Limitations of Dutch Growth Research Foundation Commercial Software Weight Velocity for Age Standard Deviation Score

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Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
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Conflict of interest: None declared

Patient: Male, 1-year-old
Final Diagnosis: Healthy
Symptoms: None
Medication: —
Clinical Procedure: Foster care
Specialty: Pediatrics and Neonatology

Objective: Rare disease

Background: The commercial software for hospitals, *Weight Velocity for Age Standard Deviation Score* (SDS_{WVA}), claims to document the growth and development of children, although published details are unavailable. The statistics-derived parameter SDS_{WVA} includes the *weight velocity* at age *t*, *WV(t)* (weight gained between *t* and (*t*–1.23) years, divided by 1.23), and 3 standard weight velocity curves at average age *AA*, defined as *AA*=*t*–1.23/2 years. SDS_{WVA} denotes the number of standard deviations that *WV(t)* deviates from the *0 SD* weight velocity at *AA*. *WV(t)* yielded erroneous outcomes when applied to weights of a seriously underweight boy with an allergy to cows' milk who showed strong weight growth after being fed on food free of cows' milk. The SDS_{WVA} software tacitly suggests that it is more accurate than *WV(t)*.

Case Report: The case of this boy was previously described in this Journal. Using $SDS_{WVA}(t,AA)$ software, his weight growth was analyzed by his third pediatrician, beginning at age 1.5 years. The diagnosis of the mother with Pediatric Condition Falsification was confirmed, adding 6 months to foster care, which totalled 8.5 months. Testing of the SDS_{WVA} software on the boy's weight curve yielded results that were complex, nontransparent, and as erroneous as *WV(t)*, explaining the misdiagnosis by the third pediatrician.

Conclusions: SDS_{WVA} software should not be used for children under 3 years and during variable weight behavior. Erroneous performance, unpublished details, and an error identified in their new but untested software make the Dutch Growth Research Foundation unlikely to meet the 2020 European Union regulations for *in vitro* medical devices.

MeSH Keywords: Body Weight Changes • Case Reports • Diagnostic Errors • Software

Full-text PDF: https://www.amjcaserep.com/abstract/index/idArt/925551

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Background

The *Dutch Growth Research Foundation (DGRF)* (*https://www.growthanalyser.org*) claims that its commercial software products, *Growth Analyser*, document the growth and development of children "*with ease*". However, details on the methods, interpretation of outcomes, and validation have not been published. The software assessment of (weight) growth at age *t*, called *weight velocity* (*WV(t)*), uses the weight gained over an interval of 1.23 years, or over the age itself if *t* <1.23 years (Eq. 1 of the Appendix), to distinguish normal from abnormal child development. Abnormal growth of young children, especially when an easy explanation is lacking, can greatly affect the quality of life of the child and the parents, e.g., when a caregiver is falsely accused of Pediatric Condition Falsification (PCF), a rare form of child abuse [1]. Therefore, their software could play a role in accurate growth assessment. However, evidence suggests that outcomes of a computerized system provide physicians with feelings of absolute certainty (see eg [2] and Discussion, second paragraph). This software should therefore be very accurate, transparent, and well tested before being marketed.

We previously showed that *WV(t)* provides seriously erroneous outcomes as a consequence of 2 concomitant issues [1]. First, the typical day-to-day fluctuations in the weights of young children cause corresponding fluctuations in weight velocity. Second, the very long age interval of 1.23 years used for *WV(t)* can cause any abrupt change in weight to propagate as a 1.23-year periodic series of "*inverse-weight-velocity-echoes*", making *WV(t)* an exceedingly complex and nontransparent function of age [1]. In October 2019, a local Dutch Radio and TV Station in Utrecht summarized our findings journalistically on its website (*https://www.rtvutrecht.nl/nieuws/1970056/*, in Dutch). The *DGRF* replied that its commercial software output is not weight velocity but *Weight Velocity for Age Standard Deviation Score* (SDS_{WVA}). The foundation sells this software exclusively to hospitals.

In the Appendix below we explain how the SDS_{WVA} method was derived by the *DGRF* from the statistics-based *Standard Deviation Score* (notation *SDS(t)*), also called Z-score (see e.g. *https://en.wikipedia.org/wiki/Standard_score*). The SDS_{WVA} includes *WV(t)* as well as weight velocities of standard weight curves, *+1 SD*, *0 SD* and *–1 SD, not* at the same age *t* but at *average age AA*, halfway between *t* and (*t*-1.23) years. Thus, in children aged <1.23 years, *AA*=*t*/2 (Appendix, Eq. 3). The reason the *DGRF* chose this approach is not known. However, the greater precision of $SDS_{WVA}(t,AA)$ than of *WV(t)* outcomes may have been expected, because average age *AA* may compensate for the long period of 1.23 years used for *WV(t)*. Nevertheless, *WV(t)* is still the key parameter in the *DGRF* software program, with all its complexities [1]. This paper was designed to show that the tacit expectation was not fulfilled.

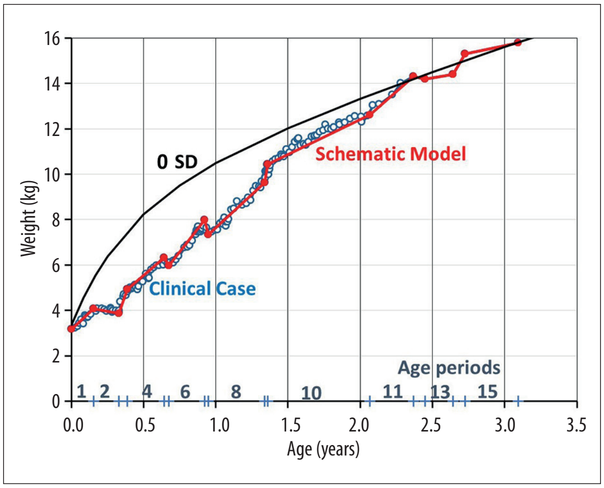

Figure 1. Clinical weights (blue open circles) [1,3]; *Schematic Model* weight curve with 15 consecutive age periods (red points), age periods indicated with blue labels on horizontal axis [1]; and *0 SD* standard weight curve (black line) [5]. Each age period and corresponding *Period-Averaged-Weight-Velocity* (period; PAWV in kg/year) are: (1;5.7), (2;–1.14), (3;17.1), (4;5.5), (5;–9.5), (6;7.5), (7;–25.5), (8;6.2), (9;45.0), (10;3.55), (11;5.12), (12;–1.31), (13;1.02), (14;10.6), and (15;1.36).

Case Report

Earlier

The erroneous behavior of *WV(t)* was evident when applied to the weight curve of an infant boy [1]. Figure 1 shows his weight curve at 15 consecutive age periods (see *Schematic Model* below). Briefly [3], the boy was born at 39 gestational weeks as the sixth child of normal parents, weighting 3.18 kg. He was hospitalized for 2 weeks during age period 2 because of a slightly negative weight gain. Allergy to cows' milk was suspected, with subsequent removal of cows' milk from his diet resulted in a rapid weight gain (periods 3 and 4). Despite impressive weight growth, during periods 3–11 (age 0.33–2.4 years), which was 1.3- to 2.3-fold greater than the corresponding weight growth on the *0 SD* standard weight curve, his first pediatrician stated in a legal summary of the second of 3 juvenile court hearings held in the boy's case that "*the boy does not grow*" and ordered his mother to increase his food intake stepwise to 3.5 times normal (period 8) [3]. During period 8 (period 6 of [3]), the boy's weight velocity was 2.1 times the *0 SD* weight velocity. This pediatrician, as well as the second pediatrician, who was willing to confirm all the erroneous statements made by the first pediatrician during the second juvenile court hearing, appeared unable to distinguish (low) weight from (exceptional) weight growth [3]. Based on these reports, the mother was diagnosed with PCF and the boy was placed in foster care for 8.5 months.

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Table 1. Summary of the 3 cases of standard definition scores.

Case	Description
(a) $SDS_{WVA}(t,AA)$	Weight Velocity for Age Standard Deviation Score of the clinical weights with WV and AA
(b) $SDS_{SM}(t,AA)$	Weight Velocity for Age Standard Deviation Score of the Schematic Model (SM) with 15 PAWV's and AA
(c) $SDS_{SM}(t)$	Standard Deviation Score of the Schematic Model (SM) with 15 PAWV's but without AA

WV – weight velocity by Eq. 1; AA – average age by Eq. 3; PAWV – period average weight velocity.

Case Report

The present case begins during period 10, after the boy was in foster care for 2.5 months, at the time his third pediatrician was appointed. This pediatrician analyzed his weight growth with *DGRF*'s software $SDS_{WVA}(t,AA)$. This software confirmed the diagnosis of PCF, as explained in the second paragraph of the Discussion, which caused the boy to be continued in foster care for another 6 months. However, the report by this pediatrician contributed to the ending of foster care by another juvenile judge after 8.5 months.

SDS(t) and $SDS_{SM}(t,AA)$ were applied to 2 weight curves of this boy (Figure 1). The first weight curve (the clinical weights) was of the actual measured weights of the boy until age 3.1 years [1,3], whereas the second weight curve, the *Schematic Model* of his weights [1], replaced the individually measured weights with weights clustered in 15 consecutive age periods by least-squares fitting. The virtually linear increase in weight in all age periods gave 15 individual but accurate *Period-Averaged-Weight-Velocities* (Table 1 in [1], summarized in the caption to Figure 1). For comparison we also show the *0 SD* standard weight curve.

We calculated (a) $SDS_{WVA}(t,AA)$, the *Weight Velocity for Age Standard Deviation Score* of the boy's clinical weights, and (b) $SDS_{SM}(t,AA)$, the *Weight Velocity for Age Standard Deviation Score* of the *Schematic Model* [1] with their exact *Period-Averaged-Weight-Velocities*, but including average age *AA*. We compared these 2 predictions with (c) $SDS_{SM}(t)$, the exact *Standard Deviation Score* of the Schematic Model with *Period-Averaged-Weight-Velocities* but without *AA*, here considered the standard for *SDS*-calculations, as these are arguably the most exact approximations of real weight growth velocity. The Table 1 summarizes the 3 case examples. This approach shows the effects on *SDS*-calculations of natural weight fluctuations, the 1.23 years of inter-weight age interval for *WV*, and the use of an average age *AA*.

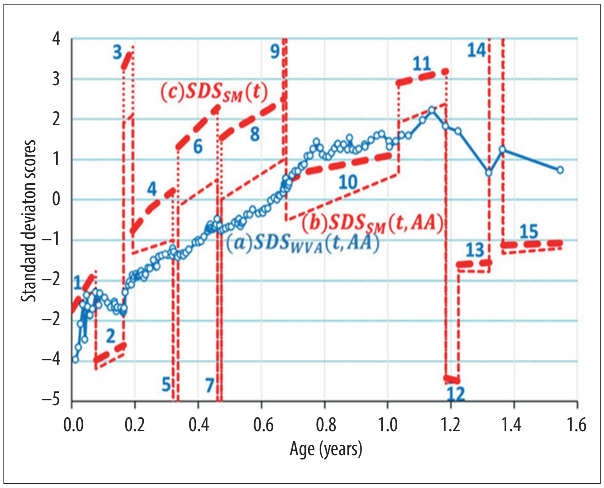

Figure 2. (a) $SDS_{WVA}(t,AA)$, *Weight Velocity for Age Standard Deviation Score* of the clinical weights (blue dots); (b) $SDS_{SM}(t,AA)$, *Weight Velocity for Age Standard Deviation Score* of the *Schematic Model*, with average age *AA* included but using the *Period-Averaged-Weight-Velocity* for each of the 15 periods (red dashed lines); and (c) $SDS_{SM}(t)$ of the *Schematic Model* using the *Period-Averaged-Weight-Velocity* for each of the 15 periods but not *AA* as the reference standard (solid red dashed lines). The Table 1 summarizes the description of the 3 cases.

Results

Figure 1 shows that, when the boy's life became normal again, the *0 SD* weight curve seemed to fit him well. Figure 2 (see Table 1 for descriptions) shows (a) $SDS_{WVA}(t,AA)$ of the clinical weights with *WV* and *AA* (dark blue open dots); (b) $SDS_{SM}(t,AA)$ of the schematic model with *Period-Averaged-Weight-Velocities* and *AA* (thin red dashed lines); and (c) $SDS_{SM}(t)$ of the schematic model with *Period-Averaged-Weight-Velocities* but without *AA* (solid red dashed lines), which served as the reference standard. The (dark blue) clinical case (a) basically duplicated all errors previously identified in the *WV(t)* curve [1], thus strongly *underestimating* values of about 2 *SDS* during period 8 (with bizarre prescribed food intake of 3.5 times normal [3]), and *overestimating* values of about 0.5 *SDS* during period 10 (with normal food intake while in foster care). *Schematic Model* case (b), with *AA* included, deviated less from the reference standard $SDS_{SM}(t)$, but still markedly underestimated weight gain during most periods, except for age periods 1, 2, and 12–15. The reference standard $SDS_{SM}(t)$ showed realistic trends during all periods. Interestingly, $SDS_{SM}(t)$ values

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during periods 1, 4, 6, 8, and 11, when the boy was at home, were up to 3 standard deviations greater than those of clinical case (a), $SDS_{WVA}(t,AA)$; but were somewhat lower when the boy was fed normal food while in foster care (period 10). The influence of *AA* can be inferred by comparing schematic model case (b), $SDS_{SM}(t,AA)$ with *AA*, and (c), $SDS_{SM}(t)$ without AA. The average age *AA* significantly reduced accuracy during most periods when compared with the best possible outcomes of $SDS_{SM}(t)$, although their relative behavior, such as between periods 8 and 10, remained correct.

Discussion

This study showed that the software package of the *DGRF* was severely limited when applied to an infant with an allergy to cows' milk. The package does not provide possible limitations of the software. Without that knowledge, use of this type of software can be harmful for innocent young children.

The key finding of this study was that the *Weight Velocity for Age Standard Deviation Score* of the clinical weights did not provide greater accuracy, as tacitly suggested. Rather, this approach is at best equally erroneous as weight velocities, a finding that was not surprising in view of the significance of *WV(t)* for $SDS_{WVA}(t,AA)$ (Eq. 4 of the Appendix). Crucially, this software predicted that $SDS_{WVA}(t,AA)$ was much lower during period 8 than during period 10 rather than being *much larger*, similar to findings with *WV(t)* [1]. Because of these errors, the third pediatrician [3], unconditionally believing these software outcomes, supposed wrongly that the boy's mother was starving him and uncritically confirmed the false accusation of PCF [3]. This software-based misdiagnosis lengthened the boy's period in foster care by 6 months, from 2.5 to 8.5 months. To reduce the likelihood of recurrence of these family disasters, and because the *DGRF* does not provide warnings about possible erroneous outcomes, we strongly recommend that the *DGRF* provides an instruction manual that clearly describes the software output and interpretation, and includes a warning when this software should *not* be used.

Erroneous outcomes of $SDS_{WVA}(t,AA)$, relative to erroneous *WV(t)* predictions and due to natural weight fluctuations and the 1.23-year age interval, have been described [4]. Surprisingly, average age *AA* contributed to errors, as shown by comparing *SDS* outcomes of the *Schematic Model* with and without *AA*, i.e., cases (b) and (c) (Table 1). Further support comes from *SDS*-calculations (not shown) of the clinical weights, with *WV* (Eq. 1) but without *AA*, which provide *SDS* outcomes about 1 standard deviation closer to the reference standard, making it more accurate than case (a) itself, except during period 10. During that period, *SDS* values were around 2.5; the erroneous behavior during periods 8 and 10 was also retained. The problematic *SDS* outcomes in period 10 refer to the low weights prior to period 3, which occurred about 1.23 years prior to the high weights of period 10 and followed from the 3.5-fold overfeeding during period 9 and a bizarre weight increase. This resulted in exceedingly large *WV(t)*-values during period 10 [1]. Finally, precise relative *SDS*-behavior, such as in periods 8 and 10, requires more precise weight velocities than *WV(t)* of Eq. 1. Interestingly, we have reported that, against expectation, shortening of the 1.23-year age interval for *WV(t)* does not increase accuracy, as it is a consequence of the typical natural weight fluctuations in young children [4].

Additionally, we purchased version *Growth Analyser EPRS 4.1.14 (Single User Edition)*. However, when applied to the child in this study, its $SDS_{WVA}(t,AA)$ outcomes exceeded their previous as well as our calculations from Eqs. 4 by about 1 standard deviation. The foundation indeed identified a software error in the assessment of average age *AA* and offered the corrected version *Growth Analyser EPRS 4.1.15 (Single User Edition)*. We believe that selling untested software versions harms the foundation's credibility.

Conclusions

The $SDS_{WVA}(t,AA)$ retailed weight growth software is erroneous, untransparent, and may be untested. Inaccuracy is due to the combined effects of natural clinical weight fluctuations, the long 1.23-year period used for *WV(t)*, and the use of an average age *AA*. This software should *not* be used to monitor weight growth of children under 3 years of age or in children with wide weight fluctuations, irrespective of age. Unreliable software performance, the absence of published details on methods, interpretation and validation, and issues of credibility suggest that the *Dutch Growth Research Foundation* may be unable to continue commercial activities, especially in regard to the new European Union regulations for *in vitro* medical devices [4].

Acknowledgments

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Conflicts of Interest

None.

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Appendix

Description and Equations of *Standard Deviation Score*, *SDS(t)*, and *Weight Velocity for Age Standard Deviation Score*, *$SDS_{WVA}(t,AA)$*

In statistics, the *Standard Deviation Score*, *SDS(t)*, is the number of standard deviations that a data point at age *t* differs from the mean of the data set at *t* (e.g., *https://en.wikipedia.org/wiki/Standard_score*). Because growth of body weight is the subject of this study, the weight velocity of the *0 SD* standard weight curve, WV_{0SD}, acts as the mean of the weight velocity data set. Weight velocities of the 3 standard weight curves, *i.e.*, WV_{+1SD}, WV_{01SD} and WV_{-1SD}, have been tabulated for Dutch children at a series of discrete ages [5]. Weight velocities at other ages require interpolation.

In Figure 3, WV_{+1SD}, WV_{0SD} and WV_{-1SD} are depicted as a function of age *t*. To demonstrate the *SDS(t)* and $SDS_{WVA}(t,AA)$ methods, a weight velocity data point at t_1=1.42 years and a $WV(t_1)$, of 7 kg/year were chosen purposely to be larger than the *0 SD* weight velocity at t_1, thus $WV(t_1)>WV_{0SD}(t_1)$. The calculation of $SDS(t_1)$ is shown by the red lines in the lower right corner. $SDS(t_1)$ is then defined as the difference in weight velocity between $WV(t_1)$ and $WV_{0SD}(t_1)$, divided by the difference in standard deviation between $WV_{+1SD}(t_1)$ and $WV_{0SD}(t_1)$. Thus, $SDS(t_1)=X/Y$=3.5 (Figure 3).

The *Weight Velocity for Age* part adds substantial complexity and indistinctness to the *SDS*. Calculation of $SDS_{WVA}(t,AA)$ is shown by the red dashed lines in Figure 3. The 7 kg/year weight velocity data point is the weight gained between t_1=1.42 years and age t_0, 1.23 years earlier than t_1, thus t_0=1.42–1.23=0.19 years, divided by 1.23 years. The average age *AA* in our case is 1.42–1.23/2=0.805 years. The $SDS_{WVA}(t_1,AA)$ is then defined as the difference in weight velocity between 7 kg/year (at t_1=1.42 years) and $WV_{0SD}(AA)$ at average age *AA* 0.805 years, divided by the difference in the standard deviation of weight velocity between $WV_{+1SD}(AA)$ and $WV_{0SD}(AA)$. Thus, $SDS_{WVA}(t,AA)=A/B=1.56$ (Figure 3).

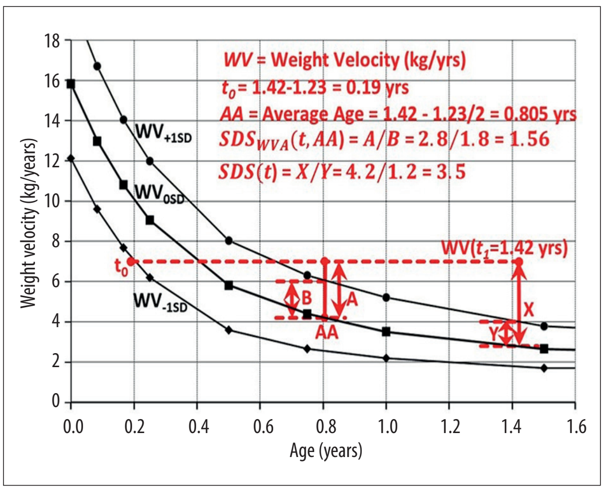

Figure 3. *Weight Velocities* of the *+1 SD*, *0 SD* and *-1 SD* standard weight curves for Dutch boys [5]. The weight velocity data point at t_1=1.42 years was set at $WV(t_1)$=7 kg/year. In the first example (red lines below/right), the *Standard Deviation Score* at age t_1 was $SDS(t_1=1.42)$=X/Y=3.5 (Eq. 2a), indicating that the weight velocity at t_1=1.42 years was 3.5 Standard Deviations above the mean of the data set, the *0 SD* weight velocity at age t_1. In the second example (red dashed lines middle), the $SDS_{WVA}(t_1,AA)$=A/B=1.56 (Eq. 4a), with the weight velocity at age t_1=1.42 years being 1.56 Standard Deviations above the mean of the data set, the *0 SD* weight velocity at average age *AA*=0.805 years.

Alternatively, when the weight velocity at t_1 is lower than that of *0 SD*, $WV(t_1)<WV_{0SD}(t_1)$, the WV_{-1SD} replaces WV_{+1SD}, both at t_1 for the $SDS(t_1)$ as well as at *AA* for the $SDS_{WVA}(t_1,AA)$ (Eqs. 4).

The *DGRF*-defined weight velocity, *WV(t)*, at age *t* is [1]:

$$WV(t) = \frac{W(t)-W(0)}{t}\ (t < 1.23\ yrs) \text{ and } WV(t) = \frac{W(t)-W(t-1.23)}{1.23}\ (t > 1.23\ yrs) \tag{1}$$

where *W* is weight in kg and *W(0)* is birth weight. If weight was not measured at age (*t*–1.23) , then the next measured weight is used.

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The *SDS(t)* is defined as:

$$SDS(t) = \frac{WV(t) - WV_{0SD}(t)}{WV_{+1SD}(t) - WV_{0SD}(t)} > 0 \qquad WV(t) > WV_{0SD}(t) \tag{2a}$$

$$SDS(t) = \frac{WV(t) - WV_{0SD}(t)}{WV_{0SD}(t) - WV_{-1SD}(t)} < 0 \qquad WV(t) < WV_{0SD}(t) \tag{2b}$$

The case of Eq. 2a is shown in Figure 3, lower right, with *SDS(1.42 yrs)*=3.5.

For $SDS_{WVA}(t,AA)$, average age *AA* is defined as:

$$AA = t/2 \;\; (t < 1.23\ yrs) \qquad AA = t - 1.23/2 \;\; (t > 1.23\ yrs) \tag{3}$$

Depending onto whether *WV(t)* is larger or smaller than WV_{0SD}, $SD_{WVA}(t, AA)$ is defined as:

$$SDS_{WVA}(t, AA) = \frac{WV(t) - WV_{0SD}(AA)}{WV_{+1SD}(AA) - WV_{0SD}(AA)} > 0 \qquad WV(t) > WV_{0SD}(AA) \tag{4a}$$

$$SDS_{WVA}(t, AA) = \frac{WV(t) - WV_{0SD}(AA)}{WV_{0SD}(AA) - WV_{-1SD}(AA)} < 0 \qquad WV(t) < WV_{0SD}(AA) \tag{4b}$$

The case of Eq. 4a is shown in Figure 3, middle, with $SD_{WVA}(t, AA)=A/B$=1.56.

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