

Supplemental Material

To Albertsson-Wikland K et al: Weight references for total, prepubertal/basic, and pubertal weight aligned for onset of puberty – using the QEPS growth model

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QEPS weight (wQEPS) growth model

The QEPS height model (1) was transformed to a corresponding QEPS weight model. The QEPS-model for height and the corresponding QEPS-functions will be called hQEPS-model and hQEPS-functions to avoid confusion with respectively wQEPS-model and wQEPS-functions. The wQEPS-model for individual growth in weight was defined by a combination of four basic shape-invariant growth functions: a prepubertal quadratic wQ -function, a prepubertal negative exponential wE -function, a nonlinear pubertal wP -function, and a stop wS -function, describing total weight in $\text{kg}^{0.5}$ as a function of age:

$$wT(\text{age}|WHF) = wQ(\text{age}/WHF) + wE(\text{age}) + wP(\text{age}/WHF) - wS(\text{age}/WHF),$$

modified by an individual weight-height-factor (WHF) as shown in **Figure S1**. $WHF=0$ stands for a normal body constitution, $WHF>0$ for heavier and $WHF<0$ for leaner body constitution. The WHF has no influence on the wE -function.

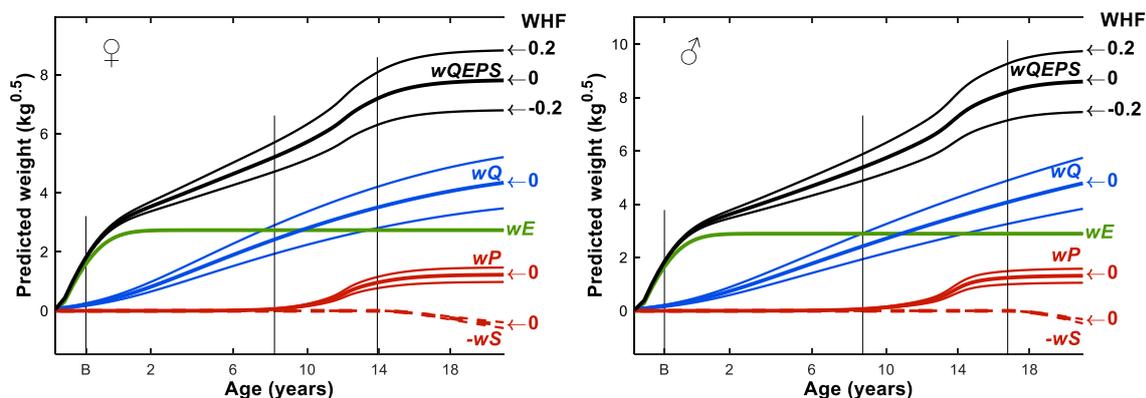


Figure S1: Total weight ($wQEPS$) in $\text{kg}^{0.5}$ for normal, heavy and lean body constitution with four growth functions wQ , wE , wP and wS .

wQ is a quadratic growth function, wE a negative exponential growth function, wP a pubertal growth function and wS a stop function modelling end of growth for function wQ . The weight-height-factor (WHF) can modify the growth functions wQ , wP and wS , but not wE . The $wQEPS$ -function is shown for normal ($WHF=0$, thick solid lines), heavy ($WHF=0.2$) and lean ($WHF=-0.2$) body constitution. Birth (B), start of wP and wS -function are marked with a vertical line. The age scale is transformed hyperbolically to stretch the early growth period.

Fitting the wQEPS model with QEPS height functions

The wQEPS model was fitted with customised hierarchical nonlinear regression on two levels:

-On group level individual QEPS weight was predicted from corresponding individual QEPS height functions as $hT(\text{age}, \beta)$, with 14 nonlinear regression coefficients, $\beta_1 - \beta_{14}$, common for all individuals within each gender of the model group.

On individual level the $hT(\text{age}, \beta)$ -function was adjusted for individual body constitution by adding $hQPS(\text{age}, \beta) * b_i$, with $b_i = WHF$, the weight-height-factor for individual body constitution. The β are equal to the 14 regression coefficients modelled on group level.

In summary the wQEPS-model was specified with QEPS height functions as predictors:

$$wT(\text{age}|WHF) = hT(\text{age}, \beta) + hQPS(\text{age}, \beta) * WHF$$

In the fitting procedure the median WHF of the model group was restricted to be zero, so $wT(\text{age}|WHF=0) = hT(\text{age}, \beta)$, an individual's predicted weight for normal body constitution (see

Figure S2). The hP -function was transformed in two wP subfunctions, $wP=wPA+wPB$ (see Figure S3). A more detailed description on how the $wQEPS$ -model was computed with nonlinear regression coefficients can be found on page 6 after “QEPS weight growth model, with detailed mathematical equations”.

Figure S2

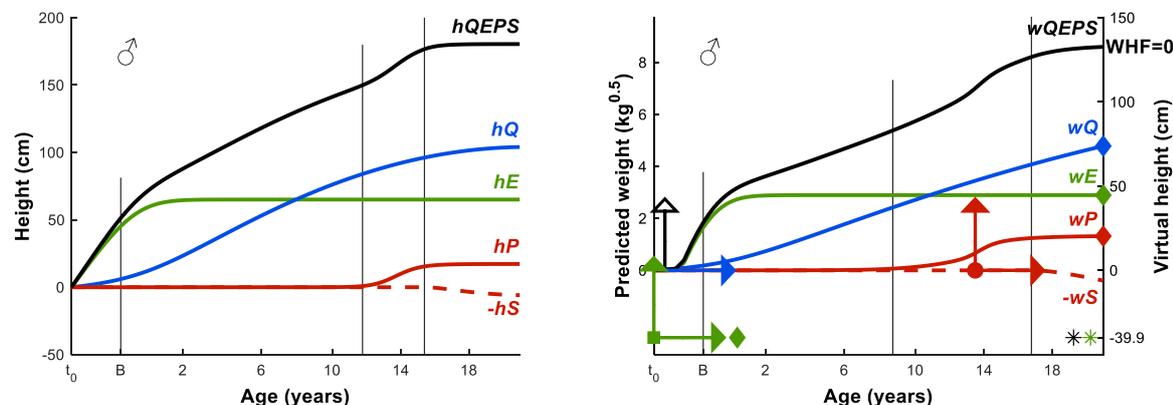


Figure S2: QEPS height and predicted normal weight ($WHF=0$)

Transforming individual QEPS height functions, $hQEPS$, for boys (left panel) into individual predicted weight functions for normal body constitution ($wQEPS(age/WHF=0)$, right panel) using $wQEPS(age/WHF=0)=hQEPS(age, \beta)$, with 14 nonlinear regression coefficients, $\beta_1 - \beta_{14}$, common for all individuals within each gender of the model group. The arrows in the right panel modify the time and height scale of the QEPS height functions. The horizontal arrows from left to right change the time-scale of the hE , hQ and hP -functions with 3+1 coefficients, since the hP -function is transformed in two wP subfunctions, $wP=wPA+wPB$ (see Figure S3). Likewise, the height-scale of the hE and hP -functions indicated with vertical solid arrows is changed with 2+1 coefficients. The solid green square indicates the upwards shift of the origin of the hE -function. The solid red circle indicates the mid puberty shift at $hAgeP50$ for the wPA -function. The previous 9 coefficients define the typical shape of the QEPS weight functions, common to all individual wQ , wE , wP and wS functions. The four solid diamonds adjust the deviation from typical mean parameter value 1 for individual estimated QEPS height scale parameters $Q_{heightscale}$, $E_{heightscale}$, $P_{heightscale}$, and $E_{timescale}$. The previous 13 coefficients define a kind of intermediate QEPS virtual height functions (in virtual cm, right panel right-hand scale with origin negative for $virtualheightE$ and $virtualheightQEPS$ -function). The 14th coefficient gives the conversion to predicted normal weight ($kg^{0.5}$, left-hand scale) by changing the scale of all $virtualheightQEPS$ -functions as indicated by the black open vertical arrow. Birth (B), start of wP and wS -function are marked with a vertical line. Notice the later start of wE -function growth, and the longer duration and earlier onset of puberty for weight compared to height.

Figure S3

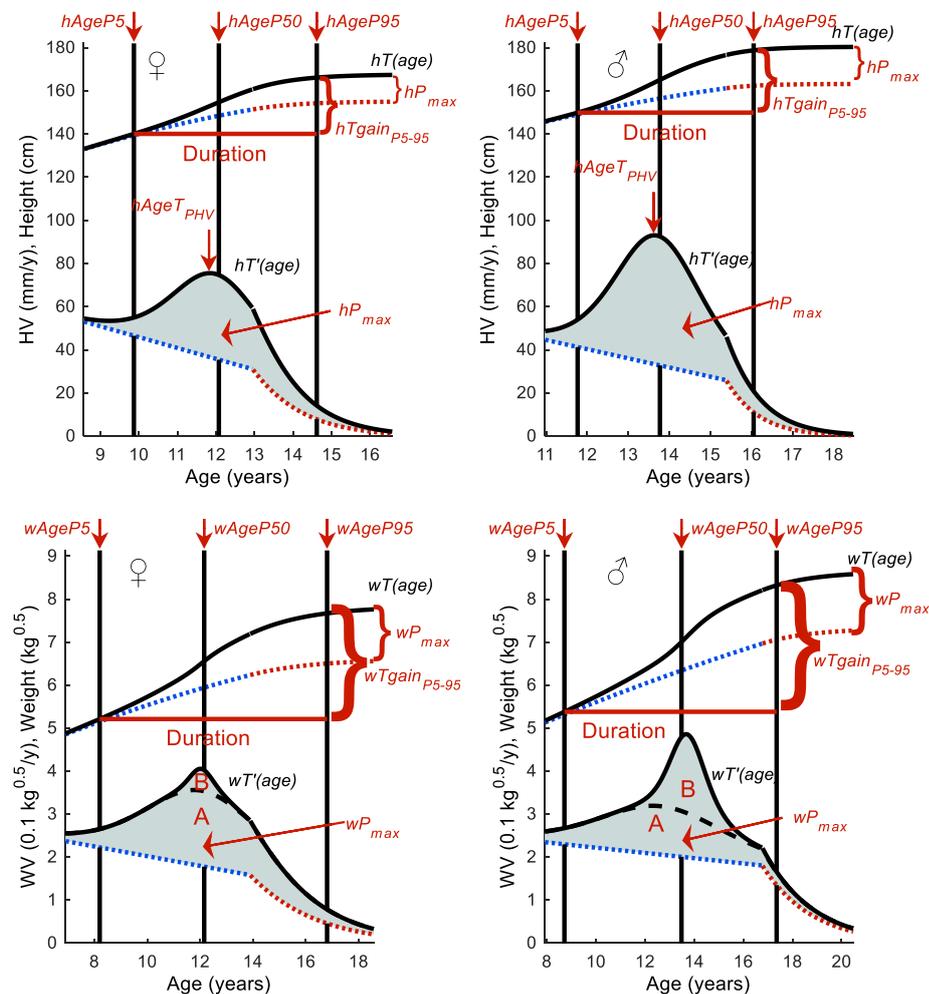


Figure S3: Detailed QEPS pubertal growth estimates for height (upper panels) and weight (lower panels) for girls and boys during puberty

Typical mean growth functions during puberty for height and height velocity (upper panels) and weight and weight velocity (lower panels) for girls (left panels) and boys (right panels). Onset, $hAgeP5$ for height and $wAgeP5$ for weight, as age at which 5% of the P -function growth is reached, mid puberty, $hAgeP50$ for height and $wAgeP50$ for weight, as age at which 50% of the P -function growth is reached and Age at Peak Height Velocity $hAgeT_{PHV}$, of the total height function hT from the QEPS height model is reached and end of pubertal growth, $hAgeP95$ for height and $wAgeP95$ for weight, as age at which 95% of the P -function growth is reached are marked with vertical lines. The duration of puberty for height and weight is indicated with horizontal lines. The pubertal height or weight gain is shown as the growth from $AgeP5$ to $AgeP95$ from the total growth curve ($Tgain_{P5-95}$), and from the specific pubertal part ($Pmax$); both shown at the top of the figure in the height and weight graphs and as the marked area in the height velocity and weight velocity graphs. The marked areas in the weight velocity graphs show that wP is a sum of two subfunctions, wPA and wPB . The wPB subfunctions for both girls and boys were restricted in the fitting procedure to have $wAgePB50$ equal to $hAgeP50$. For girls $wPBmax$ is 13% of $wPmax$ and for boys 41% of $wPmax$.

wQEPS method for reference development

References for age were constructed for both total weight and prepubertal weight and were computed for the QEPS weight reference population in two steps comparable to the ‘QEPS method’ used for the references (2, in corresponding supplement) with QEPS height functions here replaced by corresponding QEPS weight functions. Special pubertal growth-aligned references ($wQEPS_{pub}=wT_{pub}$, $wQES_{pub}$ and wP_{pub}) were constructed by aligning individual function values for $wT(age)$, $wQES(age)$ and $wP(age)$ by the individual age at onset of the pubertal growth spurt, defined as $hAgeP5$, the age at which 5% of height specific hP -function growth was reached (see Figure S3, upper panels).

Statistical evaluations

Longitudinal growth data for each individual, including height and weight measurements were exported to Matlab®(version 9.3 R2017b, The MathWorks). The Matlab Curve Fitting Toolbox was used for estimating individual QEPS height parameters by nonlinear fitting. The parameters of the wQEPS model were also fitted with Matlab. The standard error of the residuals was used to assess goodness-of-fit. To simplify general mathematical formulae, age was assumed to be equal to age corrected for GA, here 37–43 weeks. Figure 7 was prepared with SAS software, version 9.3, all other figures with Matlab.

QEPS weight growth model, with detailed mathematical equations

The QEPS height model (1) was transformed to a corresponding QEPS weight model. The QEPS-model for height and the corresponding QEPS-functions will be called hQEPS-model and hQEPS-functions to avoid confusion with respectively wQEPS-model and wQEPS-functions. The wQEPS-model for individual growth in weight was defined by a combination of four basic shape-invariant growth functions: a prepubertal quadratic wQ -function, a prepubertal negative exponential wE -function, a nonlinear pubertal wP -function, and a stop wS -function, describing total weight in $\text{kg}^{0.5}$ as a function of age:

$$wT(\text{age}|WHF) = wQ(\text{age}|WHF) + wE(\text{age}) + wP(\text{age}|WHF) - wS(\text{age}|WHF),$$

modified by an individual weight-height-factor (WHF). The wQEPS model was fitted with customised hierarchical nonlinear regression on two levels:

-On group level individual QEPS weight was predicted from corresponding individual QEPS height functions as $hT(\text{age}, \beta)$, with 14 nonlinear regression coefficients, $\beta_1 - \beta_{14}$, common for all individuals within each gender of the model group.

-On individual level the $hT(\text{age}, \beta)$ -function was adjusted for individual body constitution by adding $hQPS(\text{age}, \beta) * b_i$, with $b_i = WHF$, the weight-height-factor for individual body constitution. The β are equal to the 14 regression coefficients modelled on group level.

In summary the wQEPS-model was specified with QEPS height functions as predictors:

$$wT(\text{age}|WHF) = hT(\text{age}, \beta) + hQPS(\text{age}, \beta) * WHF$$

In the fitting procedure the SummarWHF of the model group was restricted to be zero, so $wT(\text{age}|WHF=0) = hT(\text{age}, \beta)$, an individual's predicted weight for normal body constitution.

Summarizing the published QEPS height functions not adjusted with β

The hQEPS-functions not adjusted with β gave QEPS total height in cm as a function of age:

$$hT(\text{age}) = hQ(\text{age}) + hE(\text{age}) + hP(\text{age}) - hS(\text{age}).$$

The core of the QEPS height growth model was the typical mean growth function $mhT(\text{age}) = mhQ(\text{age}) + mhE(\text{age}) + mhP(\text{age}) - mhS(\text{age})$, with four typical mean growth functions mhQ , mhE , mhP and mhS , having a shape common to all individual functions hQ , hE , hP and hS . To fit observed height measurements, six parameters were estimated with separate curve fitting for each individual: four height-scale parameters, $Q_{heightscale}$, $E_{heightscale}$, $P_{heightscale}$, $S_{heightscale}$ modifying the scale of the y-axis of respectively mhQ , mhE , mhP and mhS ; and two time-scale parameters, $hE_{timescale}$ and $hP_{timescale}$ modifying the scale of the age-axis of respectively mhE and mhP . The height scale parameter $S_{heightscale}$ was a function of the individual mid puberty parameter $hAgeP50$ (for known $Q_{heightscale}$ and $hP_{timescale}$) and was replaced by this parameter in the equations.

The QEPS typical mean height parameter values for [Girls; Boys] are:

$hQ_{linear}=[9.949738642531; 9.405436598935]$, $hQ_{quadr}=[-0.2514723125035; -0.2125041669303]$,
 $t_0=[-0.6627671903241; -0.6494334970962]$,
 $mhE_{max}=[62.54785757042; 65.04702921079]$, $hE_k=[1.823677860659; 1.833525449549]$.
 $mhP_{max}=[12.5200654; 17.2388724]$, $hP_{linear}=[1.25295488; 1.38636865]$, $hP_{quadr}=[0.0236603572; 0.0217097456]$,
 $mhAgeP50=[12.0742839; 13.7679612]$,
 $mhAgeS_0=[12.95101524; 15.379483666]$, $mhAgeS_{max}=[14.2767288; 16.198706]$,
and the estimated individual height parameters are $Q_{heightscale}$, $E_{heightscale}$, $hE_{timescale}$, $P_{heightscale}$, $hP_{timescale}$ and $hAgeP50$.

Adjusting the hQEPS-functions with β and WHF

Four basic shape-invariant wQEPS-functions could be expressed as adjusted hQEPS- functions as follows:

$$wQ(\text{age}|WHF) = hQ(\text{age}, \beta) + hQ(\text{age}, \beta) * WHF,$$

$$wE(\text{age}) = hE(\text{age}, \beta),$$

$$wP(\text{age}|WHF) = hP(\text{age}, \beta) + hP(\text{age}, \beta) * WHF,$$

$$wS(\text{age}|WHF) = hS(\text{age}, \beta) + hS(\text{age}, \beta) * WHF.$$

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The nonlinear regression coefficients β are specified below, numbered $\beta_1 - \beta_{14}$ and followed by an acronym indicating which function is adjusted. The estimated values for [Girls; Boys] are:

$\beta_1 = \beta_{Thsc} = 0.5 * [0.09524013; 0.1326592]$;
 $\beta_2 = \beta_{Qhdev} = [1.411883; 1.665129]$; $\beta_3 = \beta_{Qtsc} = [1.473111; 2.179397]$;
 $\beta_4 = \beta_{Ehdev} = [0.5727472; 0.5374842]$; $\beta_5 = \beta_{Ehsc} = [1.594266; 1.219128]$;
 $\beta_6 = \beta_{Etddev} = [0.715742; 0.7393889]$; $\beta_7 = \beta_{Etscc} = [0.8399047; 0.8153451]$;
 $\beta_8 = \beta_{E0shift} = [42.15111; 35.59802]$;
 $\beta_9 = \beta_{Phdev} = [0.5273259; 0.5826083]$; $\beta_{10} = \beta_{Phsc} = [2.053879; 1.158501]$;
 $\beta_{11} = \beta_{AgePA50shift} = [0.1376324; -1.027676]$; $\beta_{12} = \beta_{PAtscc} = \beta_3 * [1.299556; 1.142874]$;
 $\beta_{13} = \beta_{PBhsc} = [0.1324334; 0.4074699]$; $\beta_{14} = \beta_{PBtscc} = [0.3846266; 0.6856515]$;
with $T = Q + E + P - S$, $hsc = \text{heightscale}$, $hdev = \text{deviation from } hsc = 1$, $E0shift = \text{shift E zero point}$,
 $P = PA + PB$, $tsc = \text{timescale}$, $tdev = \text{deviation from } tsc = 1$, $AgePA50shift = \text{Mid puberty shift of PA-function}$

Figure S2 beta

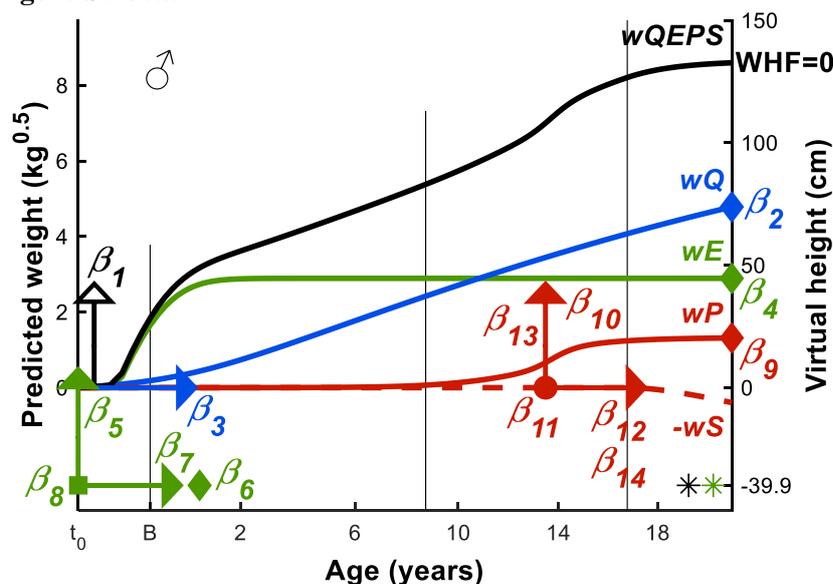


Figure S2 beta: Figure S2 with nonlinear regression coefficients β added.

The hQ -function was adjusted with nonlinear regression coefficients $\beta_1, \beta_2, \beta_3$:

$$hQ(\text{age}, \beta) = \beta_1 Q_{\text{weightscale}} mhQ(\text{age}, \beta_3)$$

with $Q_{\text{weightscale}} = 1 + \beta_2 (Q_{\text{heightscale}} - 1)$

and $mhQ(\text{age}, \beta_3) = wQ_{\text{linear}} (\text{age}_{\text{Qvirtual}} - t_0) + wQ_{\text{quadr}} (\beta_3) (\text{age}_{\text{Qvirtual}} - t_0)^2$

with $\text{age}_{\text{Qvirtual}} = (\text{age} \leq wAgeQ_{\text{max}}) \text{age} + (\text{age} > wAgeQ_{\text{max}}) wAgeQ_{\text{max}}$,

$wQ_{\text{linear}} = hQ_{\text{linear}} / \beta_3$ and $wQ_{\text{quadr}} = hQ_{\text{quadr}} / \beta_3^2$,

and $wAgeQ_{\text{max}} = t_0 - wQ_{\text{linear}} / (2wQ_{\text{quadr}})$.

The hE -function was adjusted with coefficients $\beta_1, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8$:

$$hE(\text{age}, \beta) = \beta_1 (E_{\text{weightscale}} mhE(\text{age}, hE_{\text{timescale}}, \beta_5, \beta_6, \beta_7) - \beta_8)$$

with $E_{\text{weightscale}} = 1 + \beta_4 (E_{\text{heightscale}} - 1)$ and $mhE(\text{age}, hE_{\text{timescale}}, \beta_5, \beta_6, \beta_7) = \beta_5$

$$mhE_{\text{max}} \left(1 - e^{-wE_k \frac{\text{age} - t_0}{wE_{\text{timescale}}}} \right)$$

with $wE_k = hE_k / \beta_7$ and $wE_{\text{timescale}} = 1 + \beta_6 (hE_{\text{timescale}} - 1)$.

Function $hE(\text{age}, \beta)$ was restricted to be nonnegative by setting all negative values to zero.

The hP -function was adjusted with coefficients $\beta_1, \beta_9, \beta_{10}, \beta_{11}, \beta_{12}, \beta_{13}, \beta_{14}$:

$$hP(\text{age}, \beta) = \beta_1 P_{\text{weightscale}} mhP(\text{age}, hAgeP50, hP_{\text{timescale}}, \beta_{10}, \beta_{11}, \beta_{12}, \beta_{13}, \beta_{14})$$

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with $P_{weightscale} = 1 + \beta_9 (P_{heightscale} - 1)$
and $mhP(age, hAgeP50, hP_{timescale}, \beta_{10}, \beta_{11}, \beta_{12}, \beta_{13}, \beta_{14}) = \beta_{10} mhP_{max} *$

$$\left((1 - \beta_{13}) \frac{1}{1 + e^{\frac{wPA_{linear} \frac{wAgePA50 - age}{hP_{timescale}} + hP_{quadr} \left(\frac{wAgePA50 - age}{hP_{timescale}} \right)^2}} + \beta_{13} \frac{1}{1 + e^{\frac{wPB_{linear} \frac{wAgePB50 - age}{hP_{timescale}} + hP_{quadr} \left(\frac{wAgePB50 - age}{hP_{timescale}} \right)^2}} \right)$$

with $wAgePA50 = hAgeP50 + \beta_{11} hP_{timescale}$ and $wAgePB50 = hAgeP50$
and $wPA_{linear} = hP_{linear} / \beta_{12}$ and $wPB_{linear} = hP_{linear} / \beta_{14}$.

The hS -function was adjusted with coefficients $\beta_1, \beta_2, \beta_3, \beta_{11}, \beta_{12}$:

$$hS(age, \beta) = -\beta_1 Q_{weightscale} wQ_{quadr} d_{sq}^2 \left(1 - \left(\frac{ageQ_{virtual} - ageS_{virtual}}{d_{sq}} - 1 \right)^2 \right)$$

with $Q_{weightscale}, wQ_{quadr}, ageQ_{virtual}, wAgeQ_{max}$ as defined for $hQ(age, \beta)$,

$$d_{sq} = wAgeQ_{max} - wAgeS_{max},$$

with $wAgeS_{max} = wAgePA50 + hP_{timescale} \beta_{12} (mhAgeS_{max} - mhAgeP50)$,

with $wAgePA50$ as defined for function $hP(age, \beta)$,

and $ageS_{virtual} = (age \leq wAgeS_0) age +$

$$(age > wAgeS_0) \left(wAgeS_0 + hP_{timescale} c \left(1 - e^{-\frac{age - wAgeS_0}{hP_{timescale} c}} \right) \right),$$

with $wAgeS_0 = wAgePA50 + hP_{timescale} \beta_{12} (mhAgeS_0 - mhAgeP50)$

and $c = \beta_{12} (mhAgeS_{max} - mhAgeS_0)$.

The resulting $hT(age, \beta)$ -function, giving individual total QEPS weight predicted from corresponding QEPS height, was adjusted for individual body constitution by adding $hQPS(age, \beta) * b_i$, with $b_i = WHF$, the weight-height-factor for individual body constitution.

Fitting the QEPS weight model

The nonlinear regression coefficients β were estimated by minimizing the residual sum of squares:

$$SSE = \sum_{i=1}^n \| \mathbf{wT}_{iObserved} - \mathbf{hT}_i(\mathbf{x}_i | \beta) - \mathbf{hQPS}_i(\mathbf{x}_i | \beta) b_i \|^2,$$

for vector columns $\mathbf{wT}_{iObserved}$ with n_i observed weights, vector columns $\mathbf{hT}_i(\mathbf{x}_i | \beta)$ and $\mathbf{hQPS}_i(\mathbf{x}_i | \beta)$ with corresponding n_i function values at visit ages \mathbf{x}_i and individual weight-height-factor WHF computed as,

$$b_i = \frac{(\mathbf{wT}_{iObserved} - \mathbf{hT}_i(\mathbf{x}_i | \beta))' \mathbf{hQPS}_i(\mathbf{x}_i | \beta)}{\mathbf{hQPS}_i(\mathbf{x}_i | \beta)' \mathbf{hQPS}_i(\mathbf{x}_i | \beta)}.$$

In the fitting procedure the median b_i of the model group ($n=1779$ girls and $n=1816$ boys) was restricted to be zero by computing $b_{geomean} = (\prod (1+b_i))^{1/n} - 1$ and adjusting $b_i = b_i - b_{geomean}$ for all i . Taken into account that $(1+WHF)$ is lognormal distributed and the geometric or multiplicative mean of the log-normal distribution equals the median. The standard error of the residuals was for girls $0.12207 \text{ kg}^{0.5}$ ($SSE=748.41, df=50225$) and for boys $0.11917 \text{ kg}^{0.5}$ ($SSE=706.81, df=49771$).

Abbreviations

E	negative exponential growth function of age, $hE(age)$ for height and $wE(age)$ for weight
$E_{heightscale}$	individual height-scale ratio, modifying the height-scale of the hE -function growth
E_{max}	hE_{max} gain in adult height due to hE -function and wE_{max} gain due to wE -function growth
$E_{weightscale}$	individual weight-scale ratio, modifying the weight-scale of the wE -function growth
$hAgeP5$	age at which 5% of height hP -function growth is reached
$hAgeP50$	age at which 50% of height hP -function growth is reached
$hAgeQ_{max}$	age when the maximum of the hQ -function growth is reached: for girls at 19.1 years and for boys at 21.5 years

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$hAgeT_{PHV}$	age at Peak Height Velocity of the total height function hT
$hEtimescale$	individual time-scale ratio; modifying the time-scale of the hE -function growth and therefore inversely related to the tempo of hE . The origin is at t_0 , the age when length is theoretically zero, $hE(t_0)=0$, $hQ(t_0)=0$
GA	gestational age
P	function describing the pubertal growth, as $hP(age)$ for height and $wP(age)$ for weight
$Pheightscale$	individual height-scale ratio, modifying the height-scale of the P -function
$Pmax$	$hPmax$ pubertal gain in adult height due to the hP -function growth and $wPmax$ pubertal gain due to wP -function growth
$hPtimescale$	individual time-scale ratio, modifying the time-scale of the hP -function and is therefore inversely related to the tempo of hP . The origin is at $hAgeP50$, the age at which 50% of the individual hP -function growth is reached
Q	quadratic growth function of age, specified as $hQ(age)$ for height and $wQ(age)$ for weight
QE	sum of Q and E -function giving non pubertal growth $QE(age)$, excluding puberty (P and S functions) equal to total prepubertal height (hQE) or weight (wQE) as a function of age; the growth during prepubertal years specified as $hQE(age)$ for height and $wQE(age)$ for weight
QES	QE growth stopped at the end of puberty by S -function, with $QES(age) = QE(age) - S(age)$, also called basic growth function, specified as $hQES(age)$ for height and $wQES(age)$ for weight
$QESmax$	gain in adult height or weight due to QES -function growth, so $QESmax = QEmax - SmaxS$, specified as $hQESmax$ for height and $wQESmax$ for weight
$Qheightscale$	individual height-scale ratio, modifying the height-scale of the hQ -function
$Qmax$	$hQmax$ gain in adult height due to hQ -function and $wQmax$ gain in adult weight due to wQ -function growth
$Qweightscale$	individual height-scale ratio, modifying the weight-scale of the wQ -function
S	stop function $S(age)$, stopping the Q -function at the end of growth, specified as $hS(age)$ for height and $wS(age)$ for weight
$Smax$	reduction in adult height or weight due to stopping the Q -function growth at the end of growth, specified as $hSmax$ for height and $wSmax$ for weight
T	total height or weight function: $T(age) = QEPS(age) = Q(age) + E(age) + P(age) - S(age)$, specified as $hT(age)$ for height and $wT(age)$ for weight
t_0	age when length is theoretically zero, $T(t_0)=0$, $E(t_0)=0$, $Q(t_0)=0$, at about -0.66 years for girls and -0.65 years for boys
$Tmax$	modelled total adult height, $hTmax = hEmax + hQmax + hPmax - hSmax$ and modelled total adult weight, $wTmax = wEmax + wQmax + wPmax - wSmax$
$wAgeP5$	age at which 5% of height wP -function growth is reached
$wAgeP50$	age at which 50% of height wP -function growth is reached
$wPtimescale$	individual time-scale ratio, modifying the time-scale of the wP -function and is therefore inversely related to the tempo of wP . The origin is at $wAgeP50$, the age at which 50% of the individual wP -function growth is reached

Figure S4

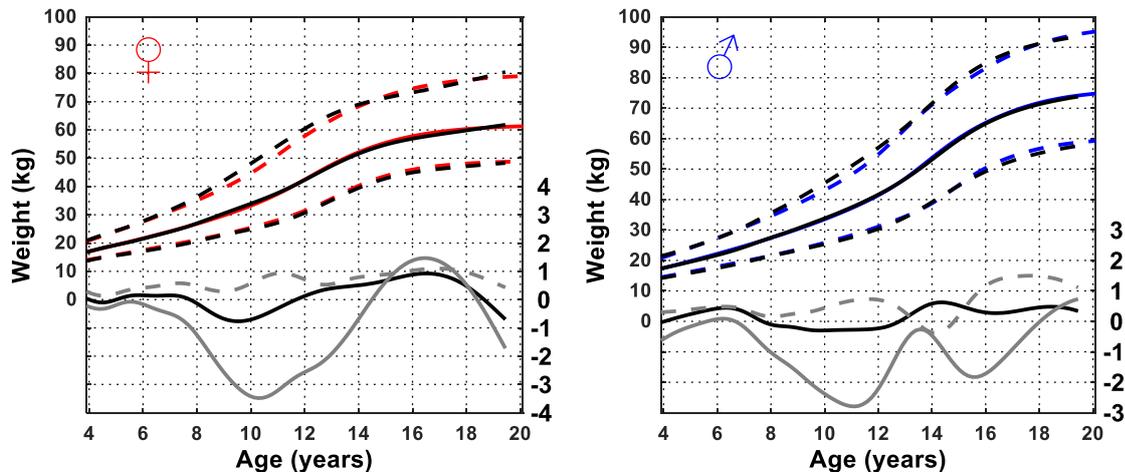


Figure S4: Total QEPS weight vs Total LMS weight

Comparison of the total 1990 QEPS weight reference (red/blue) with the published 1990 LMS weight reference (black).

Total weight references for children aged 4-18 years are shown for girls on the left and for boys on the right. The difference between the total weights obtained by the two methods, QEPS-derived or LMS-derived, are shown in the bottom of each figure. Differences in mean (thick solid black line), in +2SDS (thin solid black line) and in -2SDS (dotted black line) are shown.

Visual inspection shows that, although the mean curves based on the QEPS and LMS methods are quite similar, lines representing ± 2 SDS of the QEPS-derived reference are closer to the mean curves than lines of the LMS-derived reference. The variation of the QEPS-derived reference is smaller since it is based on fitted weight functions, excluding all sorts of weight error, whereas the LMS-derived reference is fitted on observed weight measurements, including such error.

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