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Practicability and user-friendliness of height measurements by proof of concept APP using Augmented Reality, in 22 healthy children

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Abstract

Background Child growth is a dynamic process. When measured at short intervals, children's growth shows characteristic patterns that can be of great importance for clinical purposes.

Objective To study whether measuring height on a daily basis using an APP is practicable and user-friendly.

Methods Recruitment took place via Snowball Sampling. Thirteen out of 14 contacted families signed up for a study period of 12 weeks with altogether 22 healthy children aged 3 to 13 years (response rate 93%). The study started with a visit to the family home for the setup of the measurement site, conventional height measuring and initial training of the new measurement process. Follow-up appointments were made at four, eight and 12 weeks. The children's height was measured at daily intervals at their family homes over a period of three months.

Results The parents altogether recorded 1704 height measurements and meticulously documented practicability and problems when using the device.
A 93% response rate in recruitment was achieved by maintaining a high motivation within the families. Contact with the principal investigator was permanently available, including open communication, personal training and attendance during the appointments at the family homes.

Conclusion Measuring height by photographic display is interesting for children and parents and can be used for height measurements at home. A positive response rate of 13 out of 14 families with altogether 22 children highlights feasible recruitment and the high convenience and user-friendliness of daily APP-supported height measurements. Daily APP measurements appear to be a promising new tool for longitudinal growth studies.

Take-home message for students Daily height measurements are possible and can be performed by families at home. High motivation of the participants and constant contact of the principal investigator are critical for the success of daily at-home measurements.

Introduction

Child growth is a dynamic process. When measured at three-monthly intervals, a child's growth rate over the three months of fastest growth is most frequently two to three times its slowest rate but may be seven or more times the slowest if the latter was very low (Marshall 1971). Seasonal influences on child growth have been described (Clarke et al. 2019; Lindberg et al. 2021) as well as the influence of holidays/non-holidays (Díaz-Zavala et al. 2017; Igl 1906; Tanaka et al. 2018); and there are strong effects of social, economic, political and emotional factors (Bogin 2021) on child growth. Due to practical constraints when measuring children at shorter than three-month intervals, the analysis of growth based on very frequent measurements, e.g. at regular weekly or even daily intervals ("short-term growth"), has been limited to a few publications mainly in the 1980s and 1990s (Hermanussen 1998; Hermanussen et al. 1998). Short-term growth is characterized by a number of short-scale components that are distinct from measurement error. These components have been described as "mini growth spurts" (Hermanussen 1998; Hermanussen 1988), also named "saltations" (Lampl et al. 1992). They become evident when measuring growth with conventional techniques at frequent, preferably daily intervals (Ashizawa and Kawabata 1990) or when measuring growth with high precision (Hermanussen 1988; Keller et al. 1999). Studies in newborn babies and in laboratory animals support the idea that mini growth spurts occur at intervals of approximately 4–5 days with an amplitude ranging between 2 mm and some 10 mm and a duration of each spurt that varies between less than one and up to several days for completion (Hermanussen 1998). Frequency and amplitude of mini growth spurts in older children still lack characterization. Weekly measurements of the lower leg length suggested intervals of several weeks between subsequent spurts (Hermanussen 1988; Hermanussen et al. 1988). Daily measurements of total body height of short children treated with growth hormone were published by Glock et al. (1999). They can reveal characteristic patterns of treatment responses at the start of growth promoting therapies (Hermanussen et al. 2002) and highlight the potential of daily documentation of child growth for optimizing the treatment of growth disorders. Yet, the analysis of short-term growth for clinical purposes has remained preliminary and still not achieved popularity among pediatric endocrinologists.

Hitherto published studies of short-term growth rarely exceeded a few members of one family, and measurements were usually taken by professional investigators (Kobayashi and Togo 1993; Lampl et al. 1992; Ashizawa and Kawabata 1990). Daily measurements of short-term growth taken at home by family members ("daily at-home measurements") have not yet entered the toolbox of clinical health professionals even though various technically manageable tools for hassle-free height measuring have been proposed (Apple Inc. 2022). To study the feasibility of daily at-home measurements without necessarily involving a trained professional, we used photographic display (iPhone XR, manufactured by Apple) and visual analysis by Augmented Reality (Quantum Interface LLC 2022) and tested practicability and user-friendliness.

Methods

We studied three-month series of daily body height measurements of 22 healthy children, age 3 to 14 years, from 13 families. The recruitment of the families took place between September 15th 2021 and November 9th 2021 and started with personnel from the University of Potsdam. None of the parents was a professional anthropologist. In a first attempt, seven families with one parent working at Potsdam University and three families that were personally known to the principal investigator of the study (Antonia Rösler) were contacted and given first information. All but one signed up for the study shortly afterwards. Using the method of snowball sampling (Goodman 1961), four more families were contacted in a second round and also signed up for the study after being given initial information. In the end, six of the final set of 13 families had a professional affiliation with Potsdam University.

The recruitment process consisted of an introduction of the principal investigator, general information about the interest in daily height measurement in children and the general conditions of the study. In the next step the principal investigator answered all upcoming questions and made appointments at the family homes.

These initial appointments were attended by all children participating in the study and at least one parent. They included a thorough discussion of the goal of the study, the security of the data, the insurance of the provided material, a small incentive and, once more, the timeframe of the study. Thereafter, the measurement sites were set up. Each child was assigned an individual ID for anonymizing all upcoming data. Another set of equipment to allow for measurements at different locations was provided. All appointments and instructions were arranged and carried out by the same principal investigator and always in line with currently applicable SARS-CoV-2 regulations. All families received an insignificant monetary amount of compensation per day, which helped motivate them to participate. The study was approved by the ethical committee of University of Potsdam (35/2021).

The children were measured by the parents, standing in an upright position and backside against the wall. The head was orientated in Frankfurt plane (Saller 1957). For optical reasons, the wall needed to have a neutral color, be clean and without objects or pictures standing or hanging within a radius of at least 1.5 m, except for a DIN A4 sized QR code attached to the wall to start the optic procedure. The position of the child and the measuring parent was marked on the floor. In addition, a mark was set in the child's line of sight to ensure the correct standing positions of the child and parent and the position of the child's head. All three marks and the QR code were supposed to stay in place for the whole duration of the study. The APP used to measure the height in this study was developed by Quantum Interface (Quantum Interface LLC 2022) to create a growth self-measurement solution. After finishing the initial setup, one initial measurement of body height was performed using the digital laser rangefinder *GLM Professional® Bosch 250 VF* (Schrade and Scheffler 2013). The initial measurement was essential for calibrating the APP. Each measurement consisted of four readings of which the first was discarded (warm-up measurement), and the median of the remaining three was taken, as it is more resistant against outliers and may thus be considered more accurate than the mean value. The initial training period consisted of showing the procedure to the parents 2–3 times followed by a first set of parental height measures with supervision by the conductor of the study. The measurements were recorded via the APP server and downloaded into an excel file.

All measurements were performed at home every day after 4pm – usually right before bedtime. The progress of the study and the handling of the devices were regularly controlled four and eight weeks after the initial training. At these follow-up appointments, height of the children was again re-measured by digital laser rangefinder. The appointments were not only useful for technical purposes but also and particularly for motivational reasons (giving the families a feeling of importance through the relative novelty of the data), for answering questions and discussing the progress of the study as well as for the collection of direct feedback on the measurement process. In addition, the parents were reassured that the conductor was accessible via phone and e-mail for answering upcoming questions and reacting to any problems for the whole duration of the study. After the three months period of measurements, the families were asked to answer a questionnaire, which was anonymized before saving. For assessing the motivation of the families, a five point scale was created. The scale ranged from "highly motivated" (4 points) via "interested (3 points)", "indifferent (2 points)" and "not interested (1 point)" to "not motivated (0 points)".

Results

Measurements

The parents recorded altogether 1704 height measurements and meticulously documented practicability and problems when using the devices at almost daily intervals. 231 measurements were missing, mainly due to holidays and one family that temporarily lost the iPhone while moving house. Table 1 summarizes age, measurement schedule, number of measurements per child and the number of missing measurements.

During the three-month study period, the children grew in height on average by 1.7 cm (range 0.3 cm to 2.8 cm), corresponding to an average annual increment of 6.8 cm (Table 1, Figure 1). The table mirrors the wide range of physiological growth velocity in healthy pre- and early pubertal children.

Psychology

During the control visits throughout the study period, the families reported a decrease in motivation whenever technical difficulties came up and slowed down the measurement process. It was also reported and can be seen in the higher variance of the individual measurements that the two three-year-old participants had difficulties in adopting and maintaining the upright position necessary for comparable results.

Nevertheless, all of the 13 families reported a very intuitive user experience and high practicability of the measurement process. The APP was easy to use and, after initial introduction, self-explanatory as long as no technical errors occurred.

Eight of the 13 participating families answered the final questionnaire. As, due to the anonymization, the response rate could not be enforced, we do not know for what reasons the remaining five families failed to return the questionnaire.

Concerning the physical setup for the measurement, half the families described problems to find a large enough unoccupied space in their home. Consistently, half the families who answered the questionnaire were living in houses while the other half was living in smaller apartments. For the latter this led, in all cases, to only one possible space for the setup, which in turn led to one family expressing a dislike of the QR code because the only possible setup required the code to hang in the middle of their living room wall for the entire three-month period, while another family delayed renovation plans for the room with the setup. Another family reported difficulties in finding a suitable space in a hotel room while on vacation. Thus, setting up an appropriate measuring location appeared to be an essential issue. The initial instruction and continued support provided by the principal investigator was rated positively by all 8 families. Additional training supervised by a medical professional was not thought necessary.

All 8 families completed the questionnaire with a report of an overall very interesting experience and joy to learn more about the growth of their own child/children.

When asked about the children's willingness to participate in the measurement process, the families reported either a high motivation (score of 5 points) or a decreasing motivation over time (two families, from "highly motivated" to "interested", score of 3 points). Only one family reported an interest due to the incentive being paid at the end of the study. The child-oriented graphics of the APP also made the measurement process more interesting. Four of the eight families described a high mo-

Table 1 Study sample, age of the children, measurement timespan, number of measurements, height difference between first and last measurement (digital laser rangefinder). The children 2+3, 5+6, 7+8, 9+10, 12+13, 15+16, 18+19+20 and 21+22 belonged to the same families respectively.

ID	Age at beginning of study	Timespan	No. of measurements	No. of missed measurements	Height difference [cm]
1_M	11.24	27.10.21 – 16.02.22	112	16	2.2
2_F	13.80	28.10.21 – 20.01.22	81	4	0.3
3_F	11.71	28.10.21 – 20.01.22	81	4	2.1
4_F	7.84	29.10.21 – 21.01.22	75	10	1.9
5_F	7.95	01.11.21 – 25.01.22	85	1	1.2
6_F	9.95	01.11.21 – 25.01.22	85	1	0.3
7_F	11.85	01.11.21 – 24.01.22	71	14	2.4
8_F	9.71	01.11.21 – 24.01.22	70	15	2.6
9_M	8.93	03.11.21 – 26.01.22	80	5	2.2
10_M	11.44	03.11.21 – 26.01.22	80	5	1.8
11_M	8.83	05.11.21 – 31.01.22	68	20	1.6
12_F	11.94	08.11.21 – 31.01.22	81	4	2.6
13_M	9.44	08.11.21 – 31.01.22	81	4	1.6
14_F	3.24	08.11.21 – 31.01.22	75	10	2.2
15_M	12.55	11.11.21 – 06.02.22	43	45*	0.9
16_M	3.36	11.11.21 – 06.02.22	52	36*	1.9
17_F	11.34	11.11.21 – 05.02.22	79	8	1.1
18_M	7.65	12.11.21 – 07.02.22	85	3	2.8
19_F	10.93	12.11.21 – 07.02.22	85	3	2.1
20_F	13.33	12.11.21 – 07.02.22	86	2	0.1
21_F	10.17	22.11.21 – 14.02.22	75	10	1.4
22_F	6.16	22.11.21 – 14.02.22	74	11	1.5
Sum			1704	231	
Mean			77.5	10.5	1.7

* no measurements were obtained between November 28th and December 13th 2021 due to the family moving house

tivation throughout the study without any decline. Due to the small number of questionnaires returned during this pilot study, we refrained from further statistical analysis.

Based on the informal interviews during the supervision of the participating families, the APP was considered high in its functionality and information dimension as well as its user-friendliness.

The analysis of the measurement precision of serial short-term body height determinations was not part of this study and will be published at a later date (N. Gasparatos, manuscript in preparation).

Discussion

We assumed the biggest challenges of this study to be the recruitment of families and the conduction of daily measurements. However, instead we found these two working surprisingly well with the families that were taking part and therefore found at-home measurements of body height to be practicable and height measurements by APP to be user-friendly. These two conclusions however depend on various psychological factors.

Motivation for repetitive tasks can be either intrinsic or extrinsic. The introduction of incentives which are not psychologically part of the task as well as appreciation of work from another valued individual are two factors of extrinsic motivation (Smith and Lem 1955). The motivation for the continued performance of a task by an unskilled worker is also highly dependent on the workload and the time required for the task (Smith and Lem 1955). In this study, the time needed for one measurement was about five minutes per child and day. The daily measurement process had a clearly defined start and endpoint, and the overall timeframe of the study was known to each participant from the very beginning.

The danger of repetitive tasks lies in their boredom. To avoid being boring, a task has to contain various stimuli, such as complexity, uncertainty, and novelty (Shackleton 1981). Since all families were inexperienced regarding the topic of human growth, boredom was not a restricting factor and also not the reason for missed measurements. Usually, measurements were omitted in association with public holidays or travelling of the families.

The most commonly reported cause for accidentally missed measurements was that the families just forgot about them as the new process had presumably not yet been properly included in the daily routines of the family. The building of a routine or a habit needs consistent repetition of an action within the same context, for example connected to an existing daily routine which in this case was often the bedtime routine of the child (Gardner et al. 2012). Initiating a new habit formation requires a high level of motivation, which reportedly existed in all families at the beginning of the study (Gardner et al. 2012). According to literature, habit formation takes between two and three months (Gardner et al. 2012). The habit formation during this study might have been impaired by overlaying factors and the narrow timeframe of the study ending after three months. A possible way to further increase or at least avoid a decrease in motivation could be found in the concept of gamification as explored by Sailer et al. (2017).

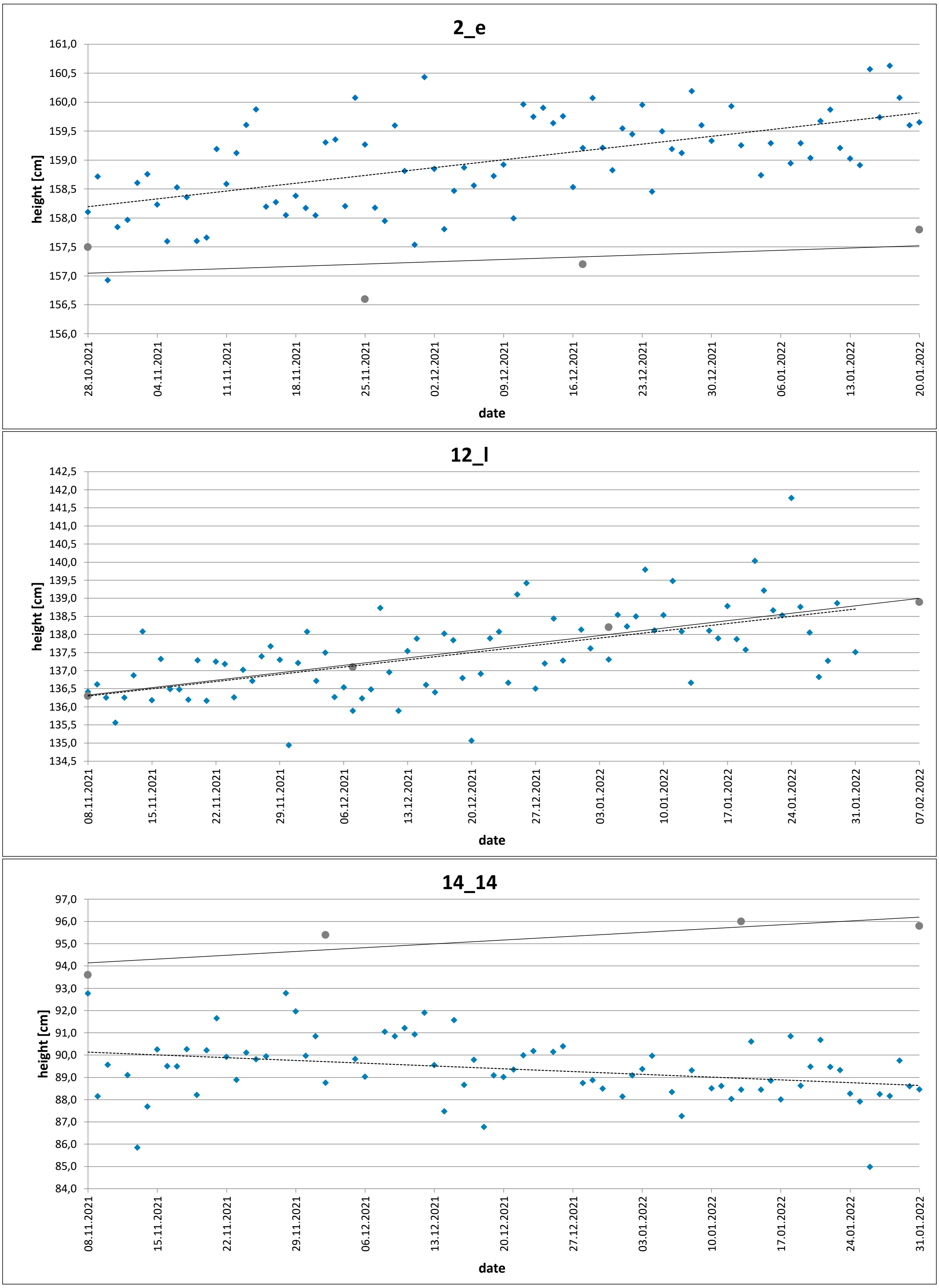

Figure 1 Height measurements by APP (closed rhombs) and laser (closed circles) of three children. Height trends are indicated by dashed lines (APP) and solid lines (laser).

Considering possible limitations to the generalization of the present findings, it may be taken into account that our families were personally known to the investigators or to other study participants and thus, may have been more motivated than a randomly drawn study sample. Yet, we assume that practicability and user-friendliness of a technical tool should largely be independent of personal contacts.

Conclusion

Daily height measurements at home are practicable and, in the case of measurements by APP, user-friendly.
Families with and without a research background can be motivated to participate in a daily task. Yet, principal investigators need to be aware of fluctuating motivation and potential technical difficulties as well as the need to be available for answering questions and providing support at all times.

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