 (3.5) ?	Cycle	Unknown	Equation not stated in manuscript.
Nguyen et al., 2012 [81]	10M/2F	14.7 (2.3) 11.3-17.5	Cycle	Unknown	Manuscript states: " <i>Percent predicted of VO2peak was calculated using reference data obtained from our laboratory</i> ". Therefore, as sex, age and modality cannot be identified, all criteria are given 'unknown' for risk of bias purposes.
Ruf et al., 2012 [82]	18M/23F	Female: 17.4 (6.4) ? Male: 15.9 (4.5) ? Whole Group Range: 12-42	Cycle	Orenstein, 1993	
van de Weert-van Leeuwen et al., 2012 [83]	85M/64F	13.29 (1.24) 12-18	Cycle	Binkhorst et al., 1992	
Armstrong et al., 2013 [84]	27 (sex unknown)*	CF not known. Wider sample (survivors): 56 (?) ? Wider sample (non-survivors): 59 (?) ? Whole group range: 41-64	Unknown	Unknown	*Wider sample of n = 135 (82M/53F), all LTx recipients, split into survivors vs. non-survivors (1 year after surgery). 27/135 were pwCF. Equation not stated in manuscript.
Ledger et al., 2013 [85]	4M/12F	10.9 (2.93) 4-15	Cycle	Unknown	Equation not stated in manuscript.
Moco et al., 2013 [86]	12M/9F	25.5 (6.0) ?	Treadmill	Neder et al., 1999	
Poore et al., 2013 [87]	5M/10F	12.6 (3.4) 7-18	Cycle	Unknown	Equation not stated in manuscript.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Prevotat et al., 2013 [88]	14M/16F	27.1 (8.4) 18-49	10m Shuttle (15 Levels)	Unknown	Equation not stated in manuscript. Within the study, VO _{2max} is predicted from the shuttle test, citing Selvadurai et al., 2003, Ped Pulm, 35, 133-138, who in turn cite Leger et al., 1988, J Sport Sci, 6, 93-101.
Savi et al., 2013 [89]	15M/5F	33 (8) ?	Cycle	Unknown	Equation not stated in manuscript.
Sovtic et al., 2013 [90]	18M/19F	11.98 (3.04) 8-17	Cycle	Unknown	Equation not stated in manuscript.
Vivodtzev et al., 2013 [91]	9M/5F	Intervention:* 28 (6) ? Control:* 32 (11) ?	Cycle	Unknown	*Participants split into two groups: intervention and control. Age mean (SD) only available for individual groups. Equation not stated in manuscript.
Barry & Horsley, 2014 [92]	1M/0F	20 (x) n/a	Cycle	Unknown	Equation not stated in manuscript.
Brun et al., 2014 [93]	1M/0F	19 (x) n/a	Cycle	Unknown	Equation not stated in manuscript.
Cohen & Orenstein, 2014 [94]	15M/9F	12.8 (?) 8-19	Treadmill	Unknown	Equation not stated in manuscript.
Hebestreit et al., 2014 [95]	39M/37F	20.6 (5.8) ?	Cycle	Orenstein, 1993	
Hulzebos et al., 2014 [96]	70M/57F	12.7 (0.9) 11-14	Cycle	Ten Harkel & Takken, 2011	All categories are technically appropriate for risk of bias, but equation for females is limited to a singular value and therefore confidence in results is unclear.
Pastre et al., 2014 [97]	53M/49F	28 (11) 17-67	Cycle	Hansen et al., 1984	
van de Weert-van Leeuwen et al., 2014 [98]	13 (sex unknown)	? (?) 12-18	Cycle	Binkhorst et al., 1992	
Armstrong et al., 2015 [99]	14 (sex unknown)*	*Wider sample: 57 (?) 40-62	Cycle	Unknown	*Wider sample of n = 54 LTx recipients. A total of n = 14 had CF/Bronchiectasis.
Bongers et al., 2015 [100]	17M/23F	14.7 (1.7) 11-18	Cycle	Bongers et al., 2012	Bongers et al., 2012 utilises boys and girls, of appropriate age, using cycle ergometry, and would therefore normally be appropriate for risk of bias. However, no explicit equations are given in this edition of the book (they are provided in Bongers et al., 2014), and therefore as the exact method for deriving %pred for VO2max is unknown, this must be given 'unknown' for risk of bias purposes.
Erickson et al., 2015 [101]	6M/7F	20.2 (11.2) 7-42	Cycle	Unknown	Equation not stated in manuscript.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Fielding et al., 2015 [102]	6M/10F	13.1 (3.9) ?	Cycle	Unknown	Equation not stated in manuscript.
Quon et al., 2015 [103]	12M/7F	30 (9) ?	Cycle	Jones, 1988	
Savi et al., 2015 [104]	20M/10F	33 (9) ?	Cycle	Jones et al., 1985	
Stevens et al., 2015 [105]	9M/10F	13.4 (3.2) ?	Cycle	Unknown	Equation not stated in manuscript.
Van Iterson et al., 2015 [106]	13M/5F	22 (2) ?	Cycle	Hansen et al., 1984	
Visschers et al., 2015 [107]	6M/9F	9.59 (3.33) 5.0-15.6	Cycle	Unknown	Equation not stated in manuscript.
Wheatley et al., 2015a [108]	12M/2F	22 (8) ?	Cycle	Hansen et al., 1984	
Wheatley et al., 2015b [109]	12M/2F	22 (8) ?	Cycle	Hansen et al., 1984	Does not explicitly state Hansen et al., 1983, but does cite the other reference from Wheatley et al., 2015 [above, 2015a], who in turn cite Hansen et al., 1984.
Avramidou et al., 2016 [110]	13 (sex unknown)	14.09 (5.16) ?	Cycle	Orenstein, 1993	
Gruet et al., 2016a [111]	12M/3F	28 (6) ?	Cycle	Jones, 1988	References Jones, 1988 in supplemental file, but not main text.
Gruet et al., 2016b [112]	17M/8F	30 (9) 18-45	Cycle	Unknown	Manuscript states further information is in supplemental file, but file cannot be found on journal web page, so ‘unknown’ status must be given for risk of bias.
Hatziagorou et al., 2016 [113]	10M/18F	14.9 (4.0) ?	Cycle	Orenstein, 1993	
Radtke et al., 2016 [114]	6M/8F	30.4 (6.1) ?	Cycle	Godfrey et al., 1971	States that Godfrey et al., 1971 is used, but equations are only present for incremental W _{max} , not VO _{2max} , so it is not clear how %pred values were obtained and is therefore given ‘unknown’ status for risk of bias.
Rodriguez-Miguel ­ ez et al., 2016 [115]	7M/9F	22 (9) 13-43	Cycle	Unknown	Equation not stated in manuscript.
Tomlinson et al., 2016 [116]	0M/1F	11 (x) n/a	Cycle	Bongers et al., 2014	
Vallier et al., 2016 [117]	17M/3F	32.6 (8.3) ?	Cycle	Unknown	Equation not stated in manuscript.
Van Iterson et al., 2016a [118]	12M/4F	23 (4) ?	Cycle	Hansen et al., 1984	
Van Iterson et al., 2016b [119]	13M/4F	23 (2) ?	Cycle	Unknown	Equation not stated in manuscript.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Decorte et al., 2017 [120]	12M/3F	28.1 (6.2) ?	Cycle	Jones, 1988	Paper does not cite Jones (1988) explicitly, but cites Gruet et al., (2016, J Cyst Fib, 15, e1-e8) as this is the same data. Gruet et al., 2016, in turn cites Jones (1988).
Dwyer et al., 2017 [121]	15M/9F	30 (8) 19-48	Treadmill	Unknown	Equation not stated in manuscript.
Edvardsen et al., 2017 [122]	21M/11F*	34.2 (11.81) ?	Treadmill	Unknown	*Only n = 14 underwent CPET. Equation not stated in manuscript.
Layton et al., 2017 [123]	7 (sex unknown)	?(?) ? *Wider sample: 57 (11) ?	Cycle	Unknown	*Wider sample of n= 68 (33M/35F), all LTx recipients. Equation not stated in manuscript.
Radtke et al., 2017 [124]	6M/8F	29 (25.5-36.0)*	Cycle	1.Godfrey et al., 1971 2.Orenstein, 1993	*Age data given as median (IQR). Manuscript states: “ <i>Data for VO_{2peak} and Watt_{max} are presented as % predicted values [22,23]</i> ”. Ref #22 = Godfrey et al., 1971 Ref #23 = Orenstein, 1993 Therefore, it could be assumed that VO _{2peak} is solely from Godfrey et al., (1971), but this is not completely clear, so both references are carried forward for risk of bias.
Tucker et al., 2017 [125]	17M/16F	19 (9) 9-43	Cycle	Unknown	Manuscript references ECFS Exercise Working Group Statement (Hebestreit et al., 2015, Respiration, 90, 332-351), although does not explicitly state which equation is used.
Vandekerckhove et al., 2017 [126]	24M/23F	12.3 (2.4) 7-17	Cycle	Wasserman et al., 2012	
Weir et al., 2017 [127]	17M/21F	11.0 (2.39) 7.3-15.7	Cycle	Cooper et al., 1984	Study cites Cooper et al., (1984, Pediatr Res, 18, 845-851). However, this study only provides equations for O ₂ pulse and therefor given ‘unknown’ status for risk of bias purposes.
Avramidou et al., 2018 [128]	45M/52F	14.9 (4.6) ?	Cycle	Orenstein, 1993	

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Causer et al., 2018 [129]	30M/15F	Adults: 31.3 (12.1) ? Children: 12.9 (2.6) ? Whole Group Range: 9.2-62.9	Cycle	Orenstein, 1993	
Chelabi et al., 2018 [130]	12 (sex unknown)	Normal LCI: 13.5 (2.6) ? Elevated LCI: 14.0 (1.8) ?	Cycle	Jones et al., 1985	Participants split into two groups based upon Lung Clearance Index (LCI). Cites Soumange et al., 2016, Thorax, 71, 804-811, who in turn cites Jones et al., 1985. Population in Jones et al., 1985, starts at 15 years of age, so only some participants will be age-appropriate in this study for risk of bias purposes.
Chen et al., 2018 [131]	10 (sex unknown)	? (?) 8-20	Cycle	Unknown	Manuscript states: “Percent predicted peak VO ₂ was calculated based on Medgraphics pediatric norms”.
Foster et al., 2018 [132]	39M/44F	14.4 (3.2) ?	Cycle	1. Orenstein, 1993 (<18 years) 2.Jones et al., 1985 (≥18 years)	Different equations used dependent upon age.
Gruet et al., 2018 [133]	23M/12F	31 (9) ?	Cycle	Jones et al., 1985	
Puppo et al., 2018 [134]	13M/8F	8.8 (2.0) ?	Cycle	Cooper & Weiler-Ravell, 1984	
Radtke et al., 2018 [135]	396M/330F	16.4 (13.0-22.1)*	Cycle	1.Orenstein, 1993 2.Jones et al., 1985	*Age data given as median (IQR). No indication given for why two different reference equations given.
Savi et al., 2018 [136]	23M/11F	33.1 (8.5) ?	Cycle	Jones et al., 1985	

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Stevens, 2018 [137]	68M/39F	SH: * 30.8 (9.8) ? No SH: 29.5 (9.3) ?	Cycle	Wasserman et al., 2005	*Participants split into two groups, based upon presence of static hyperinflation (SH) (n = 61), or no SH (n = 46). Static hyperinflation defined as RV/TLC ≥30%.
Stevens & Neyedli, 2018 [138]	58M/30F	30.4 (9.4) 18-54	Cycle	Wasserman et al., 2005	
Tomlinson et al., 2018 [139]	21M/15F	13.4 (2.7) ?	Cycle	Bongers et al., 2014	
Tucker et al., 2018 [140]	6M/8F	14 (3) 8-20	Cycle	Unknown	Equation not stated in manuscript.
Bar-Yoseph et al., 2019 [141]	31M/18F	19.7 (9.7) ?	Cycle	Unknown	Equation not stated in manuscript.
Di Paolo et al., 2019 [142]	45M/27F	Group 1: 27.5 (24-32.5) ? Group 2: 30 (27-34) ? Group 3: 29 (25-34) ?	Cycle	Unknown	*Age data presented as median (IQR). Participants split into three groups based upon pulmonary function. Group 1: ‘Normal’ lung function; FEV ₁ /FVC ≥ 0.7, and FEV ₁ ≥ 80% predicted value, and FVC ≥ 80% predicted value; n = 14. Group 2: ‘Mild Impairment’ in lung function; not satisfying criteria for G1 and FEV ₁ ≥ 70% predicted value; n = 23. Group 3: ‘Moderate Impairment’ in lung function; not satisfying criteria for G1 and 40% ≤ FEV ₁ < 70% predicted value; n = 35. Equation not stated in manuscript.
Dwyer et al., 2019 [143]	10M/5F	27 (9) 18-48	Treadmill	Unknown	Equation not stated in manuscript.
Hebestreit et al., 2019 [144]	249M/184F	16.6 (6.1) 10.0-44.5	Cycle	1.Godfrey et al, 1971 2.Orenstein, 1993	Manuscript states: “Data from lung function testing and CPET were converted to %predicted (11–13)”. Ref #11 = Godfrey et al., 1971. Ref #12 = Orenstein, 1993 Ref #13 = Quanjer et al., 2012. As this latter reference from Quanjer et al., (2012, Eur Resp J, 40; 1324-1343) is explicitly focused upon spirometry, it can be assumed that it is the equations of Godfrey et al, 1971, and Orenstein, 1993, used for VO _{2peak} . However, it is unclear if only one was utilised for VO _{2peak} , and therefore both are carried forward for risk of bias.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Kampouras et al., 2019a [145]	31M/47F	14.9 (4.68) ?	Cycle	Unknown	Explicit equations given girls and boys: Girls: $VO_{2max} \text{ (L/min)} = 0.0308806 \times \text{Height (cm)} - 2.877$ Boys: $VO_{2max} \text{ (L/min)} = 0.044955 \times \text{Height (cm)} - 4.64$ The manuscript states: " <i>VO2peak% predicted was calculated using the Orenstein gender specific equations [17]</i> ". However, upon examination of the reference list, reference #17 is Avramidou et al., (2018, Ped Pulm, 53,1,81-87). Within the list, Orenstein, 1993 is actually reference #16. Therefore, as per McKone et al., 2002, all items (apart from sex, whereby individual equations are provided), all items are 'unknown' for risk of bias.
Kampouras et al., 2019b [146]	77 (sex unknown)	14.9 (4.7) 11-20	Cycle	Unknown	Explicit equations given girls and boys: Girls: $VO_{2max} \text{ (L/min)} = 0.0308806 \times \text{Height (cm)} - 2.877$ Boys: $VO_{2max} \text{ (L/min)} = 0.044955 \times \text{Height (cm)} - 4.64$ The manuscript states: " <i>VO2peak in % predicted (VO2peak%) was calculated with the Orenstein equations (28)</i> ". However, upon examination of the reference list, reference #28 is Gustafsson et al., (2003, Ped Pulm, 35; 42-49). Within the list, Orenstein, 1993 is actually reference #31. Therefore, as per McKone et al., 2002, (and Kampouras et al., 2019a) all items (apart from sex, whereby individual equations are provided), all items are 'unknown' for risk of bias.
Rodriguez-Miguel et al., 2019 [147]	8M/7F	23 (11) ?	Cycle	Unknown	Equation not stated in manuscript.
Ruf et al., 2019 [148]	14M/6F	21.7 (8) 12-42	Cycle	Unknown	Equation not stated in manuscript.
Savi et al., 2019 [149]	3M/0F	42 (13) 30-60	Cycle	Unknown	Equation not stated in manuscript.
Tucker et al., 2019 [150]	10M/10F	Female: 15.1 (6.9) ? Male: 20.4 (11.4) ? Whole Group Range: 8-42	Cycle	Unknown	Equation not stated in manuscript.
Boutou et al., 2020 [151]	6M/5F	27.2 (4.15) ?	Cycle	Unknown	Equation not stated in manuscript.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Burghard et al., 2020 [152]	4M/3F	15.4 (5.8) 9-26	Cycle	1. Bongers et al., 2012 (≤18 years) 2. Mylius et al., 2019 (>18 years)	Bongers et al., 2012 utilises boys and girls, of appropriate age, using cycle ergometry, and would therefore normally be appropriate for risk of bias. However, no explicit equations are given in this edition of the book (they are provided in Bongers et al., 2014), and therefore as the exact method for deriving %pred for VO2max is unknown, this must be given 'unknown' for risk of bias purposes.
Causer et al., 2020 [153]	26M/20F	NGT: * 27.5 (7.6) ? IGT: 23.4 (7.6) ? CFRD: 27.8 (6.9) ?	Cycle	Orenstein, 1993	*Three groups based upon glycaemic status: NGT (normal glucose tolerance); IGT (impaired glucose tolerance); CFRD (cystic fibrosis related diabetes). This manuscript does not directly state Orenstein, 1993, but cites previous work by Causer et al., (2018), who in turn cite Orenstein, 1993.
Di Paolo et al., 2020 [154]	0M/1F	24 (x) n/a	Cycle	Unknown	Equation not stated in manuscript.
Sawyer et al., 2020 [155]	8M/6F	31 (28-35)*	Cycle	Unknown	*Age data given as median (IQR). Equation not stated in manuscript.
Torvanger et al., 2020 [156]	69M/47F	Female: 32.6 (11.0) 18-65 Male: 31.8 (11.0) 18-68	Treadmill	Edvardsen et al., 2013	Edvardsen et al., 2013 uses adults from 20+ years, whereas Torvanger uses 18+ years. Therefore, people aged 18-19 years will not be covered by reference equation and therefore is only given a partial match for risk of bias purposes.
Ulvestad et al., 2020a [157]	0M/2F*	? (?) ? Wider population range: 20-67	Treadmill	Edvardsen et al., 2013	*Wider population, n = 54 (27M/27F), all LTx recipients.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Ulvestad et al., 2020b [158]	2 (sex unknown)*	Training Group: 52.3 (11.9) ? Control Group: 51.1 (13.5) ?	Treadmill	Edvardsen et al., 2013	*Wider population, n = 54 (27M/27F), all LTx recipients. People with CF assigned to training group.
Du Berry et al., 2021 [159]	25M/24F	13.8 (?) 8.9-18.5	Cycle	Wasserman et al., 2005	Reference provided for Wasserman et al., 2005 explicitly cites page #585. However, this page is the last page of index, and therefore it cannot be ascertained which equation may have been used and all categories are awarded 'unknown' status.
Kampouras et al., 2021 [160]	78 (sex unknown)	14.9 (4.7) ?	Cycle	Orenstein, 1993	Explicitly states equations used: Girls: $VO_{2peak} \text{ (l/min)} = 0.0308806 \times \text{Height (cm)} - 2.877$. Boys: $VO_{2peak} \text{ (l/min)} = 0.044955 \times \text{Height (cm)} - 4.64$.
Rodriguez-Miguel ez et al., 2021 [161]	8M/7F	23 (11) ?	Cycle	Unknown	Equation not stated in manuscript. There is no equation in this manuscript, but it does cite Rodriguez-Miguel ez et al., 2019, although this paper does not in turn cite an equation.
Saez-Gimenez et al., 2021 [162]	14 (sex unknown)*	? (?) ? Whole sample: 48.7 (13.6) ?	Cycle	Unknown	*Whole sample of n = 29, all LTx recipients. Equation not stated in manuscript.
Sawyer et al., 2021 [163]	8M/6F	31 (28-35)*	Cycle	Jones et al., 1985	*Age data given as median (IQR).
Vendrusculo et al., 2021a [164]	33M/14F	15.9 (6.5) ?	Treadmill	Unknown	Equation not stated in manuscript.
Vendrusculo et al., 2021b [165]	10M/6F	19.4 (6.9) ?	Treadmill	Unknown	Equation not stated in manuscript.
Willmott et al., 2021 [166]	1M/0F	25 (x) n/a	Cycle	Orenstein, 1993	Manuscript doesn't directly state Orenstein, 1993, but cites Causer et al., 2018, who in turn utilise Orenstein, 1993.
Curran et al., 2022 [167]	13M/20F	26.2 (7.1) ?	Cycle	Nixon et al., 2001	Paper was ePub ahead of print in 2021, but given full record in 2022. Appeared in 2021 search, so included in this review. The cited paper of Nixon et al., 2001, does not appear to have an equation for VO_{2max} . The paper states: " <i>Peak oxygen uptake was expressed per kg body mass, and PWC was expressed as % of predicted</i> ", although the cited work of Godfrey et al., 1971, only has equations for %predicted for peak work capacity, but it is not clear where the estimation of VO_{2max} has come from. Therefore, age, sex, and modality are all given 'unknown' status for risk of bias.

Study	Sample	Age (Mean ± SD) Age Range	Modality	Equation Used	Notes
Hebestreit et al., 2022 [168]	52M/65F*	Intervention: 25.3 (11.4) ? Control: 22.8 (10.8) ? Whole Group Range: >12 years	Cycle	Orenstein, 1993	*Sample of n = 117 is at baseline. Data for VO _{2peak} at 12-month follow up of n = 103. Paper was ePub ahead of print in 2021, but given full record in 2022. Appeared in 2021 search, so included in this review. Paper does not explicitly state procedures, but refers to a previously published protocol paper (Hebestreit et al., 2018, BMC Pulm Med, 18(1):31) which indicates cycle ergometry and use of Orenstein: "A detailed description of the methodology is available in the online supplementary material and elsewhere".
Reuveny et al., 2022 [169]	12M/8F	Low BR: * 33 27-40 Normal BR: 35 16-58	Cycle	Hansen et al., 1984	*Participants split into two groups, based upon breathing reserve (BR): Low BR (<15%); Normal BR (>15%). Median age and range for both groups provided. Paper was ePub ahead of print in 2021, but given full record in 2022. Appeared in 2021 search, so included in this review.
Revuelta-Iniesta et al., 2022 [170]	48M/42F*	16.6 (13.0-25.4)* median (IQR)	Cycle	Unknown	*Age data presented as median (IQR). Of whole sample, only n = 78 (87%) performed CPET. Paper was ePub ahead of print in 2021, but given full record in 2022. Appeared in 2021 search, so included in this review. Equation not stated in manuscript.

ACCP: American College of Chest Physicians; ACSM: American College of Sports Medicine; ATS: American Thoracic Society; BR: breathing reserve; CFRD: cystic fibrosis related diabetes; CPET: cardiopulmonary exercise test; dF508: delta-F508 mutation [Class 2 mutation causing CF]; DLTx: double lung transplant; ECFS: European Cystic Fibrosis Society; ERS: European Respiratory Society; F: female; FEV₁: forced expiratory volume in one second; FVC: forced vital capacity; HLTx: heart-lung transplant; IGT: impaired glucose tolerance; IQR: interquartile range; LCI: lung clearance index; LTx: lung transplant; M: male; MRI: magnetic resonance imaging; NGT: normal glucose tolerance; NVL: no ventilatory limitation; pwCF: person with cystic fibrosis; RV: residual volume; SD: standard deviation; SE: standard error; SEM: standard error of mean; SH: static hyperinflation; SLTx: single lung transplant; TLC: total lung capacity; VL: ventilatory limitation; VO_{2max}: maximal oxygen uptake; W_{max}: maximal workload.

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Supplemental File 2: List of equations cited by included studies.

Study	Equation	Notes
ACSM, 1980 [1]	Unknown	There are no clear equations displayed within appendices, or throughout text, so it is unknown how authors citing this book would have established a %pred value.
Åstrand & Rodahl, 1977 [2]	Unknown	There are no clear equations displayed within appendices, or throughout text, so it is unknown how authors citing this book would have established a %pred value.
ATS/ACCP, 2003 [3]	Female: $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = (\text{weight} + 43) \times (22.78 - (0.17 \text{ age})^a$ Male: $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = \text{weight} \times (50.75 - 0.372 \text{ age})^b$ Female & Male: $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.046 (\text{height}) - 0.021(\text{age}) - 0.62(\text{sex}) - 4.31^c$	Article states that: “ <i>This section [within article] addresses issues related to reference values for normal sedentary North American subjects</i> ” and despite providing a table with 12 different sets of normative values that predict VO_{2max} , concludes that “ <i>In the interim and until a new set of “optimal” reference values are available, the committee considers that the two most widely used sets of references values—Jones and coworkers and Hansen and coworkers should continue to be used clinically</i> ” – referring to Jones et al., 1985 [4] and Hansen et al., 1984 [5]. a) Formula supposedly from Hansen et al., 1984 [5], but as noted below, there is no equation for female VO_{2max} in the original manuscript. From Table 15 in ATS/ACCP, 2003. Weight in kg. b) Formula from Hansen et al., 1984 [5], provided in Table 15 of ATS/ACCP, 2003. Weight in kg. c) Formula from Jones et al., 1985 [4], provided in Table 14 of ATS/ACCP, 2003. Height in cm; sex coded 1(F) or 0(M).
Binkhorst et al., 1986 [6]	Female: $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}\text{)} = 17.0 + 2.43 T_{max}^a$ $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}\text{)} = 34.2 + 1.29 T_{170}^a$ Male: $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}\text{)} = 19.6 + 2.43 T_{max}^a$ $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}\text{)} = 39.4 + 1.29 T_{170}^a$ Female & Male: $\ln VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.162 + 0.00484 W_{max}^b$ $\ln VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = -0.145 + 0.0058 W_{170}^b$	143M/136F, even year groups, aged 6-18y. All children underwent treadmill testing (Bruce protocol). Only children from 12-18 years (75M/79F) underwent cycle ergometry. a) Equations from treadmill testing. b) Equations from cycle ergometry. T_{max} : Maximal time T_{170} : Time at heart rate of 170 beats per minute. W_{max} : Maximal workload W_{170} : Workload at heart rate of 170 beats per minute

Study	Equation	Notes
Binkhorst et al., 1992 [7]	Female: $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 60.0 - 0.10 \text{ HR}_6^a$ $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 17.0 + 2.43 \text{ T}_{max}^a$ Male: $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 72.8 - 0.16 \text{ HR}_6^a$ $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 19.6 + 2.43 \text{ T}_{max}^a$ Female & Male: $VO_{2max} \text{ (L}\cdot\text{min}^{-1}) = 0.18 + 0.011 \text{ W}_{max}^b$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}) = -0.05 + 0.012 \text{ W}_{max}^c$	336 boys and girls (exact split not known). All children underwent treadmill testing (Bruce protocol). Children aged ≥12 years underwent cycle ergometry in addition. a) Equations from treadmill testing. b) Equations from cycle ergometry for 12-14 year olds. c) Equations from cycle ergometry for 16-18 year olds. HR ₆ : Heart rate in 6 th minute of test T _{max} : Maximal time W _{max} : Maximal workload
Bongers et al., 2012 [8]	Unknown	This edition of Bongers et al., 2012 [8] utilises boys and girls as per Bongers et al., 2014 [9], who underwent cycle ergometry. However, no explicit equations are given in this edition of the book (unlike Bongers et al., 2014 [9]), and therefore as the exact method for deriving %pred for VO _{2max} is unknown.
Bongers et al., 2014 [9]	Female: $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}) = (-0.0022 \times \text{age}^2) + (0.2184 \times \text{age}) - 0.4727$ $VO_{2peak} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = (-0.0025 \times \text{age}^3) + (0.064 \times \text{age}^2) - (0.1483 \times \text{age}) + 37.968$ Male: $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}) = (0.0033 \times \text{age}^2) + (0.1316 \times \text{age}) + 0.084$ $VO_{2peak} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = (-0.0015 \times \text{age}^3) - (0.0321 \times \text{age}^2) + (1.8851 \times \text{age}) + 33.355$	Data derived from n = 214 healthy Dutch children (114M/100F), aged 8-18 years. Exercise performed via cycle ergometry, using Godfrey protocol.
Cooper & Weiler-Ravell, 1984 [10]	Female: $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}) = 22.5 \text{ height} - 1837.8$ Male: $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}) = 43.6 \text{ height} - 4547.1$ Female & Male: $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}) = 37.1 \text{ height} - 3770.6$	Height in cm. Data derived from 109 children (58M/51F), aged 12 (± 3) years, range 6-17 years, performing cycle ergometry. Study also compares against existing equations from Astrand, 1952 [11]: Female: VO _{2max} = 32.6 height – 2820.3 Male: VO _{2max} = 46.4 height – 4610.6 Female & Male: VO _{2max} = 40.4 height – 3846.0

Study	Equation	Notes
Cooper et al., 1984 [12]	Female: $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = 28.5 \text{ weight} + 288.2$ Male: $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = 52.8 \text{ weight} - 303.4$ Female & Male: $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = 45.6 \text{ weight} - 197.9$	Weight in kg. Data derived from 109 children (58M/51F), age range 6-17 years, performing cycle ergometry.
Drinkwater et al., 1975 [13]	$VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 2.46 - 0.016 \text{ age}^a$ $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}\text{)} = 83.663 - 4.114 \text{ age} + 0.127 \text{ age}^2 - 0.0012 \text{ age}^3^b$ $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}\text{)} = 71.237 - 3.524 \text{ age} + 0.104 \text{ age}^2 - 0.0010 \text{ age}^3^a$ $VO_{2max} \text{ (mL}\cdot\text{kgLBM}^{-1}\cdot\text{min}^{-1}\text{)} = 90.684 - 3.808 \text{ age} + 0.118 \text{ age}^2 - 0.0011 \text{ age}^3^b$ $VO_{2max} \text{ (mL}\cdot\text{kgLBM}^{-1}\cdot\text{min}^{-1}\text{)} = 88.99 - 4.459 \text{ age} + 0.140 \text{ age}^2 - 0.0014 \text{ age}^3^a$	Data derived from n = 109 women, aged 10-68, although women aged 60 and above were excluded from analyses because of small number within this age group. For data analysis and derivation of equations, subjects were divided into two groups, either above or below the combined age group means reported for Canadian and Scandinavian women in Shephard, 1966 [14]. a) For women below age group mean. b) For women above age group mean.
Edvardsen et al., 2013 [15]	Female: $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 3.31 - 0.022 \text{ year}$ $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}\text{)} = 48.2 - 0.32 \text{ year}$ Male: $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 4.97 - 0.033 \text{ year}$ $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}\text{)} = 60.9 - 0.43 \text{ year}$	Data derived from n = 759 (394M/365F) Norwegian adults, aged 20-85 years. Exercise performed on a treadmill, using a modified Balke protocol.

Study	Equation	Notes
ERS, 1997 [16]	Female: $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = (22.78 - 0.17 \text{ age}) (\text{weight} + 43) ^a$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.046 \text{ height} - 0.021 \text{ age} - 4.93 ^b$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.0142 \text{ height} - 0.0115 \text{ age} + 0.00974 \text{ weight} + 0.651 ^c$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.0158 \text{ height} - 0.027 \text{ age} + 0.00899 \text{ weight} + 0.207 ^d$ Male: $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = (50.75 - 0.372 \text{ age}) \text{ weight} ^a$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.046 \text{ height} - 0.021 \text{ age} - 4.31 ^b$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.0142 \text{ height} - 0.0494 \text{ age} + 0.00257 \text{ weight} + 3.015 ^c$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.023 \text{ height} - 0.031 \text{ age} + 0.0117 \text{ weight} - 0.332 ^d$	ERS states that: “analysis of potential studies in healthy sedentary people providing prediction equations for peak VO ₂ obtained with incremental cycling exercise testing is reduced to three sets [Hansen, Jones, Fairbarn]. Basic characteristics of these three studies are summarized in table 7”. However, Table 7 (in which equations are displayed) goes on to display the four sets listed below. a) From Hansen et al., 1984 [5] and Wasserman et al., 1994 [17]. Age in years. Weight in kg. NB. The table within ERS, 1997 [16] acknowledges that the derivation sample for Hansen et al., 1984 [5] solely consists of males aged 34-74 years. b) From Jones et al., 1985 [4]. Height in cm. Age in years. c) From Blackie et al., 1989 [18]. Height in cm. Age in years. Weight in kg. Derivation sample of n = 128 (47M/81F), aged >55 years. d) From Fairbarn et al., 1994 [19]. Height in cm. Age in years. Weight in kg. Derivation sample of n = 231 (111M/120F), 20-80 years.
Froelicher et al., 1974 [20]	Male: $VO_{2max} = 45.7 - 0.27 \text{ age} ^a$ $VO_{2max} = 11.2 + 1.54 \text{ TT} ^b$	Data derived from n = 710 males, aged 20-53 years, undergoing treadmill testing using Balke protocol. All participants from US military. a) Age in years. b) TT = Treadmill time in minutes.
Godfrey et al., 1971 [21]	Unknown	This study, completed on n = 117 children (57M/60F), aged 6.0-15.9 years, using cycle ergometry, derived regression coefficients (and therefore equations) for prediction of W _{max} , but not VO _{2max} . Part of this investigation had children perform steady state exercise at 1/3 and 2/3 of W _{max} , and regressions (and therefore equations) are available for prediction of VO ₂ during this bout of submaximal exercise.
Gulmans et al., 1997 [22]	Unknown	This study, completed in n = 158 children (77M/81F), aged 12-18 years, using cycle ergometry, derived regression coefficients (and therefore equations) for prediction of W _{max} as an absolute value, and relative to body mass and fat free mass. No equations for prediction of VO _{2max} are provided.

Study	Equation	Notes
Hansen et al., 1984 [5]	Male: $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}) = \text{weight} \times (50.75 - 0.372 \text{ age})$	<p>Data in this study is derived from 77 male shipyard workers, aged 54.3 (\pm 9.2) years, ranging from 34-74 years. Cycle ergometry was performed in this group.</p> <p>The equation given for males is established a priori, for validation in this cohort, and is stated to be: “90% of Bruce's treadmill VO_{2max} values in his sedentary male population”, referring to Bruce et al., [23]. However, the work of Bruce et al., [23] is conducted on a treadmill and it is not clear how the 90% threshold has been chosen, nor calculated. Therefore, modality cannot be confirmed from this study and any study citing Hansen et al., [5] cannot be verified as modality-appropriate – and is listed as ‘unsure’ – for purposes risk of bias.</p> <p>Moreover, this work of Hansen et al., [5] is also cited in several documents such as ATS/ACCP, 2003 [3] and ERS, 1997 [16], which also provides the equation for females below:</p> $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}) = (\text{weight} + 43) \times (22.78 - (0.17 \text{ age}))$ <p>However, as the original work of Hansen et al., [5] is undertaken exclusively in males, it is not known how this female equation has been derived and therefore any studies to use females and cite Hansen et al., [5] cannot be verified as a being sex-appropriate – and is listed as ‘partial’ – for purposes of risk of bias.</p> <p>Weight is in kg.</p>
Hermansen, 1973 [24]	Unknown	<p>Reference is dated 1973 in citation and on PubMed (PMID 4522516). However, Suppl 399 on journal website is dated 1974. Authors have assumed this is the same article as there is no evidence to the contrary.</p> <p>Separate mean data is provided for males and females, from ages 11-16 as shown in Tables 5 & 6 of Appendix of reference, but no clear equations for predicting VO_{2max} are present.</p> <p>Modality not clear from reference.</p>

Study	Equation	Notes
Jones & Campbell, 1982 [25]	Female: $VO_{2max} \text{ (L}\cdot\text{min}^{-1}) = 2.6 - 0.014 \text{ age}$ $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 48 - 0.37 \text{ age}$ Male: $VO_{2max} \text{ (L}\cdot\text{min}^{-1}) = 4.2 - 0.032 \text{ age}$ $VO_{2max} \text{ (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 60 - 0.55 \text{ age}$	Within this book, Appendix D explicitly states the given equations for adult males and females aged 20 and above. These equations are derived from data obtained in Europe, Scandinavia, and North America as per Astrand 1956 [26], Astrand 1960 [27], Lange-Anderson et al., 1971 [28] and Shephard 1969 [29]. For children aged 8 and above with normal body fat, Appendix D within this book also suggests VO_{2max} may be predicted using a factor of 50 mL O_2 /kg/min (M) and 45 mL O_2 /kg/min (F) from age 8 upwards. This recommendation comes from Lange-Anderson et al., 1971 [28]. Modality not clear from reference.
Jones et al., 1985 [4]	Female: $VO_{2max} \text{ (L}\cdot\text{min}^{-1}) = 0.025 \text{ height} - 0.018 \text{ age} + 0.010 \text{ weight} - 2.26$ Male: $VO_{2max} \text{ (L}\cdot\text{min}^{-1}) = 0.034 \text{ height} - 0.028 \text{ age} + 0.022 \text{ weight} - 3.76$ Female & Male: $VO_{2max} \text{ (L}\cdot\text{min}^{-1}) = -0.624 \text{ sex} + 0.046 \text{ height} - 0.021 \text{ age} - 4.31$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}) = -0.492 \text{ sex} + 0.032 \text{ height} - 0.024 \text{ age} + 0.019 \text{ weight} - 3.71$	In equations applicable to both males and females, sex is coded 0 for males and coded 1 for females. For all equations, height is in cm, age in years, weight in kg. Data derived from cycle ergometry in 50 males and 50 females, aged from 15-71 years.

Study	Equation	Notes
Jones, 1988 [30]	<p>Female:</p> $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = (48 - 0.37 \text{ age}) \times 0.01 \text{ weight}^a$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 3.01 \text{ height} - 0.017 \text{ age} - 2.56$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 2.49 \text{ height} - 0.018 \text{ age} + 0.010 \text{ weight} - 2.26$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 2.25 \text{ height} - 1.84^b$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.029 \text{ weight} - 0.29^c$ <p>Male:</p> $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = (60 - 0.55 \text{ age}) \times 0.01 \text{ weight}^a$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 5.41 \text{ height} - 0.025 \text{ age} - 5.66$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 3.45 \text{ height} - 0.028 \text{ age} + 0.022 \text{ weight} - 3.76$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 4.36 \text{ height} - 4.55^b$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.053 \text{ weight} - 0.30^c$ <p>Female & Male:</p> $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 4.60 \text{ height} - 0.028 \text{ age} - 0.62 \text{ sex} - 4.31$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 3.20 \text{ height} - 0.024 \text{ age} + 0.019 \text{ weight} - 0.49 \text{ sex} - 3.17$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 2.5 \text{ height} - 0.023 \text{ age} + 0.019 \text{ weight} + 0.15 \text{ Lei} - 0.54 \text{ sex} - 2.32^d$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.83 \text{ height}^{2.7} \times (1 - 0.007 \text{ age}) \times (1 - 0.25 \text{ sex})$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.74 \text{ VC} - 1.04^e$ $VO_{2max} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.306 \text{ TV} + 0.08^f$	<p>These equations are provided in Appendix D of the book.</p> <p>For all equations, height is in cm, weight in kg. In equations applicable to both males and females, sex is coded 0 for males and coded 1 for females.</p> <p>a) For treadmill exercise, from Bruce et al., (1973) [23] and Drinkwater et al., (1975) [13].</p> <p>b) For children aged 6-17 years. From Cooper & Weiler-Ravell (1984) [10].</p> <p>c) For children aged 6-17 years. From Cooper et al., (1984) [12].</p> <p>d) Lei = Leisure activity, coded 1-4 according to hours of activity per week. 1 = <1; 2 = 1-3; 3 = 3-6; 4 = >6. From Jones et al., 1985 [4].</p> <p>e) VC = Vital capacity (litres). From Jones et al., 1985 [4].</p> <p>f) TV = Thigh volume is sum of both thighs (litres). From Jones et al., 1985 [4].</p> <p>As (a) are explicitly stated to be treadmill exercise, it could be assumed the remainder are based on cycle ergometry. However, as this modality of not explicitly stated, the authors cannot be assured for purposes of risk of bias and studies that cite this book are ‘assumed’ in relation to modality for purposes of risk of bias.</p> <p>As separate equations are given for each sex, applicable to both sexes, or sex offsets are included, each citation using Jones et al., 1988 [30] can be determined as sex appropriate for risk of bias. However, age cannot be given as appropriate unless exact equation (and therefore derived population) can be determined.</p>
Mylius et al., 2019 [31]	<p>Female:</p> $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -2537.29 + (24.3 \text{ height}) + (12.57 \text{ weight}) + (\text{spline function for age: estimate df 7.391})^a$ <p>Male:</p> $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -2537.29 + 743.35 + (24.3 \text{ height}) + (12.57 \text{ weight}) + (\text{spline function for age: estimate df 4.263})^a$ <p>Female & Male:</p> $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -3039.01 + (634.32 \text{ sex}) - (16.50 \text{ age}) + (29.22 \text{ height}) + (16.17 \text{ weight})^b$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -1469 + (673.00 \text{ sex}) + (16.87 \text{ age}) + (-0.47 \text{ age}^2) + (0.07 \text{ height}^2) + (39.70 \text{ weight}) + (-0.16 \text{ weight}^2)^c$	<p>Data derived from n = 4477 (3570M/907F) healthy Dutch adults and children, from 7.9 – 65.0 years (34.1 ± 11.8 years), undergoing CPET via cycle ergometry.</p> <p>For all equations: sex coded as 0F/1M; age in years; height in cm; weight in kg.</p> <p>a) Additive Model (df = degrees of freedom)</p> <p>b) Linear Model</p> <p>c) Polynomial Model</p>

Study	Equation	Notes
Neder et al., 1999 [32]	<p>Female:</p> $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -13.7 \text{ age} + 7.5 \text{ weight} + 7.4 \text{ height} + 372$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -12.7 \text{ age} + 13.6 \text{ height} - 170$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -14.7 \text{ age} + 9.5 \text{ weight} + 1470$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -12.5 \text{ age} + 6.4 \text{ weight} + 5.9 \text{ height} + 72.5 \text{ PA} + 164^a$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -14.5 \text{ age} + 8.3 \text{ weight} + 5.4 \text{ height} + 103.2 \text{ LT} + 535^b$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -11.0 \text{ age} + 67.4 \text{ PA} + 18.9 \text{ LBM} + 694^{a,c}$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -12.3 \text{ age} + 53.2 \text{ LT} + 21.4 \text{ LBM} + 1029^{b,c}$ <p>Male:</p> $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -24.3 \text{ age} + 12.5 \text{ weight} + 9.8 \text{ height} + 702$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -22.8 \text{ age} + 17.9 \text{ height} + 207$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -25.2 \text{ age} + 14.3 \text{ weight} + 2267$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -22.8 \text{ age} + 12.9 \text{ weight} + 6.2 \text{ height} + 132.2 \text{ PA} + 289^a$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -24.5 \text{ age} + 14.3 \text{ weight} + 4.9 \text{ height} + 197.1 \text{ LT} + 1113^b$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -20.5 \text{ age} + 132.0 \text{ PA} + 22.8 \text{ LBM} + 930^{a,b}$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = -21.5 \text{ age} + 156.8 \text{ LT} + 25.9 \text{ LBM} + 1548^{b,c}$	<p>Data derived from n = 120 (60M/60F), aged 20-80 years, undergoing cycle ergometry.</p> <p>For all equations, age in years, weight in kg, height in cm.</p> <p>a) PA = Physical activity score; sum of scores by questionnaire from Baecke et al., 1982 [33].</p> <p>b) LT = Leisure time, as per Saltin & Grimby, 1968 [34].</p> <p>c) LBM = Lean body mass, via skinfold measurements, as per Durnin & Womersley, 1969 [35].</p>
Nixon et al., 2001 [36]	Unknown	No equations are provided in this manuscript. However, references are made to Godfrey et al., 1971 [21], who in turn provides data for calculating peak work capacity as a percentage of predicted.
Orenstein, 1991 [37]	Unknown	<p>Orenstein (1993) [38] states in the preface of the book that "<i>This book is a compilation of presentations made at the Standards for Pediatric Exercise Testing Workshop in October 1991 in Scottsdale, AZ</i>".</p> <p>Therefore, as a 1991 book cannot be identified, it is assumed that the 1991 and 1993 reference are the same, and thus the same issues associated with Orenstein (1993) are applicable.</p>

Study	Equation	Notes
Orenstein, 1993 [38]	Female: $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.0308806 \text{ height} - 2.877$ Male: $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.044955 \text{ height} - 4.64$	Equations from page 159 of reference. For both equations, height is in cm. No data available about the population or modality upon which these equations are derived. It could likely be assumed that this is from a paediatric population (as this is a paediatric textbook), however this cannot be confirmed for purposes of risk of bias. In addition, several references are made within the chapter to the Godfrey protocol, implying cycle ergometry, although again this cannot be confirmed for purposes of risk of bias.
Rowland, 1996 [39]	Female: $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 3.539 - 0.915 \text{ age} + 0.104 \text{ age}^2 - 0.003 \text{ age}^3$ $VO_{2peak} \text{ (mL}\cdot\text{kg}^{-1}\text{min}^{-1}\text{)} = 58.90 - 1.15 \text{ age}$ Male: $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.859 - 0.013 \text{ age} + 0.010 \text{ age}^2$ $VO_{2peak} \text{ (mL}\cdot\text{kg}^{-1}\text{min}^{-1}\text{)} = 52.35 + 0.071 \text{ age}$	For all equations, age is in years. Where Rowland, 1996 [39] is cited, it is not clear which reference equations are used and therefore age, sex and modality cannot be verified for risk of bias. Those provided on the left are from Chapter 6 ('Maturation of Fitness') and could be assumed to be possible options and use children from 7-17 years of age. These equations are in turn from Krahenbuhl et al., 1985 [40], pooling data from 9307 children (5793M/3508F). This pooled data was "corrected" to treadmill values whereby cycle data was multiplied by 1.075. However, this offset factor of 1.075 appears to have been chosen as it is " <i>the approximate difference noted between these two modes of exercise</i> " – without any supporting reference, nor validating data.
Saris et al., 1985 [41]	Unknown	This study, performed on n = 131 children (62M/69F), aged 4-18 years (even ages only), performing cycle ergometry, derived normative data for VO_{2max} , comparing this data to prior studies. However, no equations are provided for prediction of VO_{2max} , and it is therefore unclear how this reference would have been utilised to derive a %predicted value.
Ten Harkel et al., 2011 [42]	Males: $VO_{2peak} = (0.66 \text{ age}) + 38.6$	Data derived from n = 175 children (93M/82F), 8-18 years, via cycle ergometry. Statistical analyses only identified associations between VO_{2peak} and age in boys, and not girls, hence why no normative data is given for females.

Study	Equation	Notes
Ten Harkel & Takken, 2011 [43]	Females: $VO_{2peak} = 41.5$ Males: $VO_{2peak} = (0.094 \text{ height}) + 32.2$	Same population and modality as per Ten Harkel et al., [42]. This reference from Ten Harkel & Takken, 2011 [43] is in response to a letter from Hager, 2011 [44] in relation to the original manuscript.
Wasserman et al., 1987 [45]	Female: $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = (42.8 + \text{weight}) \times (22.78 - 0.17 \text{ age})^{a,c,e}$ $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = \text{height} \times (14.81 - 0.11 \text{ age})^{a,d,e}$ $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = \text{weight} \times (44.37 - 0.413 \text{ age})^{b,c,e}$ $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = (0.79 \text{ height} - 68.2) \times (44.37 - 0.413 \text{ age})^{b,d,e}$ $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = 28.5 \text{ weight} + 288.1^{a,f}$ Male: $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = \text{weight} \times (50.72 - 0.372 \text{ age})^{a,c,e}$ $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = (0.79 \text{ height} - 60.7) \times (50.72 - 0.372 \text{ age})^{a,d,e}$ $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = \text{weight} \times (56.36 - 0.413 \text{ age})^{b,c,e}$ $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = (0.79 \text{ height} - 60.7) \times (56.36 - 0.413 \text{ age})^{b,d,e}$ $VO_{2max} \text{ (mL}\cdot\text{min}^{-1}\text{)} = 52.8 \text{ weight} - 303.4^{a,f}$	For all equations, weight in kg, height in cm, age in years. a) Cycle ergometry b) Treadmill c) Normal weight d) Overweight e) Adults f) Children Equations for adults are from Table 1 in Chapter 6 ('Normal Values'), being derived from Bruce et al., 1973 [23], Hansen et al., 1984 [5], and a personal communication from Davis et al., 1985. Equations for children are from Figure 2 in Chapter 6 ('Normal Values') and are derived from Cooper & Weiler-Ravell, 1984 [10] and Cooper et al., 1984 [12]. Not enough information is provided in studies citing this reference to determine which equation(s) are used. However, as separate equations are given for each sex, each citation using Wasserman et al. 1987 [45] can be determined as sex appropriate for risk of bias. However, age cannot be given as appropriate unless exact equation (and therefore derived population) can be determined. Moreover, as modality is not clear, this cannot be awarded appropriate status for risk of bias.

Study	Equation	Notes
Wasserman et al., 1994 [17]	Female: $VO_{2max} = (\text{weight} + 43) \times (22.78 - (0.17 \text{ age})^a$ $VO_{2max} = 28.5 \text{ weight} + 288.1^b$ Male: $VO_{2max} = \text{weight} \times (50.72 - 0.372 \text{ age})^a$ $VO_{2max} = 52.8 \text{ weight} - 303.4^b$	<p>Not enough information is provided in studies citing this reference to determine which equation(s) are used, although these two sets provided are from Chapter 6 ('Normal Values'). Units for VO_{2max} equations on left not provided in reference.</p> <p>a) If using treadmill, multiply result by 1.11. Equations from Bruce et al., 1973 and Hansen et al., 1984.</p> <p>b) Equations for children (no age given in textbook). Data is from Cooper et al., 1984 [12] and therefore presumably based on same cohort (n = 109, 58M/51F, 6-17 years). However, the equation for females in Cooper et al., [12] is $28.5 \text{ weight} + 288.2$ (not 228.1, as per Wasserman et al., [17]) – presumably the same data, but cannot be verified. Weight for both equations in kg.</p> <p>Whilst not enough information is provided in studies citing this reference to determine which equation(s) are used, as separate equations are given for each sex, each citation using Wasserman et al. 1994 [17] can be determined as sex appropriate for risk of bias. However, age cannot be given as appropriate unless exact equation (and therefore derived population) can be determined. Moreover, as modality is not clear, this cannot be awarded appropriate status for risk of bias.</p>
Wasserman et al., 1999 [46]	As per Wasserman et al., 1994 [17].	<p>Only one study cites this version of Wasserman et al., [46] and the current authors query whether this was done so mistakenly.</p> <p>Moreover, there appears to be a small referencing error, as the 3rd edition of Wasserman et al., is actually from Lippincott Williams & Wilkins (Baltimore MD). However, reference in bibliography below is maintained as published by original authors.</p>
Wasserman et al., 2005 [47]	As per Wasserman et al., 1994 [17].	<p>Whilst not enough information is provided in studies citing this reference to determine which equation(s) are used, as separate equations are given for each sex, each citation using Wasserman et al. 2005 [47] can be determined as sex appropriate for risk of bias. However, age cannot be given as appropriate unless exact equation (and therefore derived population) can be determined. Moreover, as modality is not clear, this cannot be awarded appropriate status for risk of bias.</p>

Study	Equation	Notes
Wasserman et al., 2012 [48]	<p>Female:</p> $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.9 \times \text{weight} \times (0.0404 - 0.00023 \times \text{age})^a$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = -4.9 + 0.046 \times \text{height} - 0.021 \times \text{age}^b$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = -2.26 + 0.025 \times \text{height} + 0.01 \times \text{weight} - 0.018 \times \text{age}^b$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.372 + 0.0074 \times \text{height} + 0.0075 \times \text{weight} - 0.0137 \times \text{age}^c$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = -0.588 + 0.00913 \times \text{height} + 0.02688 \times \text{weight} - 0.01133 \times \text{age} - 0.00012 \times \text{weight}^2^d$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.001 \times \text{height} \times (14.783 - 0.11 \times \text{age}) + 0.006 \times \text{weight (actual} - \text{ideal)}^e\text{§}$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = 28.5 \times \text{weight} + 288.2^f$ <p>Male:</p> $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.9 \times (0.183 + 0.0114 \times \text{height} + 0.0172 \times \text{weight} - 0.0227 \times \text{age})^g$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.9 \times \text{weight} \times (0.0521 - 0.00038 \times \text{age})^a$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = -4.31 + 0.046 \times \text{height} - 0.021 \times \text{age}^b$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = -3.76 + 0.034 \times \text{height} + 0.022 \times \text{weight} - 0.028 \times \text{age}^b$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.702 + 0.0098 \times \text{height} + 0.0125 \times \text{weight} - 0.0246 \times \text{age}^{c^*}$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = -0.069 + 0.01402 \times \text{height} + 0.00744 \times \text{weight} + 0.00148 \times \text{age} - 0.0002256 \times \text{age}^2^d$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.0337 \times \text{height} - 0.000165 \times \text{age} \times \text{height} - 1.963 + 0.006 \times \text{weight (actual} - \text{ideal)}^{e\text{†}i}$ $VO_{2peak} \text{ (L}\cdot\text{min}^{-1}\text{)} = 0.0337 \times \text{height} - 0.000165 \times \text{age} \times \text{height} - 1.963 + 0.014 \times \text{weight (actual} - \text{ideal)}^{e\text{†}ii}$ $VO_{2peak} \text{ (mL}\cdot\text{min}^{-1}\text{)} = \backslash 52.8 \times \text{weight} - 303.4^f$	<p>All data retrieved from Chapter 7 ('Normal Values'). For all equations, height in cm, weight in kg, age in years.</p> <p>a) For adults, using cycle ergometry. From Itoh et al., 1990 [49].</p> <p>b) For adults, using cycle ergometry. From Jones et al., 1985 [4]</p> <p>c) For adults, using cycle ergometry. From Neder et al., 1999 [32].</p> <p>*Possible that age coefficient has been reproduced wrong in textbook as this is 24.3 in Neder et al., 1999 [32], but 0.0246 in Wasserman [48].</p> <p>d) For adults, using cycle ergometry. From Gläser et al., 2010 [50].</p> <p>e) For adults, using cycle ergometry. From Hansen, 2001 [<i>personal communication</i>]. For adults younger than 30 years, an age of 30 should be used.</p> <p>§ Ideal weight = 0.65 x height – 42.8</p> <p>† Ideal weight = 0.79 x height – 60.7.</p> <p>i. If actual weight equals or exceeds ideal weight</p> <p>ii. If actual weight is less than ideal weight</p> <p>f) For children, using cycle ergometry. From Cooper et al., 1984 [12].</p> <p>g) For adults, using cycle ergometry. From Inbar et al., 1994 [51]. Source paper from Inbar et al., [51] is conducted using treadmill testing, but the equation provided by Wasserman et al., [48] claims to be for cycle ergometry.</p> <p>Whilst not enough information is provided in studies citing this reference to determine which equation(s) are used, as separate equations are given for each sex, each citation using Wasserman et al. 2012 [48] can be determined as sex appropriate for risk of bias. However, age cannot be given as appropriate unless exact equation (and therefore derived population) can be determined. Moreover, as modality is not clear given discrepancies in reporting noted above, this cannot be awarded appropriate status for risk of bias.</p>

ACCP: American College of Chest Physicians; ACSM: American College of Sports Medicine; ATS: American Thoracic Society; ERS: European Respiratory Society; F: female; HR₆: heart rate in 6th minute of test; M: male; LBM = lean body mass; Lei: leisure activity; LT = leisure time; PA: physical activity; T_{max}: maximal time; TT: treadmill time; T₁₇₀: time at heart rate of 170 beats per minute; TV: thigh volume; VC: vital capacity; VO_{2max}: maximal oxygen uptake; W_{max}: maximal workload; W₁₇₀: workload at heart rate of 170 beats per minute.

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No.	Study	S	A	M	5	10	O
1	Hjeltnes et al., 1984	?	?	?	N	Y	N
2	Edlund et al., 1986	?	?	?	N	Y	N
3	Marcotte et al., 1986a	Y	?	?	Y	Y	?
4	Marcotte et al., 1986b	Y	?	?	Y	Y	?
5	Stanghelle et al., 1986	Y	Y	?	N	N	N
6	Versteegh et al., 1986	?	?	?	?	?	?
7	Browning et al., 1990	Y	?	?	N	Y	N
8	Versteegh et al., 1990	?	?	?	?	?	?
9	Heijerman et al., 1991	Y	Y	Y	N	Y	N
10	Regnis et al., 1991	?	?	?	?	?	?
11	Heijerman et al., 1992	Y	Y	Y	N	Y	N
12	Nixon et al., 1992	?	?	?	?	?	?
13	Williams et al., 1992	Y	?	?	Y	Y	?
14	Freeman et al., 1993	Y	?	?	Y	Y	?
15	Henke et al., 1993	?	?	?	?	?	?
16	Kaplan et al., 1996	Y	?	?	Y	Y	?
17	Alison et al., 1997	Y	Y	Y	N	N	N
18	Evans et al., 1997	Y	?	N	N	Y	N
19	Moorcroft et al., 1997a	Y	?	?	N	Y	N
20	Moorcroft et al., 1997b	Y	?	?	N	Y	N
21	Oelberg et al., 1998	?	?	?	N	N	N
22	Pellegrino et al., 1998	?	?	?	?	?	?
23	Tuzin et al., 1998	?	?	?	?	?	?
24	Boas et al., 1999	?	?	?	N	Y	N
25	Bradley et al., 1999	?	?	?	?	?	?
26	McKone et al., 1999	Y	?	?	N	N	N
27	Schwaiblmair et al., 1999	?	?	?	Y	Y	?
28	Boas et al., 2000a	?	?	?	N	Y	N
29	Boas et al., 2000b	?	?	?	N	Y	N
30	Fink et al., 2000	?	?	?	?	?	?
31	Moser et al., 2000	Y	?	?	?	?	?
32	Frangolias & Wilcox, 2001	Y	?	?	N	N	N
33	Karlia et al., 2001	Y	?	?	N	Y	N
34	Pouliou et al., 2001	?	?	?	?	?	?
35	Blau et al., 2002	?	?	?	?	?	?
36	Hutler et al., 2002 (1)	?	?	?	N	Y	N
37	Hutler et al., 2002 (2)	Y	?	?	N	Y	N
38	McKone et al., 2002	Y	?	?	?	?	?
39	Thin et al., 2002	Y	?	?	N	Y	N
40	Frangolias et al., 2003a	Y	?	?	N	N	N
41	Frangolias et al., 2003b	Y	?	?	N	N	N
42	Klijn et al., 2003a	Y	?	Y	N	N	N
43	Klijn et al., 2003b	Y	?	Y	N	N	N
44	Sexauer et al., 2003	Y	?	?	N	N	N
45	Klijn et al., 2004	Y	?	Y	N	N	N
46	Moorcroft et al., 2004	Y	?	?	N	N	N
47	Pinet et al., 2004	?	?	?	N	N	N
48	Dodd et al., 2005	Y	?	?	N	N	N
49	Fournier et al., 2005	?	?	?	?	?	?
50	Hebestreit et al., 2005	Y	?	?	N	N	N
51	McKone et al., 2005	Y	?	?	N	N	N
52	Moorcroft et al., 2005	Y	?	?	N	N	N
53	Dodd et al., 2006a	Y	?	?	N	N	N
54	Dodd et al., 2006b	Y	?	?	N	N	N
55	Hebestreit et al., 2006	Y	?	?	N	N	N
56	Reinsma et al., 2006	?	?	?	?	?	?
57	Barry & Gallagher, 2007	Y	?	?	N	N	N
58	Barry et al., 2008	Y	?	?	N	N	N
59	Dodd et al., 2008	Y	?	?	N	N	N
60	Hubert et al., 2009	Y	?	?	Y	Y	?
61	Ruf & Hebestreit, 2009	Y	?	?	N	N	N
62	Troosters et al., 2009	Y	?	?	N	N	N
63	Zavorsky et al., 2009	Y	Y	Y	N	N	N
64	Groen et al., 2010	Y	?	Y	N	N	N
65	Gruet et al., 2010	?	?	?	?	?	?
66	McBride et al., 2010	Y	Y	Y	N	N	N

No.	Study	S	A	M	5	10	O
67	Nguyen et al., 2010	?	?	?	Y	N	N
68	Bartels et al., 2011	?	?	?	?	?	?
69	Dwyer et al., 2011 (1)	Y	Y	Y	N	N	N
70	Dwyer et al., 2011 (2)	Y	Y	Y	N	N	N
71	Dwyer et al., 2011 (3)	Y	?	Y	N	N	N
72	Gruber et al., 2011	Y	?	?	N	N	N
73	Hulzebos et al., 2011	?	?	?	?	?	?
74	Leroy et al., 2011	?	?	Y	N	N	N
75	Tejero Garcia et al., 2011	?	?	?	?	?	?
76	Traylor et al., 2011	?	?	?	?	?	?
77	Vallier et al., 2011	Y	?	?	N	N	N
78	Vivodtzev et al., 2011	?	?	?	?	?	?
79	Werkman et al., 2011 (1)	?	?	?	N	N	N
80	Werkman et al., 2011 (2)	?	?	?	N	N	N
81	Wheatley et al., 2011	?	N	?	N	N	N
82	Armstrong et al., 2012	Y	Y	Y	N	N	N
83	Bongers et al., 2012	?	Y	Y	Y	Y	?
84	Manika et al., 2012	?	?	?	?	?	?
85	Nguyen et al., 2012	?	?	?	?	?	?
86	Ruf et al., 2012	Y	?	?	N	N	N
87	van de Weert-van Leeuwen et al., 2012	Y	?	Y	N	N	N
88	Armstrong et al., 2013	?	?	?	?	?	?
89	Ledger et al., 2013	?	?	?	?	?	?
90	Moco et al., 1999	Y	Y	N	N	N	N
91	Poore et al., 2013	?	?	?	?	?	?
92	Prevotat et al., 2013	?	?	?	?	?	?
93	Savi et al., 2013	?	?	?	?	?	?
94	Sovtic et al., 2013	?	?	?	?	?	?
95	Vivodtzev et al., 2013	?	?	?	?	?	?
96	Barry & Horsley, 2014	?	?	?	?	?	?
97	Brun et al., 2014	?	?	?	?	?	?
98	Cohen & Orenstein, 2014	?	?	?	?	?	?
99	Hebestreit et al., 2014	Y	?	?	N	N	N
100	Hulzebos et al., 2014	Y	Y	Y	Y	Y	Y
101	Pastre et al., 2014	?	?	?	N	N	N
102	van de Weert-van Leeuwen et al., 2014	Y	?	Y	N	N	N
103	Armstrong et al., 2015	?	?	?	?	?	?
104	Bongers et al., 2015	?	?	?	Y	Y	?
105	Erickson et al., 2015	?	?	?	?	?	?
106	Fielding et al., 2015	?	?	?	?	?	?
107	Quon et al., 1988	Y	?	?	N	N	N
108	Savi et al., 2015	Y	Y	Y	N	N	N
109	Stevens et al., 2015	?	?	?	?	?	?
110	Van Iterson et al., 2015	?	N	?	N	N	N
111	Visschers et al., 2015	?	?	?	?	?	?
112	Wheatley et al., 2015a	?	N	?	N	N	N
113	Wheatley et al., 2015b	?	N	?	N	N	N
114	Avramidou et al., 2016	Y	?	?	N	N	N
115	Gruet et al., 2016a	Y	?	?	N	N	N
116	Gruet et al., 2016b	?	?	?	?	?	?
117	Hatziagorou et al., 2016	Y	?	?	N	N	N
118	Radtke et al., 2016	?	?	?	N	N	N
119	Rodriguez-Miguel et al., 2016	?	?	?	?	?	?
120	Tomlinson et al., 2016	Y	Y	Y	Y	Y	Y
121	Vallier et al., 2016	?	?	?	?	?	?
122	Van Iterson et al., 2016a	?	N	?	N	N	N
123	Van Iterson et al., 2016b	?	?	?	?	?	?
124	Decorte et al., 2017	Y	?	?	N	N	N
125	Dwyer et al., 2017	?	?	?	?	?	?
126	Edvardsen et al., 2017	?	?	?	?	?	?
127	Layton et al., 2017	?	?	?	?	?	?
128	Radtke et al., 2017 (1)	?	?	?	N	N	N
129	Radtke et al., 2017 (2)	Y	?	?	N	N	N
130	Tucker et al., 2017	?	?	?	?	?	?
131	Vandekerckhove et al., 2017	Y	?	?	Y	Y	?
132	Weir et al., 2017	?	?	?	N	N	N

No.	Study	S	A	M	5	10	O
133	Avramidou et al., 2018	Y	?	?	N	N	N
134	Causer et al., 2018	Y	?	?	N	N	N
135	Chelabi et al., 2018	Y	?	Y	N	N	N
136	Chen et al., 2018	?	?	?	?	?	?
137	Foster et al., 2018 (1)	Y	?	?	N	N	N
138	Foster et al., 2018 (2)	Y	Y	Y	N	N	N
139	Gruet et al., 2018	Y	Y	Y	N	N	N
140	Puppo et al., 2018	Y	Y	Y	N	N	N
141	Radtke et al., 2018 (1)	Y	?	?	N	N	N
142	Radtke et al., 2018 (2)	Y	Y	Y	N	N	N
143	Savi et al., 2018	Y	Y	Y	N	N	N
144	Stevens, 2018	Y	?	?	N	N	N
145	Stevens & Neyedli, 2018	Y	?	?	N	N	N
146	Tomlinson et al., 2018	Y	?	Y	Y	Y	?
147	Tucker et al., 2018	?	?	?	?	?	?
148	Bar-Yoseph et al., 2019	?	?	?	?	?	?
149	Di Paolo et al., 2019	?	?	?	?	?	?
150	Dwyer et al., 2019	?	?	?	?	?	?
151	Hebestreit et al., 2019 (1)	Y	?	?	N	N	N
152	Hebestreit et al., 2019 (2)	Y	?	?	N	N	N
153	Kampouras et al., 2019a	Y	?	?	?	?	?
154	Kampouras et al., 2019b	Y	?	?	?	?	?
155	Rodriguez-Miguel et al., 2019	?	?	?	?	?	?
156	Ruf et al., 2019	?	?	?	?	?	?
157	Savi et al., 2019	?	?	?	?	?	?
158	Tucker et al., 2019	?	?	?	?	?	?
159	Boutou et al., 2020	?	?	?	?	?	?
160	Burghard et al., 2020 (1)	?	?	?	N	Y	N
161	Burghard et al., 2020 (2)	Y	Y	Y	Y	Y	Y
162	Causer et al., 2020	Y	?	?	N	N	N
163	Di Paolo et al., 2020	?	?	?	?	?	?
164	Sawyer et al., 2020	?	?	?	?	?	?
165	Torvanger et al., 2020	Y	?	Y	N	Y	N
166	Ulvestad et al., 2020a	Y	Y	Y	N	Y	N
167	Ulvestad et al., 2020b	Y	Y	Y	N	Y	N
168	Du Berry et al., 2021	?	?	?	N	N	N
169	Kampouras et al., 2021	Y	?	?	N	N	N
170	Rodriguez-Miguel et al., 2021	?	?	?	?	?	?
171	Saez-Gimenez et al., 2021	?	?	?	?	?	?
172	Sawyer et al., 2021	Y	Y	Y	N	N	N
173	Vendrusculo et al., 2021a	?	?	?	?	?	?
174	Vendrusculo et al., 2021b	?	?	?	?	?	?
175	Willmott et al., 2021	Y	?	?	N	N	N
176	Curran et al., 2022	?	?	?	N	N	N
177	Hebestreit et al., 2022	Y	?	?	N	N	N
178	Reuveny et al., 2022	?	?	?	N	N	N
179	Revuelta-Iniesta et al., 2022	?	?	?	?	?	?

Supplemental File 3: Risk of bias for individual studies.

Where studies utilise more than one reference equation, these are provided in parentheses and the order matches with that provided in Supplemental File 1 (Table of Studies).

S: sex-match; A: age-match; M: modality-match; 5: equation published within 5 years or less of study; 10: equation published within 10 years or less of study.

Yes/Green = Yes, this is an appropriate match.

?/Yellow = This is either: a) partial match, b) unknown (insufficient information from author or source equation); c) assumed as a match, but cannot be verified.

No/Red = No, this is not an appropriate match.

Explanation and examples of RoB scoring provided in table below.

Category	Explanation	Example
Sex	This category assesses whether the sex of participants in the study is the same as that within the NRV publication.	<ul style="list-style-type: none">• If a study contains both men and women, and the NRV equation has either separate equations for men and women, a sex-offset within equation, or equation applicable to both sexes, this would be awarded ‘Yes’ for RoB.• If a study contains both men and women, and the NRV equation is based upon only males, this would be awarded ‘Unknown’ for RoB, as this partially matches on the basis of sex – males match, but females do not.• If a study NRV does not detail the sex of participants, this would be awarded ‘Unknown’, unless the NRV provides either separate equations for men and women, a sex-offset within equation, or equation applicable to both sexes, in which case a ‘Yes’ would be awarded.• If a study contains only females, and the NRV equation is based upon only males, this would be awarded ‘No’ for RoB.
Age	This category assesses whether the age of participants in the study is the same as that within the NRV publication.	<ul style="list-style-type: none">• If a study contains both participants aged from 20-40 years of age, and the NRV equation is based upon people from 18-50 years of age, this would be awarded ‘Yes’ for RoB.• If a study contains both participants aged from 20-40 years of age, and the NRV equation is based upon people from 30-50 years of age, this would be awarded ‘Unknown’ for RoB, as this partially matches on the basis of age – those 30-40 years match, but those from 20-29 years do not.• If either a study or NRV do not detail the age of participants/source population, this would be awarded a ‘Unknown’ status, unless an age component is built into equations that is applicable to all ages, in which case this would be awarded a ‘Yes’ for RoB.• If a study contains participants aged 10-18 years of age, and the NRV equation is based upon people aged from 20-50 years of age, this would be awarded ‘No’ for RoB.
Modality	This category assesses whether the modality used in the study is the same as that used in the NRV publication.	<ul style="list-style-type: none">• If a study utilised cycle ergometry, and the NRV used cycle ergometry, this would be awarded a ‘Yes’ for RoB.• If a study utilised cycle ergometry, and the NRV used treadmill exercise, this would be awarded a ‘No’ for RoB.• If either a study, or NRV, did not stipulate any modality, this would be awarded a ‘Unknown’ for RoB.
≤5 years	This category assesses whether the study was published within 5 years or less of the NRV publication.	<ul style="list-style-type: none">• If a study was published in 2020, and the NRV cited was published in 2013, this would be awarded ‘No’ for RoB.• If a study was published in 2020, and the NRV cited was published in 2015, this would be awarded ‘Yes’ for RoB.• If no NRV was cited, and therefore no date available, this would be awarded ‘Unknown’ for RoB.
≤10 years	This category assesses whether the study was published within 10 years or less of the NRV publication.	<ul style="list-style-type: none">• If a study was published in 2020, and the NRV cited was published in 2013, this would be awarded ‘Yes’ for RoB.• If a study was published in 2020, and the NRV cited was published in 2010, this would be awarded ‘Yes’ for RoB.• If no NRV was cited, and therefore no date available, this would be awarded ‘Unknown’ for RoB.
Overall	This category assigns an ‘overall’ RoB based upon prior categories.	<ul style="list-style-type: none">• The lowest score achieved from the prior categories is carried forward as the ‘overall’ score, thus identifying the ‘maximum’ bias possible within a study.

NRV: normal reference value; RoB: risk of bias.