Does physical fitness enhance lung function in children and young adults?

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Online Data Supplement

Table S1a. Changes in $V'O_{2max}$ and spirometry between assessments in the Odense study.

		Measure	Mean change (SD)	95% CI
Female	**Age 9-15**	$V'O_{2max}$ (L/min)	0.98 (0.27)	0.95, 1.01
	(n=366)	FEV_1 (L)	1.70 (0.30)	1.67, 1.73
		FVC (L)	1.82 (0.34)	1.79, 1.85
		FEV_1/FVC (%)	2.6 (4.7)	2.1, 3.0
	Age 15-21	$V'O_{2max}$ (L/min)	-0.06 (0.33)	-0.10, -0.02
	(n=266)	FEV_1 (L)	-0.03 (0.24)	-0.06, 0.00
		FVC (L)	0.30 (0.30)	0.26, 0.33
		FEV_1/FVC (%)	-7.3 (3.8)	-7.7, -6.8
	Age 21-29	$V'O_{2max}$ (L/min)	-0.10 (0.39)	-0.15, -0.06
	(n=276)	FEV_1 (L)	-0.03 (0.23)	-0.06, 0.00
		FVC (L)	0.18 (0.30)	0.14, 0.22
		FEV_1/FVC (%)	-4.2 (4.2)	-4.7, -3.7
Male	**Age 9-15**	$V'O_{2max}$ (L/min)	1.57 (0.44)	1.53, 1.61
	(n=420)	FEV_1 (L)	2.23 (0.50)	2.18, 2.27
		FVC (L)	2.54 (0.58)	2.48, 2.59
		FEV_1/FVC (%)	0.5 (4.7)	0.1, 1.0
	Age 15-21	$V'O_{2max}$ (L/min)	0.39 (0.55)	0.33, 0.45
	(n=301)	FEV_1 (L)	0.55 (0.49)	0.50, 0.61
		FVC (L)	1.10 (0.60)	1.03, 1.17
		FEV_1/FVC (%)	-7.0 (4.0)	-7.5, -6.5
	Age 21-29	$V'O_{2max}$ (L/min)	-0.27 (0.49)	-0.32, -0.21
	(n=306)	FEV_1 (L)	-0.09 (0.31)	-0.13, -0.06
		FVC (L)	0.16 (0.42)	0.11, 0.21
		FEV_1/FVC (%)	-3.7 (3.7)	-4.1, -3.2

Only non-pregnant participants with complete data at each age are included.

Table S1b. Changes in $V'O_{2max}$ and spirometry between assessments in the Dunedin study.

		Measure	Mean change (SD)	95% CI
Female	**Age 15-26**	$V'O_{2max}$ (L/min)	0.21 (0.56)	-0.15, 0.28
	(n=288)	FEV_1 (L)	0.08 (0.28)	0.05, 0.11
		FVC (L)	0.36 (0.32)	0.32, 0.40
		FEV_1/FVC (%)	-6.7 (4.1)	-7.1, -6.2
	Age 26-32	$V'O_{2max}$ (L/min)	-0.85 (0.54)	-0.91, -0.79
	(n=301)	FEV_1 (L)	-0.05 0.21)	-0.08, -0.03
		FVC (L)	0.15 (0.25)	0.12, 0.18
		FEV_1/FVC (%)	-3.7 (3.4)	-4.1, -3.3
	Age 32-38	$V'O_{2max}$ (L/min)	-0.13 (0.18)	-0.15, -0.11
	(n=369)	FEV_1 (L)	-0.22 (0.23)	-0.24, -0.19
		FVC (L)	-0.14 (0.25)	-0.17, -0.11
		FEV_1/FVC (%)	-2.6 (3.7)	-3.0, -2.2
Male	**Age 15-26**	$V'O_{2max}$ (L/min)	0.98 (0.80)	0.91, 1.07
	(n=371)	FEV_1 (L)	0.96 (0.67)	0.90, 1.02
		FVC (L)	1.48 (0.74)	1.41, 1.56
		FEV_1/FVC (%)	-5.8 (4.9)	-6.3, -5.3
	Age 26-32	$V'O_{2max}$ (L/min)	-0.51 (0.65)	-0.58, -0.45
	(n=403)	FEV_1 (L)	-0.22 (0.33)	-0.25, -0.18
		FVC (L)	0.01 (0.36)	-0.02, 0.05
		FEV_1/FVC (%)	-3.5 (3.9)	-3.9, -3.1
	Age 32-38	$V'O_{2max}$ (L/min)	-0.29 (0.28)	-0.32, -0.26
	(n=436)	FEV_1 (L)	-0.28 (0.31)	-0.31, -0.25
		FVC (L)	-0.24 (0.35)	-0.27, -0.21
		FEV_1/FVC (%)	-1.7 (3.5)	-2.1, -1.4

Only non-pregnant participants not taking beta-blockers with complete data at each age are included.

Table S2a. Cross-sectional analyses by sex. Odense Study:

		Female				Male				
	Dependent	**n**	**Coeff (95% CI)**	**p**		**n**	**Coeff (95% CI)**	**p**		**p(int)**
Age 9	FEV_1 (% predicted)	**647**	**2.8 (1.8, 3.8)**	**<0.001**		**646**	**2.9 (1.9, 3.8)**	**<0.001**		0.058
	FVC (% predicted)	**647**	**2.4 (1.8, 3.1)**	**<0.001**		**646**	**2.5 (1.5, 3.5)**	**<0.001**		0.257
	FEV_1/FVC (%)	647	0.3 (-0.1, 0.8)	0.170		646	0.3 (-0.2, 0.7)	0.246		**0.038**
Age 15	FEV_1 (% predicted)	**346**	**2.9 (1.1, 4.7)**	**0.001**		**406**	**3.5 (1.8, 5.1)**	**<0.001**		0.222
	FVC (% predicted)	**346**	**3.8 (2.2, 5.5)**	**<0.001**		**406**	**3.7 (2.2, 5.2)**	**<0.001**		0.386
	FEV_1/FVC (%)	**346**	**-0.8 (-2.0, 0.0)**	**0.050**		406	-0.4 (-1.3, 0.5)	0.428		0.503
Age 21	FEV_1 (% predicted)	**421**	**3.6 (2.4, 4.7)**	**<0.001**		**450**	**2.6 (1.5, 3.7)**	**<0.001**		0.229
	FVC (% predicted)	**421**	**3.4 (2.3, 4.5)**	**<0.001**		**450**	**3.1 (2.1, 4.1)**	**<0.001**		0.810
	FEV_1/FVC (%)	421	0.5 (-0.6, 0.7)	0.883		450	-0.4 (-1.1, 0.3)	0.242		0.207
Age 29	FEV_1 (% predicted)	**371**	**2.2 (1.1, 3.4)**	**<0.001**		**412**	**3.1 (1.8, 4.3)**	**<0.001**		0.434
	FVC (% predicted)	**371**	**1.9 (0.8, 3.0)**	**0.001**		**412**	**2.3 (1.1, 3.4)**	**<0.001**		0.626
	FEV_1/FVC (%)	371	0.1 (-0.6, 0.8)	0.843		**412**	**0.7 (0.1, 1.4)**	**0.034**		0.485

The independent (predictor) variable is maximal oxygen uptake ($V'O_{2max}$ (L/min)) converted to sex-specific standard deviation scores at each age (Z-scores). Coefficients represent the difference in lung function associated with each standard deviation of $V'O_{2max}$. Analyses are adjusted for height and weight, current asthma, and current smoking (age 15 onwards). Analyses exclude pregnant women. p(int) is the p value for the sex*lung function interaction.

Table S2b. Cross-sectional analyses by sex. Dunedin Study:

		Female				Male				
	Dependent	**n**	**Coeff (95% CI)**	**p**		**n**	**Coeff (95% CI)**	**p**		**p(int)**
Age 15	FEV_1 (% predicted)	**402**	**1.7 (0.0, 3.4)**	**0.047**		**431**	**4.9 (2.9, 6.8)**	**<0.001**		**<0.001**
	FVC (% predicted)	**402**	**2.6 (1.0, 4.3)**	**0.002**		**431**	**3.8 (2.1, 5.4)**	**<0.001**		**0.022**
	FEV_1/FVC (%)	402	-0.8 (-1.7, 0.2)	0.102		431	0.8 (-0.3, 1.9)	0.151		**0.001**
Age 26	FEV_1 (% predicted)	**339**	**1.8 (0.5, 3.2)**	**0.009**		**429**	**2.6 (1.3, 3.9)**	**<0.001**		0.476
	FVC (% predicted)	**339**	**2.3 (1.0, 3.6)**	**0.001**		**429**	**3.2 (1.9, 4.4)**	**<0.001**		0.482
	FEV_1/FVC (%)	339	-0.3 (-1.0, 0.4)	0.377		429	-0.3 (-1.0, 0.4)	0.416		0.561
Age 32	FEV_1 (% predicted)	401	1.2 (-0.0, 2.3)	0.052		**462**	**2.4 (1.3, 3.6)**	**<0.001**		0.172
	FVC (% predicted)	401	0.7 (-0.5, 1.9)	0.253		**462**	**2.6 (1.5, 3.6)**	**<0.001**		0.055
	FEV_1/FVC (%)	401	0.4 (-0.2, 1.0)	0.161		462	0.0 (-0.6, 0.6)	0.977		0.482
Age 38	FEV_1 (% predicted)	**430**	**1.9 (0.7, 3.0)**	**0.002**		**460**	**1.6 (0.4, 2.8)**	**0.008**		0.678
	FVC (% predicted)	**430**	**1.9 (0.8, 3.0)**	**0.001**		**460**	**1.4 (0.3, 2.5)**	**0.016**		0.492
	FEV_1/FVC (%)	430	0.1 (-0.5, 0.7)	0.773		460	0.1 (-0.5, 0.8)	0.641		0.900

The independent (predictor) variable is maximal oxygen uptake ($V'O_{2max}$ (L/min)) converted to sex-specific standard deviation scores at each age (Z-scores). Coefficients represent the difference in lung function associated with each standard deviation of $V'O_{2max}$. Analyses are adjusted for height and weight, current asthma, and current smoking (age 15 onwards). Analyses exclude pregnant women. p(int) is the p value for the sex*lung function interaction.

Table S3a. Longitudinal analyses by sex. Odense Study:

		Female				Male				
Age	**Dependent**	**n**	**Coeff (95% CI)**	**p**		**n**	**Coeff (95% CI)**	**p**		**p(int)**
9 to 15	FEV_1 (% predicted)	334	0.7 (-0.2, 1.6)	0.128		**384**	**2.9 (1.9, 4.0)**	**<0.001**		**<0.001**
	FVC (% predicted)	**334**	**1.0 (0.2, 1.9)**	**0.021**		**384**	**2.9 (1.9, 3.8)**	**<0.001**		**<0.001**
	FEV_1/FVC (%)	334	-0.3 (-0.8 0.3)	0.317		384	-0.1 (-0.6, 0.5)	0.819		0.892
15 to 21	FEV_1 (% predicted)	**249**	**1.1 (0.4, 1.9)**	**0.004**		**290**	**1.1 (0.3, 2.0)**	**0.009**		0.987
	FVC (% predicted)	**249**	**0.9 (0.1, 1.7)**	**0.020**		**290**	**1.5 (0.7, 2.4)**	**0.001**		0.330
	FEV_1/FVC (%)	249	0.1 (-0.3, 0.6)	0.571		290	-0.2 (-0.8, 0.3)	0.389		0.357
21 to 29	FEV_1 (% predicted)	265	0.5 (-0.3, 1.2)	0.207		297	0.6 (-0.1, 1.3)	0.098		0.690
	FVC (% predicted)	265	0.8 (0.0, 1.6)	0.065		297	0.5 (-0.2, 1.3)	0.146		0.749
	FEV_1/FVC (%)	265	-0.2 (-0.7, 0.2)	0.320		297	0.1 (-0.3, 0.6)	0.539		0.303

The independent (predictor) variable is the change in maximal oxygen uptake ($V'O_{2max}$) between ages converted to sex-specific standard deviation scores. Coefficients represent the difference in lung function associated with each standard deviation change in $V'O_{2max}$. Analyses are adjusted for lung function at the younger age, weight, height, asthma, and smoking at each age. Pregnant women are excluded. p(int) is the p value for the sex*lung function interaction

Table S3b. Longitudinal analyses by sex. Dunedin Study:

		Female				Male				
Age	**Dependent**	**n**	**Coeff (95% CI)**	**p**		**n**	**Coeff (95% CI)**	**p**		**p(int)**
15 to 26	FEV_1 (% predicted)	284	0.4 (-0.6, 1.3)	0.442		**366**	**1.4 (0.3, 2.5)**	**0.016**		0.191
	FVC (% predicted)	284	0.8 (-0.1, 1.7)	0.090		**366**	**2.0 (1.0, 3.0)**	**<0.001**		0.122
	FEV_1/FVC (%)	284	-0.4 (-0.8, 0.1)	0.138		366	-0.3 (-0.8, 0.3)	0.328		0.609
26 to 32	FEV_1 (% predicted)	298	-0.7 (-1.4, 0.1)	0.096		401	-0.3 (-1.1, 0.4)	0.343		0.600
	FVC (% predicted)	298	-0.6 (-1.4, 0.2)	0.115		401	-0.2 (-0.9, 0.5)	0.548		0.656
	FEV_1/FVC (%)	298	-0.1 (-0.4, 0.3)	0.738		401	-0.1 (-0.5, 0.3)	0.606		0.626
32 to 38	FEV_1 (% predicted)	369	0.2 (-0.5, 0.9)	0.569		436	-0.3 (-0.9, 0.4)	0.406		0.412
	FVC (% predicted)	369	0.3 (-0.3, 1.0)	0.307		436	-0.2 (-0.8, 0.3)	0.435		0.306
	FEV_1/FVC (%)	369	-0.1 (-0.5, 0.3)	0.596		436	-0.1 (-0.4, 0.2)	0.656		0.973

The independent (predictor) variable is the change in maximal oxygen uptake ($V'O_{2max}$) between ages converted to sex-specific standard deviation scores. Coefficients represent the difference in lung function associated with each standard deviation change in $V'O_{2max}$. Analyses are adjusted for lung function at the younger age, weight, height, asthma, and smoking at each age. Pregnant women and participants taking beta-blockers at either assessment are excluded. p(int) is the p value for the sex*lung function interaction

Table S4a. Cross-sectional analyses at age 15 in the Odense study adjusted for pubertal status.

	Dependent	**Coeff. (95% CI)**	**p**
Girls (n=340)	FEV_1 (% predicted)	**2.8 (0.9, 4.6)**	**0.003**
	FVC (% predicted)	**3.7 (2.1, 5.4)**	**<0.001**
	FEV_1/FVC (%)	**-1.1 (-2.1, -0.1)**	**0.039**
Boys (n=398)	FEV_1 (% predicted)	**2.9 (1.2, 4.6)**	**0.001**
	FVC (% predicted)	**3.4 (1.9, 4.9)**	**<0.001**
	FEV_1/FVC (%)	-0.7 (-1.6, 0.3)	0.178
All (n=738)	FEV_1 (% predicted)	**2.9 (1.6, 4.0)**	**<0.001**
	FVC (% predicted)	**3.5 (2.4, 4.6)**	**<0.001**
	FEV_1/FVC (%)	**-0.8 (-1.5, 0.1)**	**0.019**

The independent (predictor) variable is maximal oxygen uptake ($V'O_{2max}$ (L/min)). Coefficients represent the difference in lung function associated with each unit of $V'O_{2max}$. Analyses are adjusted for height, weight, current asthma, current smoking (age 15 onwards) and Tanner pubertal status. Beta values are standardised regression coefficients representing the standard deviation difference in lung function associated with each standard deviation difference in $V'O_{2max}$.

Table S4b. Tanner pubertal stages among boys and girls at age 15 in the Odense study

Tanner stage	**Girls n(%)**	**Boys n(%)**
1	0	2 (0.5%)
2	1 (0.3%)	9 (2.3%)
3	14 (4.1%)	31 (7.8%)
4	233 (68.5%)	217 (54.5%)
5	92 (27.1%)	139 (35%)

Table S5a. Cross-sectional analyses at each age excluding participants with asthma: Does lung function predict fitness?

Odense Study:

	Dependent	**Coeff (95% CI)**	**p**
Age 9 (n=1244)	FEV_1 (% predicted)	**3.1 (2.2, 4.0)**	**<0.001**
	FVC (% predicted)	**2.5 (1.8, 3.13)**	**<0.001**
	FEV_1/FVC (%)	0.3 (-0.1, 0.6)	0.117
Age 15 (n=676)	FEV_1 (% predicted)	**3.1 (1.9, 4.4)**	**<0.001**
	FVC (% predicted)	**3.8 (2.7, 5.0)**	**<0.001**
	FEV_1/FVC (%)	**-0.8 (-1.5, -0.1)**	**0.020**
Age 21 (n=775)	FEV_1 (% predicted)	**3.2 (2.3, 3.9)**	**<0.001**
	FVC (% predicted)	**3.3 (2.5, 4.1)**	**<0.001**
	FEV_1/FVC (%)	-0.2 (-0.7, 0.3)	0.400
Age 29 (n=685)	FEV_1 (% predicted)	**2.7 (1.7, 3.6)**	**<0.001**
	FVC (% predicted)	**1.9 (1.0, 2.7)**	**<0.001**
	FEV_1/FVC (%)	**0.6 (0.7, 1.1)**	**0.025**

The independent (predictor) variable is maximal oxygen uptake ($V'O_{2max}$ (L/min)). Coefficients represent the difference in lung function associated with each unit of $V'O_{2max}$. Analyses are adjusted for height and weight and current smoking (age 15 onwards). Participants reporting asthma and pregnant women are excluded.

Table S5b. Cross-sectional analyses at each age excluding participants with asthma: Does lung function predict fitness?

Dunedin Study:

	Dependent	**Coeff (95% CI)**	**p**
Age 15 (n=712)	FEV_1 (% predicted)	**2.6 (1.3, 3.9)**	**<0.001**
	FVC (% predicted)	**2.7 (1.5, 3.9)**	**<0.001**
	FEV_1/FVC (%)	0.2 (-0.9, 0.6)	0.666
Age 26 (n=630)	FEV_1 (% predicted)	**2.1 (1.1, 3.1)**	**<0.001**
	FVC (% predicted)	**2.8 (1.8, 3.7)**	**<0.001**
	FEV_1/FVC (%)	**-0.5 (-1.0, 0.0)**	**0.047**
Age 32 (n=713)	FEV_1 (% predicted)	**1.7 (0.8, 2.5)**	**<0.001**
	FVC (% predicted)	**1.5 (0.7, 2.3)**	**<0.001**
	FEV_1/FVC (%)	0.2 (-0.3, 0.6)	0.428
Age 38 (n=742)	FEV_1 (% predicted)	**1.7 (0.8, 2.5)**	**<0.001**
	FVC (% predicted)	**1.6 (0.7, 24)**	**<0.001**
	FEV_1/FVC (%)	0.1 (-0.3, 0.5)	0.686

The independent (predictor) variable is maximal oxygen uptake ($V'O_{2max}$ (L/min)). Coefficients represent the difference in lung function associated with each unit of $V'O_{2max}$. Analyses are adjusted for height, weight, pack-years smoking. Pregnant women, participants reporting asthma, and those taking beta-blockers are excluded.

Table S6a. Longitudinal analyses excluding participants with asthma. Do changes in fitness predict lung function?

Odense Study

	Dependent	**Coeff (95% CI)**	**p**
Age 9-15 (n=676)	FEV_1 (% predicted)	**1.9 (1.2, 2.6)**	**<0.001**
	FVC (% predicted)	**2.1 (1.4, 2.7)**	**<0.001**
	FEV_1/FVC (%)	-0.2 (-0.5, 0.2)	0.343
Age 15-21 (n=476)	FEV_1 (% predicted)	**1.1 (0.5, 1.7)**	**<0.001**
	FVC (% predicted)	**1.3 (0.7, 1.9)**	**<0.001**
	FEV_1/FVC (%)	-0.1 (-0.5, 0.2)	0.457
Age 21-29 (n=485)	FEV_1 (% predicted)	**0.6 (0.0, 1.1)**	**0.038**
	FVC (% predicted)	**0.6 (0.0, 1.2)**	**0.037**
	FEV_1/FVC (%)	0.0 (-0.3, 0.3)	0.977

The independent (predictor) variable is the change in maximal oxygen uptake (V'O2max (L/min)) between ages. Coefficients represent the difference in lung function associated with the change in V'O2max. Analyses are adjusted for lung function at the younger age, weight, height, and smoking at each age. Pregnant women and participants reporting asthma at either assessment are excluded.
The independent (predictor) variable is the change in maximal oxygen uptake ($V'O_{2max}$) between ages converted to sex-specific standard deviation scores. Coefficients represent the difference in lung function associated with each standard deviation change in $V'O_{2max}$. Analyses are adjusted for lung function at the younger age, weight, height, asthma, and smoking at each age. Pregnant women and participants taking beta-blockers at either assessment are excluded. p(int) is the p value for the sex*lung function interaction

Table S6b. Longitudinal analyses excluding participants with asthma. Do changes in fitness predict lung function?

Dunedin Study

	Dependent	**Coeff (95% CI)**	**p**
Age 15-26 (n=505)	FEV_1 (% predicted)	**0.9 (0.1, 1.6)**	**0.032**
	FVC (% predicted)	**1.3 (0.5, 2.0)**	**0.001**
	FEV_1/FVC (%)	-0.3 (-0.6, 0.1)	0.185
Age 26-32 (n=541)	FEV_1 (% predicted)	-0.4 (-1.0, 0.1)	0.139
	FVC (% predicted)	-0.4 (-0.9, 0.1)	0.149
	FEV_1/FVC (%)	0.0 (-0.3, 0.2)	0.784
Age 32-38 (n=638)	FEV_1 (% predicted)	-0.12 (-0.5, 0.4)	0.785
	FVC (% predicted)	0.0 (-0.4, 0.5)	0.837
	FEV_1/FVC (%)	-0.1 (-0.4, 0.1)	0.311

The independent (predictor) variable is the change in maximal oxygen uptake ($V'O_{2max}$ (L/min)) between ages. Coefficients represent the difference in lung function associated with the change in $V'O_{2max}$. Analyses are adjusted for lung function at the younger age, weight, height, and smoking at each age. Pregnant women, participants reporting asthma, and those taking beta-blockers at either assessment are excluded.