Development of Early Detection and Problem Analysis Methods for Growth Disorders among Elementary School Students -The Methods based on Height Data-

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Abstract:
Growth disorder is an important problem in child health. School nurses are responsible for child health management in elementary schools; although this task is important, it is also difficult.

In the present study, we aimed to develop a support system for school nurses performing this task. First, we focused on the screening process for growth disorders, and developed a method to identify these conditions regardless of the differences of in their ability, by using height data of approximately 400 students from the fourth to sixth grades in elementary school. Second, we evaluated the process of examining the condition in each child after screening. Finally, we developed a supporting tool that school nurses can use, in practice. This system could help school nurses in managing children health. With regard to the next step in this research, we plan to design a multiple health care management system by introducing a new indicator involving both height and weight data.

Keywords
growth disorder, early detection, problem analysis, health care management, elementary school

1. Introduction

1.1 Background

Health problems in children should be identified and treated promptly so that the condition does not hinder their development. In elementary school, school nurses are responsible for health management among the children. Growth disorder is an important health problem that should be detected by school nurses. Cotterill et al. (1993) show that body measurement made by them would be sufficiently reliable for screening of growth disorder. The two symptoms of this are short stature and growth failure. Short stature is defined as a height value that is 2 standard deviations (SD) below the mean for age. In contrast, growth failure is difficult to define (Stalman et al., 2015), and hence, various studies have defined it differently. For example, Jonathan (2004) defined it as growth deceleration (falling across major percentiles on the growth curve). Growth disorder has many different causes (Rogol et al., 2014), and therefore, it is not only a symptom of another disease, but also an environmental condition (Mukaida et al., 2010; Lee et al., 2012; Castano et al, 2013; Naruse et al., 2013; Wattchow et al., 2015). Furthermore, growth disorder may cause another problem. For example, younger and shorter children tend to be bullied in the classroom (Naiki et al., 2013). Hence, a focus on the height of the children may facilitate the detection and prevention of various health and social problems.

However, each school has only one school nurse. The nurse’s skills have to spread over several tasks that have to be done each day: treating children’s injuries, investigating school hygiene, providing health guidance, and ensuring the children’s mental health care. At present, they are unable to always detect children’s health problems such as growth disorder because of a lack of knowledge, intuition, and time.

In addition to early detection, early treatment is also important (Darendeliler et al., 2011; Antoniazzi et al., 2015). However, information available to the school nurse is not sufficient; accordingly, players involved in the
children’s health care such as their homes, schools, and hospitals have to share information. Cooperation between school nurses and these players will enable the analysis of the problems children have and the provision of appropriate treatment (Procter et al., 2015).

1.2 Basic Concept

The players involved in the disease management of infants and children include their homes, schools, educational committees, healthcare centers, clinics, and hospitals. While pediatricians are responsible for professional decision-making, it is important for all players to help in the process of disease management (DM) to better support the growth of the infants and children.

Tsuru et al. (2014) standardized the modes of DM to facilitate understanding among the players. They developed six modes of DM:

1. Healthy or no awareness
   A state in which the child has no problem related to the disease or the problem has not been recognized even though it exists

2. Managed living without medical supervision
   A state in which the problem is recognized and the child’s life is managed by a non-medical person (such as yourself or a helper) at home or in nursing facilities

3. Managed living with medical supervision
   A state in which the patient’s life is individually planned and managed based on the assessment of a qualified medical staff

4. Management by general practitioners (GPs)
   A state in which a plan is created for the patient’s disease and his or her life is managed by outpatient care by a doctor

5. Management by specialists
   A state in which a specialist evaluates the patient’s disease, a plan is created based on the evaluations, and the patient’s life is managed accordingly (aggressive intervention is not carried out)

6. Specialty intervention
   A state in which the patient is subjected to aggressive intervention (treatment) by a specialist of the disease

The modes of DM are depicted in Figure 1.
The actual management process in educational institutions should be visualized based on these modes.

1.3 Previous Study

The method for screening of growth disorders of endocrine origin was developed by Okamoto (1989). By using the WHAMES method, school nurses detect serious disorders of endocrine origin in many school children. It is the first screening tool for endocrine disorders, based on symptom markers such as weight, height, appearance, mentality, emotion, and sexual development (Figure 2). After the first screening performed by school nurses, potential patients are sent to Okamoto for diagnosis.

**Figure 2: The WHAMES method**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characteristic</th>
<th>obesity</th>
<th>emaciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>W ↑</td>
<td>a: weight gain in a short period of time</td>
<td>W ↑: extremely over weighed</td>
<td>W ↓: extremely emaciated</td>
</tr>
<tr>
<td>W ↓</td>
<td>b: abnormal proportion</td>
<td>W ↑: slightly over weighed</td>
<td>W ↓: slightly emaciated</td>
</tr>
</tbody>
</table>

W ↑, W ↓, w ↑, w ↓, a, b; each symbol indicates grading of such abnormalities and characteristics.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characteristic</th>
<th>short stature</th>
<th>high stature</th>
</tr>
</thead>
<tbody>
<tr>
<td>H ↑</td>
<td>a: impaired growth in body length during a short period</td>
<td>H ↑: extremely short</td>
<td>H ↓: extremely tall</td>
</tr>
<tr>
<td>H ↓</td>
<td>b: abnormal proportion</td>
<td>h ↑: slightly short</td>
<td>h ↓: slightly tall</td>
</tr>
</tbody>
</table>

H ↑, h ↑, H ↓, h ↓, a, b; each symbol indicates grading of such abnormalities and characteristics.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characteristic</th>
<th>abnormal or unusual appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>a: slightly abnormal or unusual appearance</td>
<td></td>
</tr>
</tbody>
</table>

A, a; each symbol indicates grading of such abnormality.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characteristic</th>
<th>impairment in mental abilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>a: slightly impaired in mental abilities</td>
<td></td>
</tr>
</tbody>
</table>

M, m; each symbol indicates grading of such abnormality.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characteristic</th>
<th>emotional and behavioral abnormality</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>a: slightly abnormal in emotion and behavior</td>
<td></td>
</tr>
</tbody>
</table>

E, e; each symbol indicates grading of such abnormality.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Characteristic</th>
<th>precocious puberty</th>
<th>delayed puberty</th>
</tr>
</thead>
<tbody>
<tr>
<td>S ↑</td>
<td>a: isosexual precocity</td>
<td>S ↑: extremely early sexual development</td>
<td>S ↓: extremely late sexual development</td>
</tr>
<tr>
<td>S ↓</td>
<td>b: heterosexual pubertal development</td>
<td>s ↑: slightly early sexual development</td>
<td>s ↓: slightly late sexual development</td>
</tr>
</tbody>
</table>

S ↑, s ↑, S ↓, s ↓; each symbol indicates abnormality patterns in sexual development.
The idea is that school nurses first perform screening in schools. However, this method is troublesome for the nurses as the standard for screening is not clear. In addition, growth disorders of endocrine origin are not the only problems; growth disorders due to environmental factors also need to be considered.

In order to resolve these issues, the WHAMES method needs to be revised to develop a practical method.

1.4 Purpose
The purpose of this study was to design a support system for elementary school nurses, with a focus on growth disorders in children. First, we developed an early detection method using body measurements. Subsequently, we developed a problem analysis method by using data from medical checkups and coordinating with school nurses and other players.

2. Direction of the Study
Based on the modes of DM outlined by Tsuru et al. (2014), we designed a Health Management Model (Figure 3) so that school nurses could understand the health condition of children by using the Plan, Do, Check, Act (PDCA) cycle, based on data from medical checkups.

According to this model, the steps of the study are as follows:

【step 1】Development of an early detection method for growth disorders: to screen for growth disorders using body measurement data.

This step corresponds to “0. Screening” in the Health Management Model.

【step 2】Development of a problem analysis method for growth disorders: to analyze the problem in order to determine appropriate intervention for growth disorders.

This step corresponds to “3. Problem analysis” in the Health Management Model.

【step 3】Development of a growth management support tool: to apply the above methods to the field of education.

Figure 3: Overview of the study

We obtained agreement to this study by the board of education of the district K, the medical association of the district K, the Jikei University School of Medicine, and the University of Tokyo. The ethics committee of the
Jikei University School of Medicine approved the study, and children’s health data were anonymized.

3. Development of an Early Detection Method for Growth Disorders

3.1 Screening by specialists

To detect growth disorders, height velocity has to be calculated and plotted accurately on a growth chart, considering the birth month of each child (Murata, 2014). It is difficult even for specialists to diagnose growth disorders based on growth charts. However, in elementary schools, school nurses need to plot growth charts and detect growth disorders in a limited time. Therefore, we provided a diagnosis support method to enable non-specialists to diagnose suspected growth disorders.

In this study, we used actual height data of approximately 400 students from the fourth to sixth grades in elementary school. These anonymized data were input into the system introduced in each school four years ago. School nurses can input body measurement data three times a year.

A specialist diagnosed the health condition of each child based on his or her growth chart, assigning children to one of three categories: healthy, observation, and problem analysis. The diagnosis was based on the following three points:

- growth pattern: normal, tall stature, short stature, growth failure
- puberty: extremely early, slightly early, normal, slightly late, extremely late
- body type: extremely overweight, slightly overweight, normal, slightly emaciated, extremely emaciated

In addition, we visualized the diagnostic logic of the specialist by interview when the diagnosis was based on the growth chart (Figure 4).

![Figure 4: Diagnostic logic of the specialist](image-url)

The specialist did not necessarily have a clear standard for three points (puberty, short stature, and growth failure); instead he relied on his knowledge and experience. Puberty evaluation is influenced by variation in judgment due to human error, as peak height velocity needs to be visually estimated. On the other hand, short stature and growth failure are diagnosed based on objective data, so human error can be eliminated and the associated burden lightened by standardizing the screening method.

3.2 Screening by school nurses

Early detection method by school nurses was developed based on discussions with the specialist. As a premise, specialist’s diagnosis shall be absolute.
This involves a two-step screening method, utilizing body measurement data and the growth chart plotted using these data. In primary screening, short stature and growth failure are detected completely using the standardized screening method. In this step, not missing short stature and growth failure is considered very important. Therefore, healthy children screened excessively are sorted by tracking each growth chart during secondary screening. This order of screening enables school nurses to detect growth disorders completely and decreases the number of growth charts that have to be checked.

3.2.1 Primary screening

The standardized screening method was determined based on the specialist’s diagnostic result and logic. The SD score (SDS) of height to detect short stature and variation in the SDS of height velocity to detect growth failure were considered appropriate. However, these indexes cannot be used to identify children with consistently low height velocity and those with normal variation in the SDS of height velocity. To detect all such cases, we adopted the SDS of height velocity anew. This index was not identified on discussion, so it is possible that the specialist considers it unconsciously. Nevertheless, it is important to visualize it.

We standardized the screening tool to be used by combining these three indexes. We diagnosed the previously mentioned approximately 400 students using this standardized index, compared these diagnoses with the diagnostic result of the specialist, and evaluated the differences. Establishment of a perfect screening tool is difficult because the diagnoses are not based on a specific rule. Therefore, we sought to identify a screening tool that would minimize the difference. Although the health condition was diagnosed on the basis of weight data as well, this screening tool is targeted only at growth disorders. The screening tool developed in this study using a trial and error approach is depicted in Figure 5 and more definite combinations of indexes are detailed in Figure 6.

This primary screening method cannot detect growth disorders in a few children. One possible cause is a measuring instrument-related error. The latest height data of four degree boys in a certain school appear to have a total measurement error of approximately 0.5–1.0 cm, which could have resulted in variations in the diagnoses of the specialist. This was confirmed with the specialist.

The other possible cause is data deficiency. To detect growth failure, this screening method use data obtained at several points. Children who tend to be absent from school require additional attention.

![Figure 5: Primary screening](image-url)
3.2.2 Secondary screening

Primary screening is viewed as important to not miss out on short stature and growth failure. Therefore, healthy children are screened more excessively compared to a specialist’s diagnosis. Most of this excessive screening is due to early or delayed puberty (Figure 7).

Figure 6: Definite combinations of indexes

<table>
<thead>
<tr>
<th>The last three values of SDS of height velocity</th>
<th>The last three values of SDS of height velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative values three times</td>
<td>Negative values twice</td>
</tr>
<tr>
<td>Negative values twice</td>
<td>2. Observation</td>
</tr>
<tr>
<td>3. Problem analysis</td>
<td>2. Observation</td>
</tr>
<tr>
<td>Negative values once or no negative values</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 7: Growth chart (example of excessive screening)

Example 1: Early puberty

Example 2: Delayed puberty
Example 1: Early puberty
In the late puberty period, the SDS of height velocity seems to decrease abnormally. Therefore, growth disorders in these children are detected. If there are no problems with height, the children are classified as “healthy.” Note that “no problem with height” means that the children are taller than the average for adults minus 2.0 SDs or that height at the beginning of puberty is more than 135 cm for boys or more than 132.5 cm for girls.

Example 2: Delayed puberty
Until the beginning of puberty, the SDS of height velocity is consistently low. Therefore, growth disorders in these children are detected. These children are assigned to the “observation” category to observe the progress of puberty.

In addition, unless puberty is obviously early or obviously delayed, estimation is difficult, and the result of primary screening is retained. The secondary screening method is depicted in Figure 8.

Figure 8: Secondary screening

4. Development of a Problem Analysis Method for Growth Disorders

While “growth disorder” might sound simple, its causative factors are various, including medical, social, and educational problems. Additionally, some children with growth disorders require medical treatment, some need environmental improvements, and others need no intervention. To provide each child with the appropriate intervention, the problem of the growth disorder needs to be analyzed.

4.1 Investigation of the causes of growth disorders

First, under the leadership of two pediatricians, we classified the causes identified by a literature search (Tanaka et al., 1997; Tanaka, 2002; Kinoshita, 2012; Cook and Rose, 2012) on the basis of intervention type in order to enable easy improvement after the cause is determined (Table 1).

<table>
<thead>
<tr>
<th>Cause</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>A The cause requiring no treatment</td>
<td>Observation</td>
</tr>
<tr>
<td>(1) Short stature that is no problem</td>
<td></td>
</tr>
<tr>
<td>(2) Deferring of cause specification</td>
<td></td>
</tr>
<tr>
<td>B The cause requiring medical treatment to growth disorder</td>
<td>Medical treatment</td>
</tr>
<tr>
<td>(1) Abnormal of puberty</td>
<td></td>
</tr>
<tr>
<td>(2) Disease of growth disorder</td>
<td></td>
</tr>
<tr>
<td>(3) Disease leading to growth failure</td>
<td></td>
</tr>
<tr>
<td>C The cause requiring review of treatment method for another disease</td>
<td>Medical treatment (for allergy)</td>
</tr>
<tr>
<td>(1) Excess removal of nutrition by food allergy</td>
<td></td>
</tr>
<tr>
<td>D The cause requiring improvement of home environment</td>
<td>Improvement of home environment</td>
</tr>
<tr>
<td>(1) Disturbance of lifestyle</td>
<td></td>
</tr>
<tr>
<td>(2) The problem of family relationship</td>
<td></td>
</tr>
<tr>
<td>E The cause requiring improvement of educational environment</td>
<td>Improvement of educational environment</td>
</tr>
<tr>
<td>(1) Social stress</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Classification of the causes of growth disorders according to intervention type
In addition, the symptoms and observations of each cause were investigated in detail and organized according to the players involved in children’s health care (Table 2). In this case, the following four players are incorporated, based on a previous study (Tsuru et al., 2014)

1. People at home: They are the most familiar with the child.
2. Homeroom teachers: They are familiar with the children and have an objective viewpoint
3. School nurses and school physicians: They have specialized knowledge about the health care of school children
4. Specialists: They have specialized knowledge about medical care

<table>
<thead>
<tr>
<th>Player</th>
<th>Idiopathic short stature</th>
<th>Familial short stature</th>
<th>Deferment of cause specification</th>
<th>Delayed puberty</th>
<th>Precocious puberty</th>
<th>Small-for-gestational age short stature</th>
<th>Short stature due to growth hormone deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(1)</td>
<td></td>
<td></td>
<td>(1)</td>
<td></td>
<td>(2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Height SDS</td>
<td>Height SDS</td>
<td>Height SDS</td>
<td>Height velocity</td>
<td>Roentgen photograph</td>
<td>Height SDS</td>
<td>Blood sampling after administering the drug which have an effect of releasing a hormone</td>
</tr>
<tr>
<td></td>
<td>*Height SDS</td>
<td>*Height SDS</td>
<td>*Height SDS</td>
<td>*Height velocity</td>
<td>*Roentgen photograph</td>
<td>*Height SDS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>*Height SDS</td>
<td>*Height SDS</td>
<td>*Height SDS</td>
<td>*Height velocity</td>
<td>*Roentgen photograph</td>
<td>*Height SDS</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Player</th>
<th>Food allergy</th>
<th>Bad life style</th>
<th>Child abuse</th>
<th>Bullying</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Abnormalities appear on the body to eat certain things</td>
<td>Nutrition State</td>
<td>Appearance</td>
<td>Appearance</td>
</tr>
<tr>
<td></td>
<td>*Medical checkups</td>
<td>*Nutrition State</td>
<td>*Action and attitude</td>
<td>*Action and attitude</td>
</tr>
<tr>
<td></td>
<td>*Food allergy research</td>
<td>*Life rhythm</td>
<td>*Communication</td>
<td>*Communication</td>
</tr>
<tr>
<td></td>
<td>*Oral food challenge</td>
<td>*Height SDS</td>
<td>*Height velocity</td>
<td>*Height SDS</td>
</tr>
<tr>
<td></td>
<td>*Height SDS</td>
<td>*Height velocity</td>
<td>*Height SDS</td>
<td>*Height velocity</td>
</tr>
</tbody>
</table>

Table 2: A summarized version of the symptoms and observations

4.2 Problem analysis by school nurses

The information required to analyze the problem is dispersed among various players, so cooperation of the players is required. In this study, we developed a method where school nurses gather information about children, analyze it, and determine the appropriate intervention.

First, we designed the following narrowing process so that school nurses can analyze problems efficiently and effectively.

- Primary narrowing:
  
  They gather information such as medical history and allergies from medical checkups.
Secondary narrowing:
They ask homeroom teachers questions not only about health but also about lifestyle, home environment, and friendship.

Tertiary narrowing:
They ask people at home detailed questions to obtain information that could not be obtained in the previous phases.

This three step narrowing process is depicted in Figure 9.

The examination sheet provided to homeroom teachers and people at home was designed on referring to health checkup sheets created by the school health committee and an existing checklist about child abuse and bulling.

Next, we designed the actual method of gathering information and analyzing children detected to have growth disorders by screening. School nurses analyze the problem using the information obtained (Table 2). Priority is given to identifying diseases that require medical treatment. If children have no symptoms of the disease, the nurses need to determine whether the children have other important problems by using information about the surrounding environment. This problem analysis method for growth disorders is depicted in Figure 10.
5. Development of a Growth Management Support Tool

It is difficult for school nurses to understand and manage all the health conditions of children because of a lack of knowledge, intuition, and time. In particular, it is their responsibility to plot the growth curves of children and detect growth disorders, which can be burdensome. Therefore, we developed a growth management support tool for school nurses (Figure 11).

This tool can utilize the body measurement data efficiently and effectively and extract information necessary to analyze the growth problem. This support is mainly for the detection of growth failure, since the tool can calculate the SDS and plot the growth curves of all children based on the data input into the school system. It can thereby diagnose growth disorders automatically, using the rule of primary screening. Height data and the growth chart for each child is output in a single sheet. When a child is suspected to have a growth disorder, the tool outputs a danger signal. It is useful in puberty judgment during secondary screening.

![Growth management support tool](image)

Figure 11: The growth management support tool

6. Case study

This method and tool was applied to approximately 120 students from the fifth and sixth grades in school A. All body measurement data since admission to the school were used.

6.1 Assessment of the early detection method

We verified whether the early detection method developed in this study could detect growth disorders or raise suspicion in children without omission. Using the growth management support tool, we applied primary screening to the acquired data. Based on this primary screening result, an author with no specialized knowledge performed secondary screening by judging puberty based on the growth charts. In addition, a specialist diagnosed the same children and assigned them to one of three categories (healthy, observation, or problem analysis). We then examined the differences in the results.

A comparison of the diagnostic results between our method and that of the specialist is depicted in Figure 12. On using our method, growth disorder was not missed in any of the cases. On the other hand, 23 children received a more severe diagnosis compared to the specialist’s diagnosis on using our method.
6.2 Assessment of the problem analysis method

We verified whether the problem analysis method developed in this study could specify the cause of growth disorders. We conducted interviews with the school nurse and principal, who was also the homeroom teacher in this case, of school A regarding 8 children assigned to the “problem analysis” category by the two-step screening process. Under the guidance of the specialist who diagnosed the children, the problems were diagnosed in as much detail as possible.

Considering that the body measurement and medical checkup data could be referred to quickly, we conducted primary and secondary narrowing simultaneously. The results of this case study determined using the problem analysis method developed (Figure 10) are depicted in Figure 13.

Figure 13: Result of the case study using the problem analysis method

Six children had no abnormal symptoms or observations, so they were assigned to “observation.” Two children had symptoms of disease such as light eating, short stature of the parents, and extreme worry, so they were assigned to “management by GPs.” In addition, tertiary narrowing of the examination to include people at home is needed, because of the severity of the growth disorder.

7. Discussion

On comparing the result and required time for the detection of growth disorders between the early detection method and specialist’s diagnostic method, we found that our method enabled school nurses to detect growth disorders efficiently and effectively. Therefore, it is safe to say that our method can solve the problems of WHAMES Method that the standard for screening is not clear and growth disorders due to environmental
factors are not considered.

The diagnosis using our method was more severe than the specialist’s diagnosis in 23 children. There are three possible reasons for this. The first is the difference in puberty estimation. Delayed puberty is assigned to the “observation” category in secondary screening. However, the specialist assigned delayed puberty to the “healthy” category. Second, primary screening is defined by round number. Finally, measurement error and input error could be a reason for the discrepancy.

It is possible that children with growth disorders were diagnosed using height as an index by our method. In this case, primary and secondary narrowing was conducted simultaneously along with a specialist. The examination sheet needs to be improved such that secondary and tertiary narrowing can be conducted without advice from the specialist.

Currently, school A doesn’t pay attention to most children assigned to the “observation” category. Therefore, this study helps build awareness, and continuous observation can lead to early detection and treatment.

The case study results suggest that growth disorders in children can be managed using the method we developed, which is the subject of this study. However, obesity and emaciation should also be detected based on body measurement data. Additionally, since specialists diagnose health conditions in children by multiplying height and weight, weight data should be introduced as a new index in the support tool.

8. Conclusion

The feasibility of the early detection and problem analysis method for growth disorders was confirmed. For further validation, this needs to be implemented in several other elementary schools. Enhancing the precision of screening and standardizing knowledge among veteran nurses and specialists can help even school nurses, who have little knowledge and experience, manage the health of children.

In addition, the introduction of height and weight data into the support tool will help establish a health care management system for educational institutions.

References:


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