

Reference Predicted Normal Values

This document describes in detail, which predicted normal values are implemented in the products of ndd. The parameter of each predicted source are listed, the publications are referenced and specialties like ethnic corrections are described.

Description of Predicted tables

The predicted tables, shown at the end of this document contain the following items:

Reference:	Name of predicted normal reference used in EasyOne or the software. The name is the study name, or the name of the authors of the publication.
Year of Publication:	Year when the study was published (see also table with reference papers).
Abbreviation:	Abbreviation for the study. The abbreviation is used if parameters from other studies are copied. Example: For most studies, 'Cherniak' (CH) values are used for the MVV parameter.
Age Range:	Age range of the study. If range was extended beyond the study range, the extended range is shown in parenthesis.
Height Range:	Height range of the study. Extended range also listed in parenthesis, as in age range.
Weight Range:	Weight range of the study. In most studies, weight is not used.
EasyOne Availability:	The following codes are used: V2,5,6 stands for EasyOne firmware version 2.x, version 5.x and version 6.x
Ethnicity:	Ethnic groups that are supported by the study. Green with 'o' means that the value is directly supported by the study, a green field means that the predicted values are computed using ethnic correction values in the software.
Parameter:	In the parameter list the following indicators are used: O the parameter is available in the study FVC, IVC the value of the parameter is copied from listed parameter of the same source FEV1/FVC FEV1/FVC is computed from the predicted of FEV1 and FVC of the same source X FEV1/FVC is used for FEV1/VC (or vice versa)
LLN of Parameter:	This table lists which lower limits of normal (LLN) are provided by the study. If the Lower limit of normal values are not available as an equation, then the values are computed using the following formula: $LLN = Predicted - 1.645 * SEE$ (Standard Error of Estimate). If there is no SEE value, then the LLN is set to 80% of the predicted for normal parameters (FVC, FEV1 etc.) and 90% of predicted for relative parameters like FEV1/FVC%.
Lung Age:	Lung age is based on the measured FEV1 value of a patient. Using the predicted equation for FEV1 lung age is computed by resolving the equation for age: Input variables are the patient demographics (gender, height) and the measured FEV1 value, output variable is the 'lung' age. Lung age therefore is the age at which the measured and the predicted FEV1 value of a patient are equal. The computation is based on the following publication: Spirometric Lung Age Estimation for Motivating Smoking Cessation. J.F. Morris, W. Temple. Prev Med 14, 655-662 (1985).

Extended predicted range

Published spirometry predicted values are normally computed based on a 'normal' population. Based on the measured data from this publication 'normal' values for certain spirometry parameters are derived; these 'normal' values can usually be computed using published formulas. The formulas take into account gender, age, height and in some cases ethnicity and/or weight of the patient. The use of these formulas is usually limited to the age and height ranges present in the 'normal' population. When the caution message 'Extended predicted range used' is displayed the original formulas of the publication are used, age and/or height of the patient, however, is slightly above or below the 'normal' population that was used for this study. Furthermore, the formulas have been checked to be stable in the extrapolated range.

Ethnic correction

Ethnic correction factors are only applied if the study does not directly support the selected ethnic group (see predicted overview table). The following two examples are used for clarification:

1. NHANES-III has predicted equations for Caucasian, African and Hispanic ethnic groups. Ethnic correction factors defined in the EasyWarePro software are therefore only used for the ethnic groups Asian and Other.
2. ERS predicted values only have predicted equations for Caucasian ethnicity. In this case ethnic correction factors are used for all other ethnic groups.

The use of ethnic correction factors is always indicated on the report and in the software in the following way: NHANES-III * x.xx, where x.xx is the correction factor applied.

The following table lists how the predicted values are affected by ethnic correction:

Applied Correction	Parameters (and LLN)
Multiplication by factor	FVC, FIVC, FEV1, FEV3, FEV6, VC, FEV0.75, FEV0.5, MVV, VA, TLC, RV, IC, FRC
No correction	FEV1/FVC, FEV1/VC, FEV0.75/FVC, FEV0.5/FVC, FEV3/FVC, FEV1/FEV6, FEF25, FEF50, FEF75, FEF2575, PEF, PIF, MIF, DLCO, DLadj, DLCO/VA, RV/TLC, LCI

Note: Neither DLCO nor DLCO/VA are adapted using ethnic correction factors. The population data suggests that no ethnic correction is required for DLCO. Since the DLCO parameter is calculated from a VA derived from the tracer gas dilution, and it directly affects DLCO in the calculation, any alteration in VA would also alter DLCO, and DLCO/VA. So, in DLCO predicted values, we have to predict DLCO to "match" as closely to the Normal/Healthy populations as possible, which does not require any ethnic corrections for either DLCO or DLCO/VA.

Remarks regarding predicted normal values for Diffusion Capacity

1. The article of B. Make et al. compares different predicted normal value sources and concluded that *"the same subject may be classified as 'normal', 'abnormal' or 'very abnormal' depending on which equation is used"*. This specifically applies to the predicted sources of Burrows (very low values) and Ayers (no age dependency).
2. Goldman and Becklake predicted values are only used for TLCsb, RVsb, RV/TLCsb and FRC.
3. Thompson et al. predicted values can only be used down to the age of 45 years (see official publication). In cooperation with the authors it was decided to combine the predicted values of Thompson with those of Miller for ages <45 years.
4. VA and/or DLCO/VA predicted values are computed based on TLCsb predicted values minus the anatomic dead space Vd (see also note in 'Transfer factor for carbon monoxide' by M. Horstman, F. Mertens, H. Stam).
5. DLCO predicted values by Vazquez Garcia et al. (ALAT 2016) depend on the 'altitude of residence' of the patient. The appropriate value must be entered in the patient entry form.

Software Versions

Predicted Library	V1.24.0
Easy on-PC	EasyOne Connect V3.3.0.11
EasyOne Pro / LAB	EasyOne Connect V3.3.0.11

	Reference	Abbrev.	Predicted Normals for Spirometry Publication List
North America, Canada	NHANES III (Hankinson)	NH	JL Hankinson, JR Odencrantz, KB Fedan. Spirometric Reference Values from a Sample of the General U.S. Population. Am J Respir Crit Care Med, Vol 159, p 179-187, 1999.
	Knudson 1983	KN83	Knudson, Ronald J, Michael Lebowitz, Holberg Catherine J., Benjamin Burrows. Changes in the Normal Maximal Expiratory Flow-Volume Curve with Aging. American Review of Respiratory Disease, Volume 127, p. 725-734, 1983.
	Knudson 1976	KN76	Knudson, Ronald J, R Slatin, M Lebowitz, B Burrows. The maximal Expiratory Flow-Volume Curve. American Review of Respiratory Disease, Volume 113, p. 587-600, 1976.
	Crapo	CR	Crapo RO, Morris AH, Gardner RM. Reference spirometric values using techniques and equipment that meets ATS recommendations. Am Rev Respir Dis Vol 123, p.659-664, 1981. Crapo RO, Morris AH, Clayton PD, Nixon CR. Lung Volumes in Healthy Nonsmoking Adults. Bull europ Physiopath resp, 419-425, 18, 1982.
	Morris	MO	Morris, James F., Koski, Arthur, Lavon Johnson. Spirometric Standards for Healthy Non-Smoking Adults. American Review of Respiratory Disease, Volume 10-3, p. 57-67, 1971 Morris, J.F. West J. Med (1976) 125:110-118.
	Hsu	HS	KH Hsu, PH Bartholomew, V Thompson, GSJ Hsieh. Ventilatory Functions of Normal children and Young Adults-Mexican-American, White, Black. I. Spirometry. J Pediatr Vol 95:14-23, 1979.
	Dockery, Wang (Harvard)	DO	X. Wang, D.W. Dockery, D. Wypij, M.E. Fay, B.G. Ferris. Pulmonary Function Between 6 and 18 Years of Age. Pediatr Pulmonol. 1993; 15:75-88.
	Polgar	PO	Polgar, Promadhat. Pulmonary Function Testing in Children: Techniques and Standards. W.B. Saunders Co., Philadelphia, 1971.
	Gutierrez (Canada)	CA	C. Gutierrez, RH Ghezzi, RT Abboud, et al. Reference values of pulmonary function tests for Canadian Caucasians. Can Respir J 2004; 11(6):414-424.
	Eigen	Ei	H Eigen, H Bieler, D Grant, K Christoph et al. Spirometric Pulmonary Function in Healthy Preschool Children. Am J Respir Crit Care Med Vol 163, 619-623, 2001.
Cherniak	CH	RM Cherniak, MB Raber. Normal Standards for Ventilatory Function using an Automated Wedge Spirometer. American Review of Respiratory Disease. Vol 106, p.38-46, 1972.	
Latin America	Pereira 1992	PE92	Carlos Alberto de Castro Pereira, Sueli da Penha Barreto, João Geraldo Simões, Francisco W.L. Pereira, José Gerson Gerstler, Joge Nakatani. Valores de referência para a espirometria em uma amostra da população brasileira adulta, Jornal de Pneumologia 18(1):10-22, maio de 1992.
	Pereira 2006, 2008	PE06	Pereira CAC et al. Espirometria em adultos 2006 and 2008. Remark: Spirometry predicted values 2006 and 2008 are identical.
	Pérez-Padilla (PLATINO)	PP06	Age > 40: Pérez-Padilla R et al. Spirometric Reference Values in 5 Large Latin American Cities for Subjects Aged 40 Years or Over. Arch Bronconeumol 2006; 42(7):317-325. Age < 40: Since the PLATINO study only applies for age ≥ 40 years NHANES-III is selected for patients with age < 40 years.
	Pérez-Padilla (Mexico)	PP01	Pérez-Padilla R, Regalado-Pineda J, Vázquez-García JC. Spirometry reproducibility and reference values in Mexican workers claiming disability. Salud Publica Mex 2001; 43:113-121.
	Pérez-Padilla (Mexico Ped.)	PP03	Pérez-Padilla R, Regalado-Pineda J et al. Spirometric Function in Children of Mexico-City Compared to Mexican-American Children. Pediatr Pulmonol 2003; 35:177-183.
	Chile 2010, 1997	CHI	Age > 18: MC Gutiérrez, GC Valdivia, LP Villarroel, GT Contreras et al. Nomogramas de ecuaciones de referencia espirométrica SER 2009. Rev Chil Enf Resir 2010; 26:9-15. Age < 18: MC Gutiérrez, FC Rioseco, AO Rojas, DZ Casanova. Reference spirometric values for the Chilean population at sea level. Rev Med Chile 1996; 124:1295-1306.
Europe	ERS (ECCS, EGKS)	ER	P.H. Quanjer. Lung Volumes and Forced Ventilatory Flows. Eur Respir J, Vol 6, Suppl 16, p. 5-40, 1993.
	Zapletal 1977	ZA	A. Zapletal, T. Paul, M. Samanek. Die Bedeutung heutiger Methoden der Lungenfunktionsdiagnostik zur Feststellung einer Obstruktion der Atemwege bei Kindern und Jugendlichen. Z. Erkrank. Atm.-Org., Volume 149, 343-371, 1977. A. Zapletal, M. Samanek, T. Paul. Upstream and total airway conductance in children and adolescents. Bull europ Physiopath resp 1982, 18, 31-37.
	Zapletal 2003	ZA03	A. Zapletal, J. Chalupová. Forced Expiratory Parameters in Healthy Preschool Children (3-6 Years of Age). Pediatr Pulmonol 2003; 35:200-207.
	Stanojevic 2009 (GLI)	ST	S. Stanojevic, A. Wade, TJ Cole, S Lum et al. Spirometry Centile Charts for Young Caucasian Children. Am J Respir Crit Care Med, Vol 180, pp 547-552, 2009. www.lungfunction.org .
	Quanjer 2012 (GLI)	QU	P.H. Quanjer, S. Stanojevic, T.J. Cole, X. Baur, G.L. Hall, B. Culver, P.L. Enright, J.L. Hankinson, M.SM. Ip, J. Zheng, J. Stocks and the ERS Global Lung Function Initiative. Multi-Ethnic Reference Values For Spirometry For The 3-95 Year Age Range. The Global Lung Function 2012 Equations. ERJ Express, 10.1183/09031936.00080312.
	Rosenthal	RO	M Rosenthal, SH Bain, D Cramer, P Helms, D Densison, A Bush, JO Warner. Lung function in white children aged 4 to 19 years: I – Spirometry. Thorax 1993; 48: 794-802.
	Austria 1988	FO88	G. Forche, K. Harnoncourt, E. Stadlober. Neue spirometrische Bezugswerte für Kinder, Jugendliche und Erwachsene. Öst. Ärztztz. 43, 15-16, 1988.
	Austria 1994	FO94	G. Forche, H. Schinko. Skriptum Spirometrie der österreichischen Gesellschaft für Pneumologie. 1994.
	Sapaldia	SA	SAPALDIA team, O Brändli, CH. Schindler, N. Künzli, R. Keller, A.P. Perruchoud. Lung function in healthy never smoking adults: reference values and lower limits of normal of a Swiss population. Thorax 1996; 51:277-283.
	Spain (Roca, SEPAR)	BA	J. Roca et al. spirometric reference values for a Mediterranean population. Bull Eur Physiopathol Respir, 18:101-102, 1982. J Castellsagué, F Burgos, J Sunyer, JA Barberà, J Roca. Prediction equations for forced spirometry from European origin populations. Respir Med 1998 Mar; 92(3):401-7.
	Garcia-Rio (SEPAR 2013)	GR	F. Garcia-Rio, M. Calle, F. Burgos, P. Casan, F. del Campo, J.B. Galdiz, J. Giner, N. Gonzalez-Mangado, F. Ortega, L.P. Maestu. Normativa SEPAR. Espirometria. Arch Bronconeumol 2013; 49(9): 388-401.
	Vilozni 2005	VO	D Vilozni, A Barak, O Efrati, A Augarten, C Springer, Y Yahav, L Bentur. The role of computer games in measuring spirometry in healthy and 'asthmatic' preschool children. Chest 2005; 128: 1146-1155.
	Klement (Russia)	KL	R.F. Klement et al. Users instructions of main spirometry indexes predicted values formulas and tables. 1986.

	Reference	Abbrev.	Predicted Normals for Spirometry Publication List
Scandinavia	Hedenström (Sweden)	HE	Female: H. Hedenström, P. Malmberg, K. Agarwal. Reference values for lung Function tests in females. Bull. Eur. Physiopathol. Respir. 21, p. 551-557, 1985. Male: H. Hedenström, P. Malmberg, H.V. Fridriksson. Reference values for lung function tests in men. Upsala J. Med. Sci., 91:299-310, 1986.
	Gulsvik (Norway)	GU	A. Gulsvik. Spirometri (Korrespondanser). Tidsskr Nor Loegeforen nr. 31, 105:2240-2, 1985.
	Berglund, Birath (Sweden)	BE	E. Berglund, G. Birath, J. Bjure, G. Grimby, I. Kjellmer, L. Sandqvist, B. Söderholm. Spirometric Studies in Normal Subjects. Acta Medica Scandinavica, Vol. 173, fasc. 2, 185-192, 1963. FEF2575, MVV; G. Birath, I. Kjellmer, L. Sandqvist. Spirometric Studies in Normal Subjects. Acta Medica Scandinavica, Vol. 173, fasc. 2, 193-198, 1963.
	Langhammer (Norway)	LA	A. Langhammer, R. Johnson, A. Gulsvik, T.L. Holmen, L. Bjermer. Forced spirometry reference values for Norwegian adults. Eur Respir J 2001; 18:770-779.
	Finnish	FI	Adult: The Scandinavian Journal of Clinical & Laboratory Investigation, Vol. 42 - Suppl 159, 1982. Pediatric: Suomen Lääkärilehti, Vol. 53, 395-402, 1998.
	Nystad	NY	W Nystad, SO Samuelson, P Nafstad, E Edvardsen, T Stensrud, JJK Joakkola. Feasibility of measuring lung function in preschool children. Thorax 2002; 57: 1021-1027.
Australia	Hibbert	HI	Marianne E. Hibbert, M App SCI, Anna Lannigan, RN, Louis I. Landau, MD, Peter D. Phelan, MD. Lung Function Values From a Longitudinal Study of Healthy Children Adolescents, Pediatric Pulmonology 7:101-109 (1989).
	Gore, Crockett	GO	CJ Gore, AJ Crockett, DG Pederson, ML Booth, A Bauman, N Owen. Spirometric standards for healthy adult lifetime nonsmokers in Australia. Eur Respir J, 1995, 8, 773-782.
Africa, Asia	Chhabra (India)	CH	S.K. Chhabra, R. Kumar, U. Gupta, M. Rahman, D.J. Dash. Prediction Equations for Spirometry in Adults from Northern India. Indian J Chest Dis Allied Sci 2014; 56:221-225.
	Dejsomritrutai (Thailand)	DE	Dejsomritrutai W, Nana A, Maranetra N, et al. Reference spirometric values for healthy lifetime nonsmokers in Thailand. J Med Assoc Thai 2000; 83: 457-466.
	Ethiopia	ET	Y.A. Mengesha Y. Mekonnen. Spirometric lung function tests in normal non-smoking Ethiopian men and women. Thorax 1985; 40:465-468.
	Indonesia	IN	Hasil Penelitian Tim Pneumobile Project Indonesia 1992.
	Ip (China, Hongkong)	IP	M.S.M. Ip et al. Updated Spirometric Reference Values for Adult Chinese in Hong Kong and Implications on Clinical Utilization. CHEST 2006 ; 129 : 384-392 M.S.M. Ip et al. Lung Function Reference Values in Chinese Children and Adolescents in Hong Kong. Am J Respir Crit Care Med Vol 162, 2000, 424-429.
	JRS 2001	JR01	日本人のスパイログラムと動脈血液ガス分圧基準値 日本呼吸器学会肺生理専門委員会 2001年4月
JRS 2014	JR14	M. Kubota et al. Reference values for spirometry, including vital capacity, in Japanese adults with LMS method and compared with previous values. Respiratory investigation 52 (2014) 242-250.	

	Reference	Abbrev.	Predicted Normals for Lung Volumes and Diffusion Capacity Publications
North America	Ayers	Ay	Ayers LN, Ginsberg ML, Fein J, Wasserman K. Diffusing capacity and interpretation of diffusing defects. West J Med 1975; 123:255-264.
	Burrows	Bu	Burrows BJ, Kasik JE, Niden AH, Barclay WR. Clinical usefulness of the single-breath pulmonary diffusing capacity test. Am Rev Respir Dis 1961; 84:798-806.
	Cotes	Co	Cotes JE. Lung function, 4 th ed. Oxford: Blackwell Scientific, 1979.
	Crapo	Cr	Crapo RO, Morris AH. Standardized single breath normal values for carbon monoxide diffusing capacity. Am Rev Respir Dis 1981; 123:185-189.
	Goldman & Becklake	GB	Goldman HI, Becklake MR. Respiratory function tests; normal values at median altitudes and the prediction of normal results. Am Rev Tuberc. 1959 Apr;79(4):457-67.
	Knudson	Kn	Knudson RJ, Kaltentbom WT, Knudson DE, Burrows B. The single-breath carbon monoxide diffusing capacity: Reference equations derived from a healthy nonsmoking population and effects of hematocrit. Am Rev Respir Dis 1987; 135: 805–811.
	McGrath & Thompson	MT	McGrath MW, Thompson ML. The effect of age, body size and lung volume change on alveolar-capillary permeability and diffusing capacity in man. J Physiol 1959; 146:572-582.
	Miller	Mi	Miller A, Thornton JC, Warshaw R, Anderson H, Teirstein AS, Selikoff IJ. Single breath diffusing capacity in a representative sample of the population of Michigan, a large industrial state. Am Rev Respir Dis 1983; 127:270-277.
	NHANES	NH	LM Neas, J Schwartz. The determinants of pulmonary diffusing capacity in a national sample of U.S. adults. Am J Respir Crit Care Med, 153(2), 1996, 656-664.
	Gutierrez (Canada)	CA	C Gutierrez, RH Ghezzi, RT Abboud, et al. Reference values of pulmonary function tests for Canadian Caucasians. Can Respir J 2004; 11(6):414-424.
Polgar	Po	Polgar, Promadhat. Pulmonary Function Testing in Children: Techniques and Standards. W.B. Saunders Co., Philadelphia, 1971.	
Europe Scandinavia	ERS	ER	P.H. Quanjer. Lung Volumes and Forced Ventilatory Flows. Eur Respir J, Vol 6, Suppl 16, p. 5-40, 1993.
	Zapletal	Za	A. Zapletal, T. Paul, M. Samanek. Die Bedeutung heutiger Methoden der Lungenfunktionsdiagnostik zur Feststellung einer Obstruktion der Atemwege bei Kindern und Jugendlichen. Z. Erkrank. Atm.-Org., Volume 149, 343-371, 1977.
	Roca	Ro	Roca J, Rodriguez-Roisin R, Cobo E, Burgos F, Perez J, Clausen JL. Single breath carbon monoxide diffusing capacity prediction equations from a Mediterranean population. Am Rev Respir Dis 1990; 141:1026-1032. Roca J, Burgos F, Barbera JA, Sunyer J, Rodriguez-Roisin R, Castellsague J, Snchis J, Antoo JM, Casan P, Clausen JL. Prediction equations for plethysmographic lung volumes. Respir Med, 1998, 92, 454-460.
	Hedenström	He	<u>Female</u> : H. Hedenström, P. Malmberg, K. Agarwal. Reference values for lung Function tests in females. Bull. Eur. Physiopathol. Respir. 21, p. 551-557, 1985. <u>Male</u> : H. Hedenström, P. Malmberg, H.V. Fridriksson. Reference values for lung function tests in men. Upsala J. Med. Sci., 91:299-310, 1986.
	Gulsvik	Gu	Gulsvik A, Bakke P, Humerfelt S, Omenaas E, Tosteson T, Weiss ST, Speizer FE. Single breath transfer factor for carbon monoxide in an asymptomatic population of never smokers. Thorax 1992; 47:167-173.
	Verbanck	SV	S Verbanck, BR Thompson et al. Ventilation heterogeneity in the acinar and conductive zones of the normal ageing lung. Thorax 2012; 67:789-795.
	Klement (Russia)	KL	R.F. Klement et al. Users instructions of main spirometry indexes predicted values formulas and tables. 1986.
	Stanojevic (GLI)	ST17	S. Stanojevic et al. Official ERS technical standards: Global Lung Function Initiative reference Values for the carbon monoxide transfer factor for Caucasians. Eur Respir J 2017; 50: 17000 10.
Other	Pereira 2008	PE08	Neder JA et al. Volumes pulmonares, diusão de CO, VVM e força muscular.
	Thompson	Th	Thompson BR, Johns DP, et al. Predicted equations for single breath diffusing capacity (Tlco) in a middle aged caucasian population. Thorax 2008; 63:889-893.
	Ip (China Hong Kong)	Ip	M.S.M. Ip et al. Reference values of diffusing capacity of non-smoking Chinese in Hong Kong. Respirology (2007) 12, 599-606.
	Kim	KI	Kim YJ, Hall GL, Christoph K, Tabbey R, Yu Z, Tepper RS, Eigen H. Pulmonary diffusing capacity in healthy caucasian children. Ped Pul 47:469-475 (2012).
	Vazquez Garcia	VG	Vazquez-Garcia JC, Perez-Padilla R, Lopez V, Muino A, Schönfeld P, Jardim J, Montes de Oca M, Casas A. Normal values of inspiratory capacity and carbon monoxide uptake in the lung in Latin America. ALAT, 2016.

