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Reference values for short term height velocity – a brief practical guide

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Abstract

Assessing body height and changes in height over time (growth velocity) are essential for preventive health care and the clinical evaluation of growth. Yet, its assessment must account for the time interval between height measurements. We provide practical reference tables with common centiles for annual changes in height-for-age z-scores (HAZ) and correction factors for aligning short-term growth estimates with the reference values for annual changes in HAZ.

Take-home message for students Short-term growth is volatile. Its assessment must account for the time interval between height measurements. Correction factors are needed for aligning short-term growth estimates with reference values for annual growth velocity.

Assessing body height and changes in height over time (growth velocity) are essential for preventive health care and the clinical evaluation of growth. Yet, assessing growth velocity is not trivial. Short-term growth is volatile. Its assessment must account for the time interval between successive height measurements (Hermanussen and Burmeister 1989). Seasonal effects, intercurrent illnesses, mini-growth spurts (Hermanussen et al. 1988), and emotional factors (Bogin 2021) modulate short-term growth. Extrapolating height differences obtained at short intervals and referring such extrapolations to references for annual height differences leads to substantial misinterpretation of growth velocity.

The purpose of this brief communication is to allow readers to be aware that references for short-term growth velocities have been published (Hermanussen et al. 2019), yet in a journal that is not Open Access and not familiar to interested clinicians and researchers. Thus, we summarize essentials of our previous publication along with an abbreviated explanation of the methodology used to construct these references. Readers interested in the detailed methodology may purchase access to the published article or contact the senior author (MH).

We use z-scores for describing height-for-age (HAZ). Assessing HAZ is convenient for growth monitoring, and we describe growth velocity by changes in HAZ (vel_HAZ). By definition, the average progression of HAZ over time is zero. Children who stay within their height centiles do not change much in HAZ, whereas children who catch up or catch down, and cross centiles show upward or downward shifts in HAZ.

Table 1 provides references for annual changes in HAZ (annual vel_HAZ). The table has been adopted from longitudinal measurements from 1879 healthy infants (age 0 to 1 year) and 1528 healthy children and adolescents up to age 18 years from national growth studies conducted in France, Lithuania, Poland, Switzerland, Spain, the Czech Republic, Hungary, and the US (Hermanussen et al. 2019). Z-scores were derived from the respective national sets of data. The data were obtained according to ethical requirements at the time of their original publication and provided by courtesy of the respective first authors.

Assessing growth velocity requires consideration of the time interval between measurements. Tanner and coworkers compared increments in height obtained at annual and 6-month intervals and stated that 6-month increments "…have consistently higher variability than the yearly increments (when both are converted in cm/yr)" (Tanner et al. 1966). The variability continues to rise as the time interval between successive measurements decreases. This was exemplified in a study of 119 children of both sexes, aged between 4.5 and 14.9 years (Hermanussen and Burmeister 1989). The children were measured once or twice weekly by Harpenden stadiometer and by knemometry (Hermanussen et al. 1988) over periods between 161 and 202 (mean 186) days for 11 to 50 times by the same trained observer at the same time of the day (plus or minus 30 minutes) between noon and 4:00 pm. A total of 37 093 short-term height differences were then compared with the respective 119 half-yearly growth rates. The technical error of the height measurements was 1.5mm.

More than 30% of all one-month differences in height and still 5% of all two-month differences in height under- or overestimated the half-yearly difference in height by more than 100%. The data underscore the importance of references for short-term growth velocity. This study was used to create correction factors for aligning short-term growth with references for yearly growth velocities. These factors are supposed to be multiplied with short-term changes in HAZ before being referred to

Table 1 Common centiles for annual changes in HAZ (yearly vel_HAZ). Average vel_HAZ are zero by definition (Hermanussen et al. 2019). Number used in the example is printed in bold

	Boys				Girls			
Age	Centiles				Centiles			
	p3	p10	p90	p97	p3	p10	p90	p97
2y/3y	-1.19	-0.70	0.74	1.48	-1.18	-0.69	0.71	1.43
3y/4y	-0.87	-0.53	0.50	0.94	-0.92	-0.54	0.49	0.93
4y/5y	-0.87	-0.42	0.39	0.77	-0.87	-0.48	0.45	0.78
5y/6y	-0.81	-0.39	0.37	0.86	-0.70	-0.40	0.38	0.69
6y/ 7y	-0.75	-0.38	0.38	0.81	-0.64	-0.38	0.33	**0.78**
7y / 8y	-0.60	-0.32	0.31	0.57	-0.56	-0.30	0.29	0.53
8y / 9y	-0.51	-0.29	0.25	0.49	-0.51	-0.27	0.28	0.55
9y / 10y	-0.46	-0.24	0.23	0.41	-0.47	-0.29	0.32	0.57
10y / 11y	-0.41	-0.25	0.23	0.51	-0.51	-0.33	0.35	0.76
11y / 12y	-0.43	-0.27	0.31	0.63	-0.54	-0.33	0.35	0.54
12y / 13y	-0.47	-0.34	0.37	0.58	-0.57	-0.41	0.38	0.61
13y / 14y	-0.52	-0.38	0.38	0.56	-0.51	-0.41	0.48	0.67
14y / 15y	-0.55	-0.39	0.41	0.66	-0.36	-0.28	0.37	0.68
15y / 17y	-0.46	-0.37	0.45	0.66	-0.22	-0.18	0.19	0.43
16y / 17y	-0.33	-0.26	0.37	0.62	-0.15	-0.12	0.15	0.28
17y / 18y	-0.23	-0.18	0.23	0.46	-0.13	-0.11	0.11	0.28

reference values for one-yearly changes in HAZ (Table 2, column A).

Height measurements are afflicted with error (Ulijaszek and Kerr 1999). The shorter the time interval between measurements, the greater its relative contribution to the assessment of a growth rate. The original study published in 1989 (Hermanussen and Burmeister 1989) addressed this problem by combining conventional height measurements with highly accurate lower leg length measurements (knemometry). Improved measurement accuracy increases the predictive accuracy, but the study also showed that the extent of these improvements remained limited. The knemometric data served as the basis for aligning the slope of linear regressions of multiple short-term records of HAZ with one-yearly vel_HAZ, rather than differences between just two single measures (Table 2, column B).

We give a practical example:

A 6-year-old girl with partial growth hormone deficiency was 101 cm tall (HAZ = -2.76, WHO reference). After starting growth hormone treatment, she grew 2.7 cm within the first three months of therapy (103.7 cm, HAZ = -2.46, WHO reference) and caught up in HAZ by 0.30. This corresponds to an extrapolated one-yearly rise in HAZ of 1.20 (vel_HAZ=1.20). We ask: Does the increase in HAZ falls within the expected physiological range of vel_HAZ or does it exceed it?

At age 6y/7y, the 97th centile for one-year vel_HAZ is 0.78, and thus, below the extrapolated one-yearly vel_HAZ of 1.20, but the observed vel_HAZ requires correction as it was derived from a 3-month interval. The correction factor for vel_HAZ obtained within 91 to 100 days is 0.63 (Table 2, column A). We multiply the extrapolated

Table 2 Correction factors for assessing changes in HAZ (vel_HAZ) depending on the time interval between two successive HAZ (column A) or on the slope of multiple HAZ (column B). Numbers used in the example are printed in bold

Interval	A Correction factor for two measures	B Correction factor for multiple measures
42 to 50 days	0.50	0.62
51 to 60 days	0.54	0.65
61 to 70 days	0.58	0.66
71 to 80 days	0.60	0.68
81 to 90 days	0.63	0.69
91 to 100 days	**0.63**	**0.70**
101 to 110 days	0.65	0.72
111 to 120 days	0.66	0.73
121 to 130 days	0.68	0.75
131 to 140 days	0.68	0.75
141 to 150 days	0.69	0.76
151 to 160 days	0.71	0.77
161 to 170 days	0.72	0.78

one-yearly vel_HAZ with the correction factor: 1.20*0.63=0.76.

0.76<0.78. The corrected vel_HAZ is below the 97th centile and thus questions whether the catch-up in height is significant. If the doctor would have measured the girl more frequently, and if he would have based the growth assessment on multiple height measurements, he could have used the correction factor of Table 2, column B (0.70 for multiple measurements at age 6y/7y) and multiplied accordingly: 1.20*0.70=0.84.

0.84>0.78. The corrected vel_HAZ is greater than the 97th centile indicating that the catch-up in height was statistically significant and suggesting clinical relevance.

The tables are useful for practical purposes. More elaborate statistical assessments, e.g., of series of daily height measurements, can be performed using jump-preserving smoothing techniques (Caino et al. 2005) or changepoint analyses (Gasparatos et al. 2023).

Conclusion

Short-term growth is volatile. Its assessment must account for the time interval between successive height measurements. Correction factors are provided to align short-term growth estimates with reference values for annual growth velocity.

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