

Is the “adolescent growth spurt in body height,” an established theory of growth in the 20th century, a universal phenomenon among humans? :

Through observations of hunter-gatherers Moken (Salon) and Mlabri (Phii ton luang)

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Abstract

The established theory in the study of human growth and auxology, claims that the adolescent growth spurt always exists during the process of height growth in humans. However, this phenomenon is not found in Moken (Salon) and Mlabri (Phii ton luang), hunter-gatherer's tribes from Myanmar and Thailand respectively. Moken tribe lifestyle is based on sea and Mlabri tribe lifestyle is primarily dependent on the forest.

The period of height growth in males and females of Moken and Mlabri is longer than European, American or Japanese people. The growth of height in both groups gradually grows until the age of 20 years or older. During the period of height growth, the European, American and Japanese females are taller than males for only two years but Moken and Mlabri females are consistently taller than males until the age of 12 years and 14 years respectively. Based on the results, the study challenged the established growth theory which claims that “adolescent growth spurt always exist during the process of height growth in humans.”

1. Introduction

At the end of the 18th century, Philippe Guéneau de Montbeillard (1720-1785), a French nobleman, measured his son's height every six months from the age of 8 years to 18 years and kept a record of his height growth. This was the first longitudinal data of height growth recorded in the world. In 1927, Scammon RE (1927) [1], an anatomist at the University of Minnesota, publicized the existence of this growth curve, which would later have a major impact on the field of auxology, the study of human growth and development. He also calculated the growth rate per year from the curve and showed that the existence of large peak on the curve appeared around adolescence. Until now, this

phenomenon of rapid growth in height during adolescence is considered as a significant indicator of human growth during adolescence.

Shuttleworth FK (1938) [2] confirmed this Peak Height Velocity (PHV) phenomenon with a larger sample of data and showed that the pattern was found in all individual measurements at adolescence without any exception. Although, he discussed the variation in the timing of the appearance of the patterns. The representation of this model established the PHV phenomenon as a theory in auxology.

Tanner JM and colleagues (1966) [3] in the year 1966 confirmed the PHV theory by using a set of data from

British people, then it was positioned as a standard physical sign that it always appears in the process of human adolescent growth. With the publication of the book titled “Growth at Adolescence,” the PHV theory become well known around the globe. Since then, PHV theory has been considered to universally exist in human adolescence literature to present (Fig. 1 (A picture drawn with the image of the Figure by Tanner JM (1978) [4]). It has become so influential that there are hardly any textbooks for auxology that does not introduce this theory.

It has been considered universal phenomenon that exists among humans regardless of countries, ethnic groups, or other factors. Also, there is no difference found in results using longitudinal, or cross-sectional research methods. Moreover, it is widely discussed that along with the onset of PHV the secondary sexual characteristics such as menarche, body hair, breasts, genitalia, and voice change can be observed. PHV is a typical indicator of biological changes during adolescence, and the timing of its appearance plays a

major role in relation to applied questions in various fields (Eveleth PB, Tanner JM, 1976 [5],1990 [6]; Takaishi M, Miyashita M, 1977 [7]; Falkner F, Tanner JM, 1986 [8]; Malina R, Bouchard C, 1991 [9]; Togo M, 1998 [10]; Ohsawa S, 2015 [11]).

However, there are critics of the theory that existed in the literature. The Quetelet A (1870) [12] known as the father of modern statistics, once reported that the PHV did not exist in the growth data from European populations. However, the findings were criticized and not approved by experts in auxology (Tanner JM, 1981) [13]. After the findings from Tanner JM, 1981, no other publication denies the existence of PHV theory.

However, in recent years, the debate over the existence of PHV in the hunter-gatherer, Pygmy of West Africa (Van de Koppel JMH, Hewlett BS, 1986) [14] was discussed and raised doubt on PHV theory existence.

In addition, the research on hunter-gatherer Baka women in the same region, showed that some ethnic groups have negligible PHV (Hagino et al., 2013) [15]. The findings did not completely deny the existence of PHV but remain uncertain about the focus of the research question, discussing on the fact that hunter-gatherers are short in stature.

There are very few hunter-gatherers in Southeast Asia, and this research is focusing on the hunter-gatherers in the region to discuss the PHV. The tribes in the South Asian region such as Moken and Mlabri in Myanmar and Thailand have different characteristics to Pygmy or Baka, tribes in the Western African region in stature. Also, they are of Mongoloid descend and their genetic position is not contested (Ohta H, et al., 2005) [16]. Thus, research focusing on South Asian tribes to examine the research questions.

In this background, the objective of this study is to examine the question that whether PHV is indeed a biological trait that is universally inherent in human beings. Also, investigates the established growth theory of the universal existence of PHV. This research is significant in the context of auxology and the implication of the discussion on the scholarship (Ohsawa S, et al., 2018 [17], 2021 [18]).

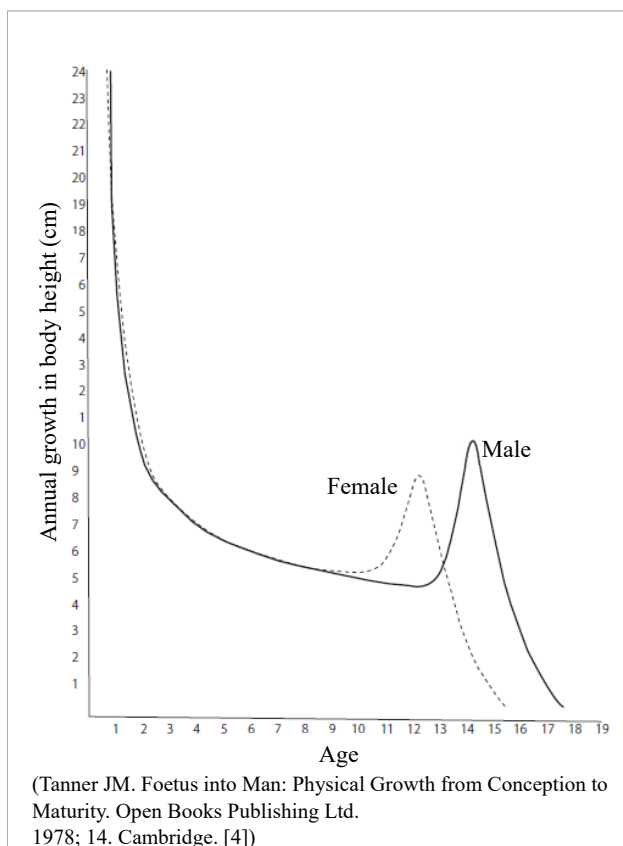


Fig. 1. The image of the general adolescent spurt of height

2. The issue of PHV among hunter-gatherers

To this day, of the knowledge of human growth accumulated over the past century, mainly in Western countries and East Asia, do the following theories that seem to be the most important apply to Mlabri and Moken the hunter-gatherer?

Q1. “The adolescent growth spurt always exist in the human growth process.”

Q2. “There are always gender differences in the human growth process. At adolescence, female is temporarily larger than male, and a few years later male catch up with female. Eventually male grow larger than female.”

The knowledge of human growth and development is accumulated over a century. Most of the research was discussed with respect to Western countries and East Asia. In this research, the theories were applied to hunter-gatherer populations, (Moken and Mlabri) in South Asia to investigate two important phenomena. First, the adolescent growth spurt always exists in the human growth process and second there are always gender differences in the human growth process. The gender difference in the height growth process during adolescence, it is found that females are temporarily taller than males, and in a few years, males catch up with females and grow taller than females eventually. In this context, the research questions are what is the growth process of Moken and Mlabri tribes and what differences can be seen in comparison to modern people? “What the developmental process of Moken and Mlabri, the hunter-gather, is and what differences can be seen compared to modern people’s one.”

3. Methodology

To achieve the objective of the research, two hunter-gatherer populations, Moken in Myanmar and Mlabri in Thailand, are selected as the research subjects. Both tribes are living as hunter-gatherers in the present world. Detailed understanding of their position in human history, the sphere of life, and the lifestyle are described in the appendix (1-3) at the end of the paper.

3.1. Area and object for the research - Moken

The Moken (or Salon) are hunter-gatherers who still live a nomadic lifestyle current in the 21st century. They live on islands in the Andaman Sea, east of the Bay of Bengal (administratively the Tanintharyi Region of Myanmar) (Fig. 2). The distribution range of Moken extends from the Tanintharyi Region in Myanmar to the islands of Ranong Province in Thailand. In this study, we surveyed Moken who live on the islands of *Don pu le aw*, *Pa lunn war*, and *Don nyaun mai* during the rainy season, which is located in the northern part of the Andaman Sea in the southernmost part of Myanmar.

We surveyed 93 males and 100 females. All of them are aged between 2.5 and 22 year old. The measurements were conducted five times periodically during the study period (August 2015 to October 2018), and it was from 9 a.m. to 11 a.m. The total of collected data was 465 samples for males and 500 for females. The dataset is mixed longitudinal study that pooled data from 193 individuals who were measured longitudinally over several years, five times during the period. The age of participants’ was confirmed by confirming the date of birth through reliable government records (Myanmar resident registration), and the decimal age was calculated from that date to the date of measurement.

3.1.1. Measurement method

We used an anthropometer to measure the instruments and conducted more than three measurements and the median value was selected as the data to record.

The data was collected from the elementary schools in Tanintharyi region, *Done pu le aw* island and other areas in the Republic of the Union of Myanmar. The data was collected by a Japanese researcher, the principal and assistant (teacher) of an elementary school in *Done pu le aw* island. The team was proficient in acquiring the correct data. The limitation of data collection was irregular measurement due to the movement of Moken across the ocean and difficulties to take measurements during dry seasons. One person was measured in total five times during the data collection period.

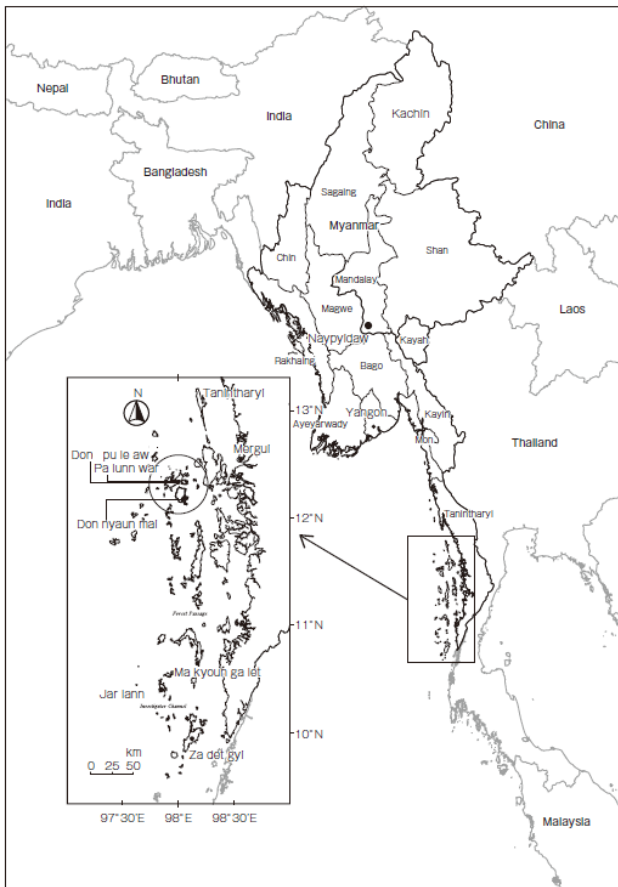


Fig. 2. Location of the survey - Moken

3.2. Study area and research object – Mlabri

Until the end of the 20th century, Mlabri had lived nomadic style as hunter-gatherers in Thai forests. It was in the late 20th century when the forest in Thailand began vanishing rapidly. As a result, Mlabri people start losing their livelihood gradually, because they are dependent on the forest for their basic needs. With the Thai government’s policy inducement, they began to change their adaption strategies from nomadic style to life as permanent residents.

In the 21st century, most Mlabri settled in new permanent dwellings set up by the Thai government in the mountain district of Nan province. Another dwellings is in Nan province, Ban Ruang district, Huai yuak in Thailand. At the beginning of the 21st century, Mlabri had a total population of approximately 300 people, today approximately 60% of that total population settled in Huai yuak.

Switching from nomadic style to permanent residents is called “Settlement Revolution” (Nishida, 2007)

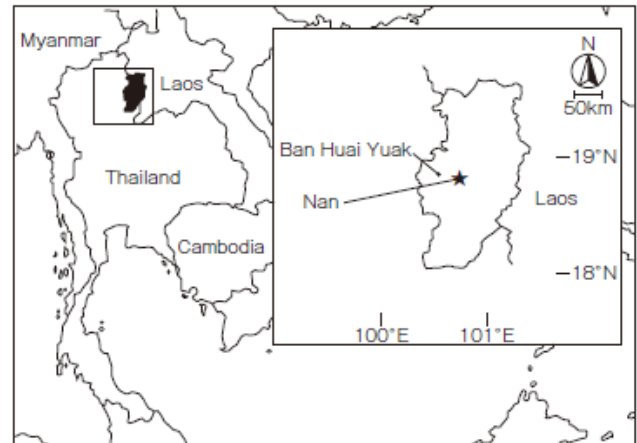


Fig. 3. Location of the survey - Mlabri

[19]and it has brought a drastic change of the lifestyle of Mlabri people. Historically, the Japanese people have also shifted from the nomadic lifestyle in the Paleolithic Period to the modern age through the Jomon Period’s “Settlement Revolution.” Almost 20 years have passed since the Mlabri settled in the late 20th century. However, those years are considered as a short period compared to the length of time they were nomadizing in the forest. Therefore, around the year 2015 when this research was conducted, we could say that it is the time when their settlement to permanent dwellings had just begun. The Mlabri people met during the data collection process discussed the time they led the nomadic life in the forest.

In total, 96 Mlabri men and women of age between 1.5 years to 30 years are surveyed. The data were collected from 41 males and 55 females. The data collection was conducted eight times between March and September of 2012 and 2016. The final count of the total collected sample of data was 240 for males and 267 for females.

However, few people were not able to survey all eight accounts. This is identified as the limitation of the data collection process. Therefore, the collected is mixed with the longitudinal survey by pooling the collected data. The age of males and females are converted in months (provided by the Thai government) and decimal places were rounded off. In general, when the growth data is analyzed, it is used measurement data taken once a year as the value of the age. To reduce the positive and negative errors in data, the analysis of age is converted into the months beside years and rounded off the

decimal age group to easily comprehend.

The survey was conducted after receiving the full consent and cooperation of the Mlabri tribe people and their families and representatives/officials of Ban Huai Yuak district.

3.2.1. Measurement method

The height measurement was conducted as per MARTIN method (Practical Human Biology, 1981, Academic Press) in Ban Huai Yuak, Ban Ruang district, Nan province in Thailand. Two researchers proficient in height measurement along with a veteran teacher from Thailand conducted the data collection process.

4. Results

4.1. Growth curve of Moken Males in Height

In the section, observed the growth curve of height in Moken males (n = 465) and investigates the existence or absence of adolescent growth spurt (PHV). Previously, it was assumed that the human height growth curve would be a gentle sigmoidal curve but in Moken males the gentle arching curve was identified. This type of growth curve was not described by Scammon RE (1930) [20]. The fit of the polynomial is calculated as $r = 0.923$, shown using Equation 1 (Fig. 4).

In Fig. 4, the horizontal axis represents the age and vertical axis is the height. In total (n = 465) sample data was used to obtain the growth curve for Moken (male).

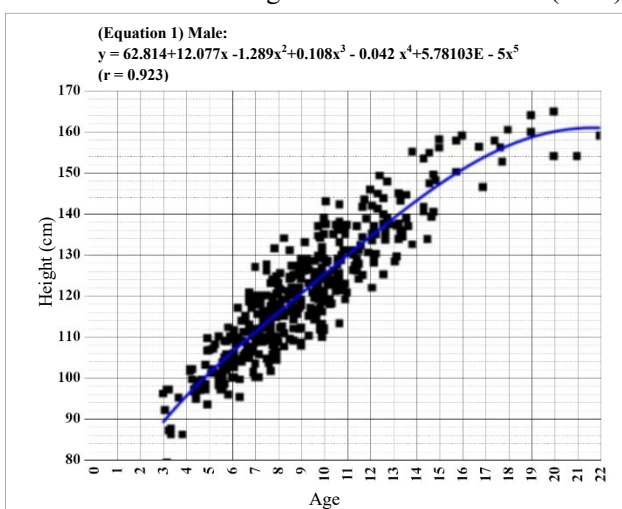


Fig. 4. Height growth of Moken (Male)

(Ohsawa S, Shimoda A, Than Naing. On the Salone (Moken) people in whom adolescent growth spurt of height have not been seen. Jpn J Hum Growth Dev Res. 2021; 90, 1-10. [18])

The fifth-order polynomial equation was found to be the most suitable to estimate the highest correlation coefficient. Calculated using Equation 1 (Fig. 4), the (y) obtained by substituting the decimal age (x) in this estimation equation is the best average estimate of body height for Moken (male).

From this growth curve, we can observe the growth process of Moken (males). After attainment of the age of 2.5 years, the height increases linearly from infancy to childhood till the 14 years of age. After reaching the age of 14 years, the height growth is slower, but it did not stop growing after the age of 17 or 18 years. It is found that it stops after the attainment of 20 years of age in Moken (males). During the growth process, adolescence growth is not spurted, but only increases predictably and gradually. It is an important point to note here that the rapid changes in height growth are not observed during the adolescence in Moken males.

4.1.1 Growth curve of Moken Females in Height Development

The Fig. 5 showed the growth curve of height development in Moken females. The calculation of the data showed the fifth-order polynomial was appropriate for females and males. As shown in Equation 2 (Fig. 5), that the correlation coefficient is high.

As shown in Fig. 5, they axis represents the age in rounded off decimal numbers of years. The x-axis is the measured height of females during those years of age.

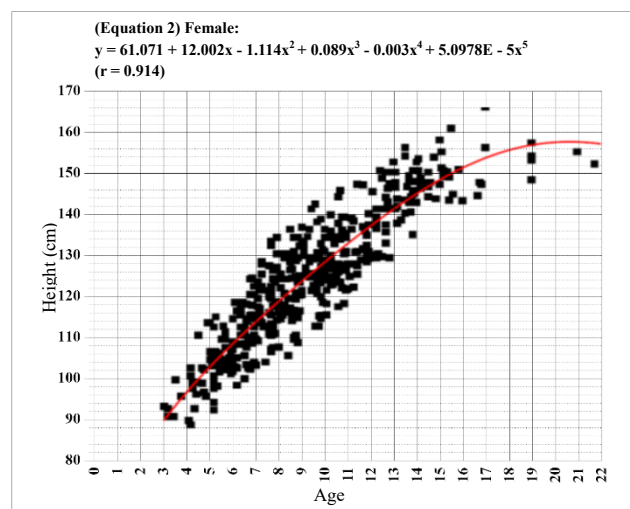


Fig. 5. Height growth of Moken (Female)

(Ohsawa S, Shimoda A, Than Naing. On the Salone (Moken) people in whom adolescent growth spurt of height have not been seen. Jpn J Hum Growth Dev Res. 2021; 90, 1-10. [18])

This value is used in later section to examine the difference between gender height growth.

The analysis of the growth curve of the growth process in the females showed that similarly to males, females grow rapidly as well. For females, the growth curve continues increasing rapidly after the age of 2.5 years, and this trend continued in early childhood days. From infancy through childhood, the growth was observed growing moderately and increasing with a very small convex curve until around the age of 13 years. Afterwards, it increases moderately until the age of 18 years. It is observed that similar to males, females continue to grow slightly until the age of 20 years.

We observed that the growth of males and females grow to a maximum of 161.9 cm and 157.4 cm respectively. The Moken are found to be taller than Japanese Jomon people (which is 159 cm for males and 148 cm for females). Japanese people height was measured by Kimura K (1979) [21]. Moken are found taller than the Mlabri (157.7 cm for males and 149.4 cm for females) as well. Finally, it is observed that Moken females are the tallest.

4.2. Growth Curve of Mlabri in Height (Male)

As shown in Fig. 6, the x-axis represents the age and y-axis represents the body heights. In total 240 sample data was analysed and used to create the growth curve for Mlabri males. Equation 3 (Fig. 6) of 9th order

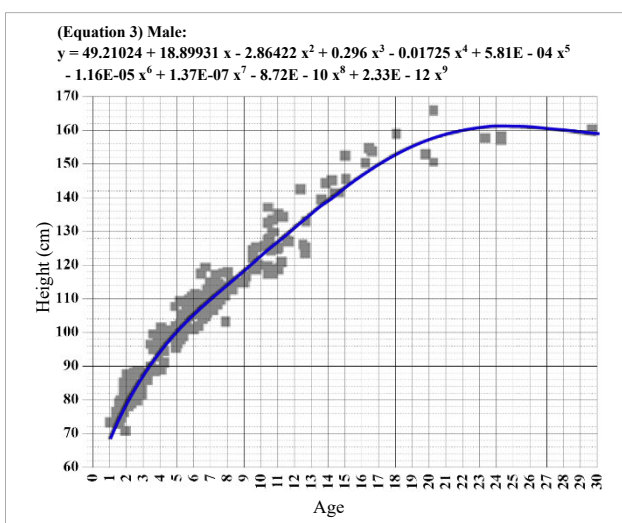


Fig. 6. Height growth of Mlabri (Male)

(Ohsawa S, Shimoda A, Sriskhontamit S, Pradit N. On the Mlabri people in whom adolescent growth spurt of height have not been seen. Jpn J Hum Growth Dev Res. 2018; **80**, 30-38. [17])

polynomial was used.

As shown in Fig. 6, it is observed that the growth curve sharply rises after the age of 1.5 years. From birth to childhood, the height growth continues linearly till the age of 15 years. After that age, the gradient becomes gentle and continues increasing slightly from adolescence to the age of 25 years. The attained height (adult height) of males is 157.7 cm.

The growth curve of humans is generally a gentle sigmoid curve. The Scammon RE (1930) [20] called this the growth age as the general type of growth. However, for Mlabri, it increases linearly up to the age of 15 years and it is different than the well-known sigmoid curve. Based on the observation, it is estimated that the growth curve till the age of 25 years is close to the logarithmic curve and equation 1 (polynomial) applies well with $r = 0.984$.

4.2.1. Growth Curve of Mlabri Females

Fig. 7, represents the growth curve using sample data from 267 Mlabri females. Analysis of data was obtained to have the highest correlation coefficient, the 9th order polynomial (Equation 4-Fig.4) found to be the appropriate choice for Females, similar to males. The polynomial equation applies well and calculated $r = 0.984$.

The growth curve analysis showed that Mlabri females grow rapidly from birth, similar to Mlabri males.

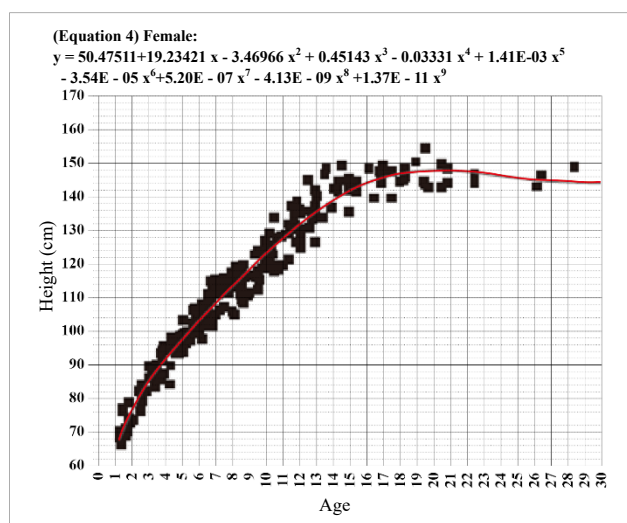


Fig. 7. Height growth of Mlabri (Female)

(Ohsawa S, Shimoda A, Sriskhontamit S, Pradit N. On the Mlabri people in whom adolescent growth spurt of height have not been seen. Jpn J Hum Growth Dev Res. 2018; **80**, 30-38. [17])

It is found that the gradient of the curve is steeper for females than for the males. The growth curve increases sharply after the age of 1.5 years and continue to grow to childhood years. From birth to childhood (which is age between 2 and 10 years), the height increases linearly until around age 15 years and afterwards increases at a slow pace until around age 17 years. For females, the height continues to grow slightly till the age of 20 years. Based on the results, it is found that the height of adult females grow to 149.4 cm, which is considered short.

5. Does the rapid spurt of adolescence exist?

From the observation of the growth velocity curve

Observation of Growth Velocity Curve: Existence of Adolescence Spurt? To analyze the height development process, the above equation is further differentiated to first order to draw the height growth rate curve, which is shown in Fig. 8 and 9.

5.1. The PHV (Peak Height Velocity) Curve of Moken

The PHV curve (Fig. 8) for the height of the Moken males is obtained by first-order differentiation of equation (Equation 1) (Methods are shown latter in the analysis of Mlabri). The Fig. 8 showed the height velocity curve per year that the velocity decreases rapidly around 7 cm per year in or around age of 3 years. Between the age of 7 and 12 years, the level stays constant at 4.7 cm per year. After the age of 13 years, the speed decreases further and continues to decrease at a constant slope until the age of 22 years. The growth of body height does not completely stop until the age of 22. In particular, it is important to note that the curve is not found increasing in the adolescence and PHV is not observed at all.

In the case of females, as can be seen in Fig. 8, in the early childhood stage the curve decreases sharply from 7.3 cm per year, which is a slightly higher than that of males. It moderately decreases from around the age of 7 year to 12-13 years. After that, the curve decreases linearly until the age of 20 years of age, at which point it completely stops growing. The velocity curve after the age 10 years follows a lower position than males.

Based on results, it is conclusive that in case of

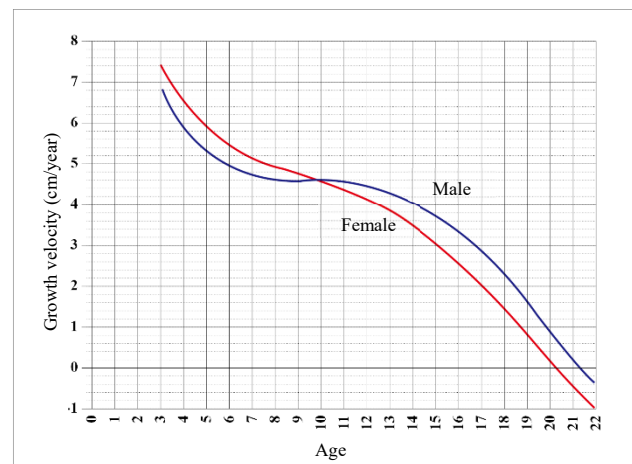


Fig. 8. Growth velocity curve in height of Moken- PHV is not seen in both genders -

(Ohsawa S, Shimoda A, Than Naing. On the Salone (Moken) people in whom adolescent growth spurt of height have not been seen. Jpn J Hum Growth Dev Res. 2021; 90, 1-10. [18])

Moken males, there is no adolescent growth spurt (PHV) was found in growth velocity of males and females.

Moreover, Moken males continue to grow until age of 22 years and females until age 20 years at a slower pace. This is very similar to the cessation of height growth of Mlabri males and females, which is estimated as 25 years for males and 20 years old for the females. Therefore, it is interpreted from the data of the two hunter-gatherer populations residing in Southeast Asia that the hunter-gatherer lifestyles lead to longer height growth periods.

5.2. Growth curve in height of Mlabri

The growth velocity curve of Mlabri males and females are differs from the growth curve that others that has been reported and generally discussed in the standard texts in auxology (Fig. 1). Generally, the growth velocity curve discuss the existence of adolescent growth spurt but this is completely absent for Mlabri males and females growth curve. Furthermore, it is analyzed that the curve is flat in adolescent. Therefore, the age at which PHV occurs cannot be calculated. As shown in Fig. 9, during infancy, the velocity curve rapidly drops from a higher position to the age of about age of 3 years. At the age of 5 years, the growth velocity suddenly comes to standstill, falling to a maximum of 30.8% for males and 38.5% for females, and continues

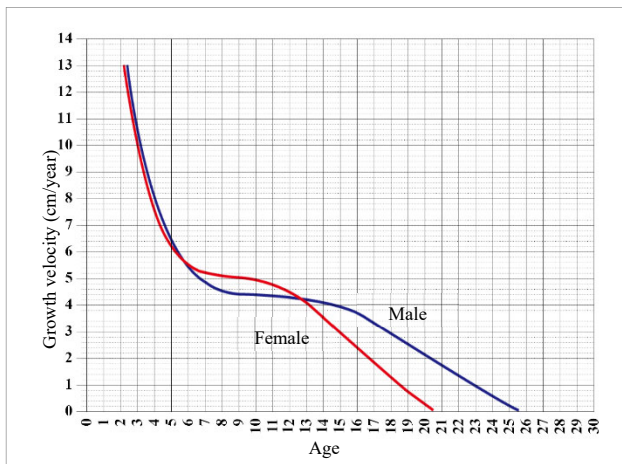


Fig. 9. Growth velocity curve in height of Mlabri
 (Ohsawa S, Shimoda A, Sriskhontamit S, Pradit N. On the Mlabri people in whom adolescent growth spurt of height have not been seen. Jpn J Hum Growth Dev Res. 2018; **80**, 30-38. [17])

at a certain level until the age of 12.5. Moreover, after the age of 13 years, the growth continues at a slower rate until the age of almost 25 years for males and 20 years of age for females. Mlabri continues to grow, in their late teenage years. The period of gradual decrease is 12 to 13 years for males and it is slightly longer than for females.

It can be confirmed based on the analysis that there is no occurrence of adolescent growth spurt and PHV in Mlabri as well as Moken males and females. For both Moken and Mlabri the growth velocity becomes null at the age of 25 for males and 20 for females. In comparison between Moken and Mlabri, Mlabri males and females has an exceedingly longer adolescent period than Moken

Calculation for the growth velocity curve in body height (method)

To analyze the aspect of the growth process, we can further differentiate the equation showing above by first-order differentiation to obtain the following equation.

(Equation for the growth velocity of Mlabri male, See Fig. 9)

$$(Equation 3') y = 18.89931 - 5.72844x + 0.888x^2 - 0.069x^3 + 2.90E-03x^4 - 6.97E-05x^5 + 9.56E-07x^6 - 6.98E09x^7 + 2.10E-11x^8$$

(Equation for the growth velocity of Mlabri female, See Fig. 9)

$$(Equation 4') y = 19.23421 - 6.93932x + 1.35429x^2 - 0.13324x^3 + 7.05E-03x^4 - 2.13E-04x^5 + 3.64E-06x^6 - 3.30E-08x^7 + 1.23E-10x^8$$

6. Consideration and discussion for questions

In this section, we consider the results and discuss them in accordance to research questions posed in earlier sections.

6.1. Regarding Question 1

First of all, the section discusses the proposition that “The adolescent growth spurt always exist in the human growth process.” This statement is supported by the literature on the human growth since the 18th century.

As shown in Fig. 8 and 9 and based on the analysis, it is conclusive that the adolescence spurt (PHV) cannot occur in Moken and Mlabri.

Therefore, it is clear that the universal proposition showed and discussed in auxology literature that the “adolescence development spurt always exists in human growth process” is not a valid statement. Ohsawa’s proposal (2018) [17], that it should be investigated on many of individuals and populations that have the adolescent growth spurt in their growth, and others, while others have no adolescent growth spurt at all, is supported during our analysis. It was previously reported that no PHV was found among the hunter-gatherer Pygmy of West Africa (Van de Koppel JMH, Hewlett BS, 1986) [14] and the author of paper interpreted the absence of PHV is due to the short stature of pygmies needs to be re-examined to understand its validity.

6.2. Regarding Question 2

Another proposition is that “the gender difference always exist in the human growth process. At adolescence, females temporarily surpass males, and a few years later males catch up with females. But eventually males become taller than females.” In response to this statement, authors discussed the question in light of estimates obtained by the aforementioned equations (Equations 1 and 3) for males and the equations (Equation 2 and 4) for females. The

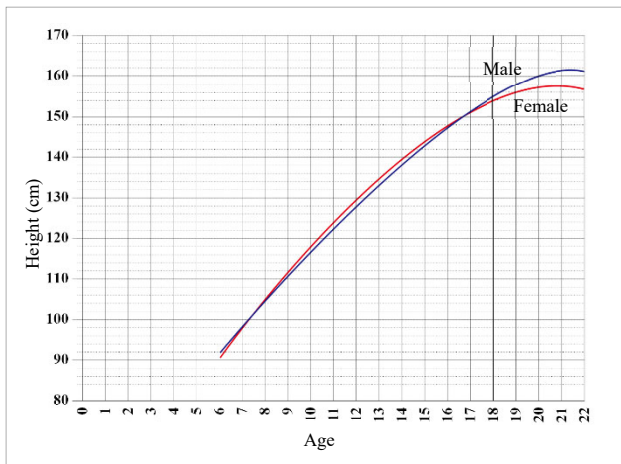


Fig. 10. Comparison of the growth of Moken in height between male and female

(Ohsawa S, Shimoda A, Than Naing. On the Salone (Moken) people in whom adolescent growth spurt of height have not been seen. *Jpn J Hum Growth Dev Res.* 2021; **90**, 1-10. [18])

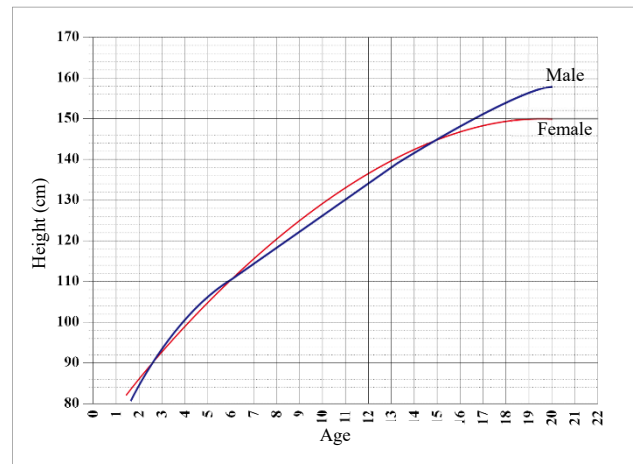


Fig. 11. Comparison of the growth of Mlabri in height between male and female

(Ohsawa S, Shimoda A, Sriskhontamit S, Pradit N. On the Mlabri people in whom adolescent growth spurt of height have not been seen. *Jpn J Hum Growth Dev Res.* 2018; **80**, 30-38. [17])

results are shown in Fig. 10 and 11. Based on the interpretation of results the statement is proved not true.

6.2.1. Gender differences in the growth of Moken

For Moken, as shown in Fig. 10, the 5-year-old females (102.3 cm) are estimated taller than males (102.0 cm). It is estimated that females are consistently taller than males until the age of 14 years. The difference (0.3 cm taller for females) is 0.8 cm at age 6 years, 1.8 cm at age 9 years, and this widens with growing age, which remains the difference at 1.8 cm until the age of 11 years old.

After the age of 11 years, the gender difference gradually decreases until the age of 15 years. At the age of 15 years, male height growth finally catch up with female and they grow to 148.1 cm. This results in same heights for males and females. After the age of 16 years, the difference between males and females reverse the direction and males exceed the height than of females. The gap gradually increases, and males were found 4.9 cm taller than females at the age of 22 year.

The Japanese females exceed the height of males only in two years between the age of 10 and 11 years, and that is limited to only the adolescent period. The difference is 1.2 cm at age 10 year and 1.6 cm at 11 years. Meanwhile, Mlabri females height exceed the height of males for a long period of 7 years and 6 months, from age 7 to 14.5 years.

In contrast, Moken females are already taller than males at the age of 5 years, even earlier than Mlabri. Therefore, the statement “females are temporarily taller than males,” which appears in the proposition that “Gender differences exist in the human developmental process is not understood not entirely true In adolescence, females temporarily exceed the height of males, and after a few years males height catch up with females, and eventually, males are taller than females,” is appropriate to be rephrased as for Moken tribe, more than 10 years from Birth, in childhood, the females are taller than males.

Our analysis proved that statement widely discussed in the domestic and foreign text on the growth of humans is not universal for diverse ethnic groups.

6.2.2. Gender difference in the growth of Mlabri

According to the Fig. 11, females (72.7 cm) are already taller than males (71.9 cm) at the age of 1.5 years. Also, males (86.7 cm) are slightly taller than females (86.5 cm) at the age of 3 years and males (107.6 cm) are taller than females until the age of 6.5 years.

However, females (110 cm) exceed males (109.8 cm) again at the age of 7 years and females (142.4 cm) are taller than males (141.8 cm) from the age of 7 to 14.5 years. During this period, the maximum gender difference is noticeable at the age of 12 years and females are taller than males by 2.3 cm. At the age of 15 years, males catch up with females, and both genders

reach 143.6 cm.

The differences between males and females gradually increased after the age of 15 years, and the height of males are 157.7 cm and females are 149.4 cm at the age of 20 years. The gender difference increased to 8.3 cm. Compare to Japanese males and females, the difference between Japanese males and females is approximately 0.7 cm at the age of 12 years and 2.3 cm for Mlabri. Moreover, the dominant period of females in Mlabri is longer and it lasts at 7.5 years. The findings represent the major differences between Mlabri and Japanese.

As the result, the gender difference of growth exist even in hunter-gatherer (Mlabri), moreover, the period that female is taller than male considerably longer period. Thus, it is clear that the growth of hunter-gatherers does not fit the growth theory induced from data collected in Western and East Asian countries.

The future research can explore the reason that why there is no adolescent growth spurt occurs in the developmental process of Moken and Mlabri. This seems to provide an understanding of interactions between human developmental phenomena and the environment.

7. Discussion

Results showed that it was difficult to spot the PHV in adolescence of the hunter-gatherers, which is in line with the results from previous studies on African Pygmies. However, the authors reasoned based on height development of Pygmy or Baka, who is considered the shortest people in the human race. Indeed, for the Pygmy or Baka the height is in range of 154 cm of range, even in adult male. The cause of the short stature is interpreted to be growth retardation in the adolescent (Van de Koppel JMH, Hewlett BS, 1986) [14]. Moreover, we are concerned about the fact that these materials were obtained through a cross-sectional survey, which means the results can be different if it is the longitudinal data.

In any case, the reasoning of the argumentation is the hypothesis that “short stature means there will be = lack of PHV curve.” However, insights from the studies conducted on the ethnic groups in Southeast Asia by

now, the hill tribes are generally of short stature; the height of Mon people is 158.2 cm, Aka for 159.4 cm, Lisu for 161.5 cm, Lahu for 158.5 cm, Karen for 159.0 cm (Kokudo et al., 2010) [22], Wa for 159.7 cm (Ohsawa et al., 1996) [23]. However, it doesn't mean that PHV cannot be found because of the short stature. In addition, all of the data were cross-sectional data. Therefore, it is unlikely that short stature and cross-sectional surveys are causing the lack of PHV curve in the study. Furthermore, the results of a large-scale cross-sectional survey of Japanese people and other populations indicated the existence of PHV, so we cannot simply attribute the reasons to the cross-sectional survey.

Shea BT (1988) [24] suggests that the lack of PHV can be related to the inability to determine the exact date of birth for the hunter-gatherers with the Pygmy's data. It seems that the core of the issue has been neglected here, as the existence and absence of PHV is considered dependent on the research methodology. Authors seems to think that PHV curve would be visible fit is verified with longitudinal data. In both the cases, studies avoided any discussion of PHV.

In contrast, Hagino I, et al. (2013) [15] recently conducted a cross-sectional study of 349 males and 277 females of Pygmy and reported that their PHV curve is considerably smaller. The authors interpreted that PHV existed, although the existed curve was smaller. They pointed out that it should be verified with longitudinal data. They, too, do not accept the existence of the ethnic groups without PHV. However, even with cross-sectional data, it is debatable that PHV does exist in each case (based on the conventional theory), which makes the argument not convincing. so this argumentation is by no means a complete one.

Based on the above discussion, it seems that head-on denial of the existence of PHV is still a dangerous practice for auxology scholars. In other words, the existence of PHV is considered to be an undebatable subject in auxology.

However, in this paper authors noticed that there was no existence of PHV in both the two hunter-gatherer populations of Moken and Mlabri in Southeast Asia. Moreover, the study is not based on data obtained from a simple cross-sectional survey, but it was based on a

mixed-longitudinal study, in which, individuals were measured longitudinally about six times every six months or for a short period of several years. Their recorded age were converted into decimal age which was based on the birth date provided by the official government-issued resident registration cards. Based on results and analysis, authors challenge the established theory of auxology arguing about the universal existence of PHV in the human growth process. This was agreed upon for over a century. The authors recommend a revision to the theory.

The study also revealed that the developmental processes of the Moken and Mlabri were similar to each other and they shared many characteristics in common as hunter-gatherers. In other words, the discovery in the study regarding the growth of females more precociously than male. Also, from infancy to the age of 16 years in the hunter-gatherer's males and females, females are found to be taller than males shed the light on the research outcome.

These findings were different from the shared knowledge in the field of auxology. This seems that research was mostly conducted and based on urban children from Europe, the United States, and East Asia or elsewhere, neglecting the other part of the human race.

The study revealed that “there is not always an adolescent growth spurt in the human growth process,” this was proved after researching on hunter-gatherers, and it is expected that future studies on hunter-gatherers will expand our knowledge of human growth on a broader scale.

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Appendix 1. Position of Moken and Mlaburi in Human History

The lifestyle of Moken is nomadic hunting and gathering and is classified as one of the oldest lifestyles in the history of human growth, called the "Man's Way (1959) [A1]" by Goldschmid R. (Ohsawa S, 2016) [A2]. The Mlaburi, on the other hand, has already shifted from a mobile lifestyle to a sedentary lifestyle since the end of the 20th century, so it can be said that is the lifestyle of settlement evolution which is slightly closer to modern society than Moken.

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Appendix 2. Lifestyle of Moken

Since Salon is still migrating in the ocean, we believe that they have retained various life and physical skills from prehistoric times. Fishing methods still rely on bare-diving and fishing spear, not doing fishing or net fishing. Of course, they don't use snorkels or



Fig. A1. Moken's House by the Sea (Photo by Ohsawa S., 2013)

motorized fishing gear of any kind. This fishing skill is equivalent to the Paleolithic fishing technology in Japan (Obayashi T, 1996) [A3]. The life history of the Moken was reported by a missionary White WG (1997) [A4] at the Oxford University Anthropological Society in 1922, and explorer and ethnologist Bernatzik HA (1938) [A5] left a slightly detailed ethnography.

We express surprise at the fact that these reports from more than 70 years ago are almost the same as what the author was able to learn from his field research in the early 21st century. That is to say, the basic lifestyle of these people is as it was in ancient times, and they are still living the lifestyle of people who lived more than 10,000 years ago.

However, until the first half of the 20th century, foreign researchers were allowed to enter this area of Myanmar, but now foreigners are prohibited to conduct research activities in these waters. The authors' research trip was made possible because of the exceptional care taken by the local government. Incidentally, the minister in charge of the local government and Mayor Myeik accompanied us on the survey as well as several police officers for security purposes.

As nomads, where they reside in one place for the longest part of the year on the islands is *Don pu le aw*, *Pa lunn war*, and *Don nyaun mai* in these waters. On *Don pu le aw* Island, the center of the islands, Kayin and Burmese people inhabit and are mainly engaged in fishing. On the beach of these islands, Moken build huts like the one in the photo (Fig. A1) to spend the rainy season.

Although there is no electricity or drinking water supply on *Don pu le aw* Island, there is an elementary school for Kayin and Burmese, a very small Buddhist temple, a Christian church, and a small medical office with nurses, as well as local officials are in residence. There are a few small stores, and although the number of people is only a few hundred the houses of the Kayin and Burmese people, whose livelihood is fishing, are clustered in several places.

The people of Moken are gentle. They don't fight against their neighbors or other ethnic groups (Ivanoff J, 1997) [A6], and they coexist with different ethnic groups. During the rainy season when not suitable for navigation, they live in huts on the beach of the island.

Their livelihood is hunting and gathering. They live a mobile life at sea for several months of the year. Their foundations of existence depend on the richness of the Andaman Sea for its blessing, and the flora and fauna or fish and shellfish of the islands. However, like the other hunter-gatherers, they do not cultivate plants or raise livestock or chickens.

Currently, the government of the Tanintharyi Region is also encouraging students to attend school. Recently, it is said that some exceptional children receive schooling from among the Moken, however, none of the people surveyed in this study was enrolled in school. It is a non-literate society, and children are born, grow up, and become adults in nature. The family is a nuclear family, and children accompany the family on the navigation by the houseboat. They grow up playing on



Fig. A2. Brother and sister of Moken on *Done pu le aw* island (Photo by Ohsawa S., 2012)



Fig. A3. Houseboat, Moken's place of life (Photo by Ohsawa S., 2013)

the beach, except for helping to gather fish and shellfish or fruits. The children seem to be enjoying their freedom (Fig. A2) itself in marine nature. A population census was conducted in Myanmar in 2016, and no details of the population of Moken have been released in the past.

During the dry season, the Moken navigate through the Andaman Sea by houseboat (Fig. A3) and spend their lives hunting for prey in the sea. All of our possessions, including all of their household goods and the tools necessary for livelihood, are compactly arranged and utilized in this small boat. During navigating on the sea, they occasionally anchor on scattered islands and spend a few days there, procuring water, food, and other necessities, or bartering. After about four months of fishing, they return to the port where they left and spend their life on the beach during the rainy season. All the living space is concentrated in a small houseboat, and the interior of the ship is simple to the limit. They scrimp and scrape all food, clothing, and shelter to the limit. Of course, no refrigerators for storage they have (Basically, They don't preserve anything.). The only things in the kitchen are plates, knives, pots, pans, or kitchen stoves. As for the environment in which children grow up, there are no children's toys or childcare tools in the houseboat at all, and the only thing they have is a hammock which is used in the hut on the beach. Their lifestyle, in a manner, is the environment of growth and development before civilization modify the people's lives and bodies in various ways.

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Appendix 3. Lifestyle of Mlabri

Until the end of the 20th century, Mlabri had lived nomadic style as the hunter-gatherer. It was in the late 20th century that the forest in Thailand began vanishing rapidly. As a result, Mlabri gradually lost the basis of their livelihood, because they earned their daily bread from the blessings of nature. With the Thai government's policy inducement, they began to change their adaption strategies from nomadic style to life as a permanent resident. Moreover, they remained strongly the various kinds of the art of living or lifestyle they used in the forest. For example, a few Mlabri people came along to do something or go out to play in the nearby woods by fits and starts, then returned to their settlements. The Mlabri children used to play in the woods as their playgrounds. Even now, the forest as



Fig. A4. Forest where Mlabri's sphere of life (Huai yuak, Nan province, Thailand; Photo by Ohsawa S., 2016)



Fig. A5. Mlaburi boy climbing a tree (Photo by Ohsawa S., 2017)

their habitat could be not only a valuable space for them but also a native place (Fig. A4; Fig. A5.). Having an interaction with them, it seems that the current lifestyle is an extension of life in the forest. They also retain some interesting physiological features, such as physical abilities, which may have been gained over the long forest life.

By the early 21st century, most of the nomadic hunter-gatherers had disappeared from the planet. Japanese ancestors also shifted from the nomadic style

to the settled habitation more than 10,000 years ago. Mlabri may forget the life in the forest from their memories soon. Therefore, in this 21st century, it is very rare and valuable to conduct survey research on the people who led the nomadic life until recently and just begun the settlement. Moreover, exploring the growth and development of Mlabri, who retains the physical features of hunter-gatherers, is one of the ways to approach the primordial growth of human beings and is expected to be intriguing insights.

Abstract (Japanese)

人の身長発育過程には思春期スパートが必ず存在する，ということは現在の発育学の定説である。しかし，ミャンマーのモーケン（サロン）とタイ山地の森で生活していた狩猟採集民のムラブリ（ピートンルアン）とでは，この身長の思春期スパートが存在しない。これらの狩猟採集民の発育期は非常に長く，男女ともに 20 歳以上まで緩やかに発育が続く。さらに女子が男子より身長が大型である期間は，欧米人や日本人の 2 年間よりはるかに長く，モーケンで 12 年間，ムラブリで 14 年間である。これらの研究結果を総合すると，20 世紀中葉から現在まで定説とされてきた“人類には思春期スパートが必ず存在する”という定説は修正される必要がある。

キーワード：思春期スパート，狩猟採集民，ムラブリ，モーケン，身長発育

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