Anthropometric mismatch between student's body dimensions and school furniture in Indonesian elementary school and proposed dimensions

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Abstract. The objective of this study is to examine whether the school furniture dimensions provided by school authorities in Indonesia match with anthropometric data of Indonesian elementary school students. School furniture's dimensions were evaluated each for seat height, seat depth, seat width and backrest height of the chair, and the height of desk by comparing with student's anthropometry. A number of 940 students age between 7 – 12 years old was participated. Results indicated high percentage of mismatch between Indonesian children's anthropometry and the school furniture provided for them. The seat height presented the highest mismatch with percentage are ranging from 90.1% to 100% for small type and 75% to 98.8% for large type. For desk height, the dimension was too high for almost all students in Grade 1, Grade 2 and Grade 3 and all student in Grade 4, Grade 5 and Grade 6. Hence, we found that the current dimensions of school furniture as provided by school authorities in Indonesia were not yet appropriate and need to be redesigned. Four different sizes of school furniture have been proposed which could cover the variability associated with anthropometric of the students from Grade 1 to Grade 6.

Keywords: the school furniture, anthropometric dimensions, elementary school children, mismatch

1. INTRODUCTION

School children carry out most of their activity such as reading, drawing, writing and listening teacher's materials in the sitting position. Being seated for a long period of time on school furniture is being associated with reports of musculoskeletal discomfort and pain (Fallon & Jameson, 1996). The chairs that are too low have a significant association with the occurrence of neck pain, upper back pain and lower back pain (Murphy et al., 2007). Meanwhile chair backrest that is too high has been significantly associated with lower back pain (Castellucci et al., 2014). Considering this, it is necessary that the school authorities provide students with the school furnitures which could promote good sitting posture. School furniture is a key factor for the adoption of proper posture (Castellucci et al., 2014).

In our literature study, it can be observed that concern about school furnitures and their match with student's body dimensions has increased. This concern is proved by the large number of studies showing clear mismatch between school furniture under study and student's body dimensions (Panagiotopoulou et al. 2004; Gouvali and Boudolos, 2006; Mououdi and Choobineh, 1997; Assuncao et al. 2013; Parcells et al., 1999; Dianat et al., 2013; Castellucci et al., 2010). Few studies reported that mismatch between student's body dimensions and school furnitures carried negative effect for the students (Murphy et al., 2007; Assuncao et al. 2013; Parcells et al., 1999). A study by Yanto et al. (2008) in a private elementary school in Indonesia also found that most children did not match with their school furniture caused pain in some area of their body.

In Indonesia, the elementary school authorities tend to provide the same size of school furniture for all grades

(Yanto et al., 2008). In some school, two types are used i.e small type for lower grade students (grade 1, grade 2 and grade 3) and large type for higher grade students (grade 4, grade 5 and grade 6). However, the comprehensive study need to be conducted to investigate whether the current school furnitures match with the update student's body dimensions.

This study aims to examine whether *the current school furniture which were provided by school authorities* match with the update anthropometric data of Indonesian children. To achieve the aim of the study, we compared elementary school students' anthropometric measures with the school furniture dimensions and determine whether there is match or mismatch between them.

2. METHODOLOGY

2.1 Participants

Based on Indonesian educational system, every elementary school has six grades with student's age ranging from six to 12 years old. Specifically for public school, the minimum age of student who enrolled should be at least 7 years old. In this study, the sample involved 940 children with their age ranging from seven to 12 years old. All subjects were taken from five public elementary schools in Jakarta, Indonesia. The sample covered gender and every school grade from Grade 1, Grade 2, Grade 3, Grade 4, Grade 5 and Grade 6. Table 1 presents the grade and gender distribution of students who participated in this study.

2.2 The school furniture dimensions

The school furniture dimensions were evaluated each for seat height, seat depth, seat width and backrest height of the chair and the height of the desk. The dimensions for each type of chair and desk are presented in Table 2. The school furniture dimensions are defined as the following (Figure 1):

Seat Height (SH)**:** The vertical distance from the floor to the highest point on the front of the seat.

Seat Depth (SD)**:** The horizontal distance from the back of the sitting surface of the seat to its front.

Seat Width (SW)**:** The horizontal distance from the outer left side of the sitting surface of the seat to outer right side.

Backrest Height (B): The vertical distance from the top side of the seat surface to the highest point of the backrest.

Desk height (DH)*:* The vertical distance from the floor to the top of the front edge of the desk.

There two types of chair and desk provided by school authorities for the students, i.e small and large chair and desk. The school authorities informed that small size were intended for students in Grade 1, Grade 2 and Grade 3 while the large chair and desk were intended for Grade 4, Grade 5 and Grade 6. Hence the equations were also applied following this allocation.

2.3 Anthropometric dimensions of the students

Figure 2.a illustrates the anthropometric dimensions measured in this study. Meanwhile Figure 2.b illustrates the actual measurement for one of subject's body dimension. All measures were collected with children in the sitting posture (except for stature). Body dimensions, landmarks and the measurement of each body dimension procedures were defined by Pheasant and Haslegrave (2006), as the following:

Stature : The vertical distance from the floor to the crown of the head, children stood erect, looking straight ahead.

Elbow Rest Height (E)*:* The vertical distance from the seat surface to the underside of the elbow, taken with the elbow flexed at 90^0 angle.

Shoulder Height (S)*:* The vertical distance from the seat surface to the acromion of the students.

Popliteal Height (PH)*:* The vertical distance from the floor or footrest to the popliteal angle at the underside of the knee where the tendon of the biceps femoris muscle inserts into the lower leg, knee flexed at 90^0 angle.

Popliteal Length (PL): The horizontal distance from the posterior surface of the buttock to the posterior surface, knee flexed at 90^0 angle.

Hip Breadth (HB): The maximal horizontal distance across the hips in the sitting position.

Table 1. Sample distribution based on grade and gender

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Subtotal
Boys	86	99	70	86	100	36	477
Girls	61	90	81	85	101	45	463
Subtotal	147	189	151	171	201	81	940

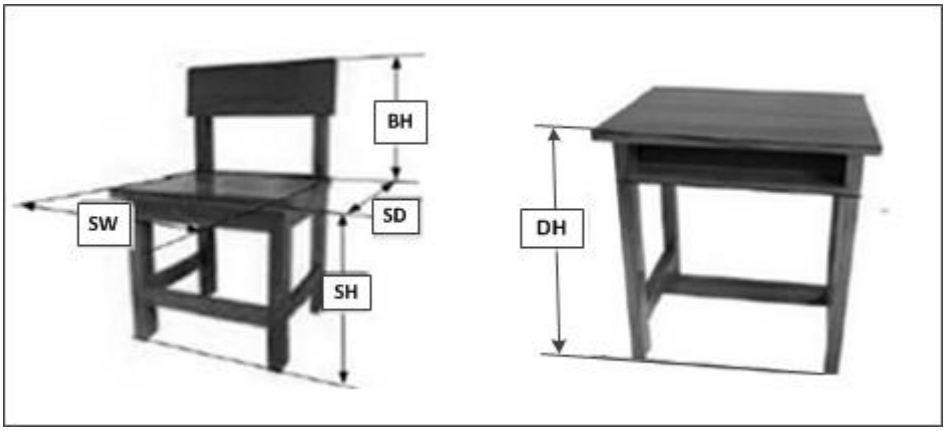

Figure. 1 The school furniture dimensions provided by school authorities

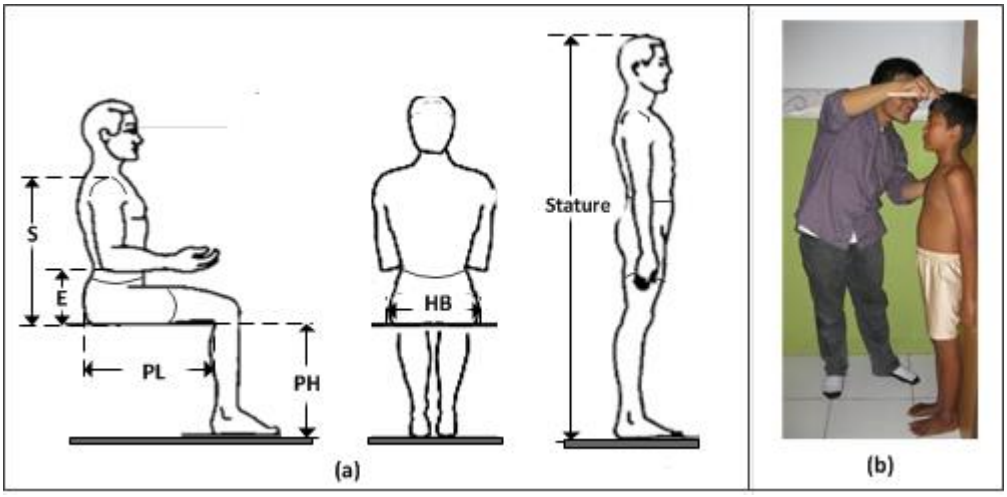

Figure. 2 Illustration of anthropometric dimensions measured in this study

2.4 Application of the measures

Anthropometric dimensions of the student were compared to school furniture dimensions to identify a match or mismatch. A mismatch is defined as incompatibility between the school furniture dimensions and the dimensions of the student's body (Parcells et al., 1999). Five equations were used to test the mismatch between anthropometric measures of the students and the school furniture dimensions. The "mismatch" was defined when the school furniture dimension is higher than the maximum limit or lower than the minimum limit for two way criteria, or lower than the minimum limit for one way criteria.

2.4.1 Seat height

The seat height needs to be adjusted relative to the popliteal height (Dul and Weermeester, 1998; Helander, 1997; Corlett and Clark, 1995). Gouvali and Boudolos (2006) recommended that seat height should be lower than popliteal height so that the lower leg constitutes a 5–30^0 angle relative to the vertical, and the shin-thigh angle is between 95 and 120^0. A 2cm correction for shoe height should be added to popliteal height to determine the seat height (Sanders and McCormick, 1993, Gouvali and Boudolos, 2006). Therefore, the seat height match criteria in this study was defined according to the Equation (1).

$$(PH + 2)\ Cos\ 30^0 \leq SH \leq (PH + 2)\ Cos\ 5^0 \qquad (1)$$

2.4.2 Seat depth

If the seat depth is greater than buttock-popliteal length, the students will not be able to use the seat backrest to support lumbar spine without compression of the popliteal surface (Milanese and Grimmer, 2004). Many researchers defined a seat depth mismatch when the seat depth was either < 80 % or >95 % of buttock-popliteal length (Parcells et al., 1999; Castelluci et al., 2010; Panagiotopoulou et al., 2004).The match criteria was defined according to the Equation (2):

$$80\%\ PL \leq SD \leq 95\%BP \qquad (2)$$

2.4.3 Seat width

Castelluci et al. (2010) recommended that the seat width should be larger than the hip width (one way criteria: SW>HW). Seat width should be enough to support ischial tuberosities and allow space for lateral movements. For these reasons, seat width should be large enough to accommodate even the users with the largest hip breadth (Evans et al., 1988; Sanders and McCormick, 1993). The match criteria in this study was defined according to the Equation (3).

$$110\%\ HB \leq SW \quad (3)$$

2.4.4 Seat backrest

Few researchers recommended that the backrest height should be kept lower than or at most on the upper edge of the scapula which is 60% to 80% of shoulder height (Gouvali and Boudolos, 2006; Diana et al., 2013). Considering these, the match criteria in this study was defined according to the Equation (4).

$$60\%\ S \leq BH \leq 80\%\ S \quad (4)$$

2.4.5 Desk Height

Parcells et al. (1999) suggested that desk height should be adjusted to elbow-floor height, so that it would be minimum when shoulders are not flexed or abducted, and maximal when shoulders are at 25^0 flexion and 20^0 abduction (elbow rest height 0.8517+shoulder height 0.1483; Parcells et al., 1999). Then the equation has been modified by Gouvali and Boudolos (2006) based on the fact that elbow-floor height is the sum of elbow rest height and seat height. In this study, the match criteria was defined according to the Equation (5) (Gouvali and Boudolos, 2006):

$$E + (PH + 2)\ Cos\ 30^0 \leq DH \leq [(PH + 2)\ Cos\ 5^0] + (0.8517E) + (0.1483S) \quad (5)$$

3. RESULTS

3.1 The school furniture dimensions

Currently, the school authorities provided two types of chair and desk for students i.e small and large chair and desk. The dimensions of both types are given in Table 2.

3.2 Anthropometry of the students

Table 3 presents the descriptive statistics of anthropometric data of the students in grade 1, grade 2 and grade 3 both boys and girls while Table 4 presents the descriptive statistics of students in grade 4, grade 5 and grade 6. Regarding Table 3 and Table 4, the anthropometric data show a consistent increase in mean by grade group for all dimensions. Independent t-test results showed that there were no significant differences between boys and girls for stature in Grade (all *p-values* are greater than 0.01). Results of anova test showed that there were significant differences among student's body dimensions following grade level for stature (p-value=0.00) and popliteal height (p-value=0.00).

3.3 Mismatch between the school furniture and student's anthropometry

Figure 3 shows the percentage of 1st, 2nd, 3rd 4th, 5th and 6th grade students whose anthropometric measurements did not match with the the chair dimensions (small and large type). Figure 4 shows the percentage of all students whose anthropometric measurements did not match with the desk dimension height.

As can be seen in Figure 3a, seat height of small chair was not appropriate for most students with the percentage ranging from 90.1% to 100%. The similar mismatch problem was also found for large chair where the seat height was not appropriate for majority of the students of 4th, 5th and 6th grade (more than 90% for students in Grade 4 and Grade 5 and 75% boys and 80% girls student in Grade 6). The results indicated that the mismatch occurrence between student's popliteal height and seat height dimension decreased with higher grade level for both small and large type.

For seat width, small percentage of mismatch were found in grade 3 (1.4% boys and 1.2% girls) and grade 6 (2.2% girls) as shown in Figure 3c. The results indicated that the seat width dimensions are appropriate for almost all students in all grade.

Table 2 The school furniture dimensions provided by school authorities (in cm)

School furnitures	Furniture dimensions	Small type	Large type
Chair	Seat Height (SH)	40	42
	Seat Depth (SD)	35	37
	Seat Width (SW)	39	42
	Backrest Height (BH)	35	33
Desk	Desk Height (DH)	66	75

Table 3. Anthropometric dimensions of 1st, 2nd and 3rd grade students (in cm)

Anthropometry dimensions	Gender	Grade 1				Grade 2				Grade 3			
		Mean	SD	P5	P95	Mean	SD	P5	P95	Mean	SD	P5	P95
Stature	Boys	122.4	5.1	114.4	130.9	125.5	5.8	115.9	133.8	129.7	5.4	121.0	137.2
	Girls	120.5	6.3	111.6	129.1	124.4	6.0	116.6	134.4	129.4	6.3	120.8	140.7
Sitting shoulder height	Boys	40.9	2.7	37.0	45.3	42.5	3.4	37.8	48.9	44.1	3.1	39.0	48.8
	Girls	39.5	3.4	33.7	44.4	41.5	2.8	37.7	47.2	43.8	3.1	38.7	49.1
Sitting elbow height	Boys	15.4	2.2	11.9	18.3	16.7	2.3	13.3	20.1	17.1	2.7	13.1	22.4
	Girls	15.5	2.1	12.1	18.4	16.8	2.5	13.5	21.2	17.2	2.3	13.6	20.5
Popliteal height	Boys	31.5	1.8	28.7	34.7	32.4	1.4	30.4	35.0	34.2	1.8	31.1	36.8
	Girls	31.2	2.2	27.4	34.2	32.3	1.8	30.0	35.5	34.3	2.2	31.4	38.4
Popliteal length	Boys	35.1	2.5	30.7	39.4	35.6	1.9	33.0	38.0	37.7	2.2	35.0	41.2
	Girls	35.1	2.5	30.7	38.0	36.0	2.2	33.0	39.3	38.5	2.9	35.2	43.6
Hip Breadth	Boys	22.8	2.6	19.5	28.0	22.6	2.6	19.2	27.3	24.5	3.1	20.9	30.8
	Girls	21.8	2.9	16.8	26.3	22.6	2.6	19.0	27.2	23.2	3.4	18.8	28.4

Table 4. Anthropometric dimensions of 4th, 5th and 6th grade students (in cm)

Anthropometry dimensions	Gender	Grade 4				Grade 5				Grade 6			
		Mean	SD	P5	P95	Mean	SD	P5	P95	Mean	SD	P5	P95
Stature	Boys	135.6	6.0	127.2	146.1	137.9	6.5	127.1	149.6	148.3	7.0	139.3	159.0
	Girls	137.3	7.8	124.4	149.0	141.5	7.7	128.8	152.6	146.7	6.5	137.8	156.7
Sitting shoulder height	Boys	46.5	3.4	41.2	51.8	46.6	3.5	40.5	52.1	50.6	3.0	46.0	55.5
	Girls	47.3	3.6	42.1	52.9	48.3	3.8	41.4	54.0	51.1	3.2	46.2	56.4
Sitting elbow height	Boys	17.5	2.3	14.3	21.3	18.3	2.6	14.4	22.3	19.1	2.2	16.0	23.1
	Girls	18.5	2.7	15.3	23.1	19.3	2.2	15.8	23.4	19.3	2.1	15.7	21.8
Popliteal height	Boys	35.2	2.0	31.7	38.4	35.8	2.2	32.3	40.3	38.1	1.9	35.7	41.2
	Girls	35.6	2.5	31.1	38.5	36.3	2.3	32.3	40.0	37.9	1.9	35.3	41.0
Popliteal length	Boys	38.9	2.5	35.1	43.5	39.5	2.8	35.0	44.9	41.6	2.5	37.4	45.3
	Girls	39.4	2.8	34.5	43.6	40.5	3.3	34.8	45.9	42.1	2.9	37.8	47.7
Hip Breadth	Boys	24.1	2.9	20.9	29.8	23.3	3.0	19.7	29.7	26.1	2.9	23.5	30.9
	Girls	24.9	3.2	20.3	30.2	24.6	3.7	18.9	31.0	25.9	3.0	22.8	29.9

Figure 3b shows the percentage of mismatch between seat depth and student's anthropometry. For small chair, the seat depth was too deep for students in Grade 1 and Grade 2 with the mismatch percentage ranging from 24.3% to 68.9%. large chair was too shallow for majority of the students in Grade 4, Grade 5 and Grade 6 with the percentage ranging from 15.6% to 48.8%. The mismatch percentage decreased constantly with the higher grade level for both boys and girls for each chair.

The backrest height dimension of small chair was inappropriate for majority of the students in Grade 1, Grade 2 and Grade 3 as presented in Figure 3.d. The highest mismatch percentage was found in Grade 1 (83.7% boys and 86.9% girls). For students in Grade 1 and Grade 2 the mismatch indicated that the backrest height is too high for them. Compared with small type, lower mismatch percentages were found for large chair in Grade 4, Grade 5 and Grade 6 (ranging from 5% to 8.3%).

Figure 4 shows the mismatch percentages for desk dimension by gender and grade level. Regarding Figure 4, the desk height dimensions of both types were inappropriate for almost all student with percentage of 100% (except inappropriate for 97.1% of boys in Grade 3).

4. DISCUSSION

4.1 Evaluation of the school furniture dimensions

This study found the mismatch between the school furniture dimensions provided by school authorities and anthropometric dimensions of Indonesian elementary school children from Grade 1 to Grade 6. Again, it is important to mention that the school furnitures differ between students in grade 1-3 and grade 4-6. Hence the Equation 1-5 were applied for students in grade 1-3 for small type and grade 4-6 for large.

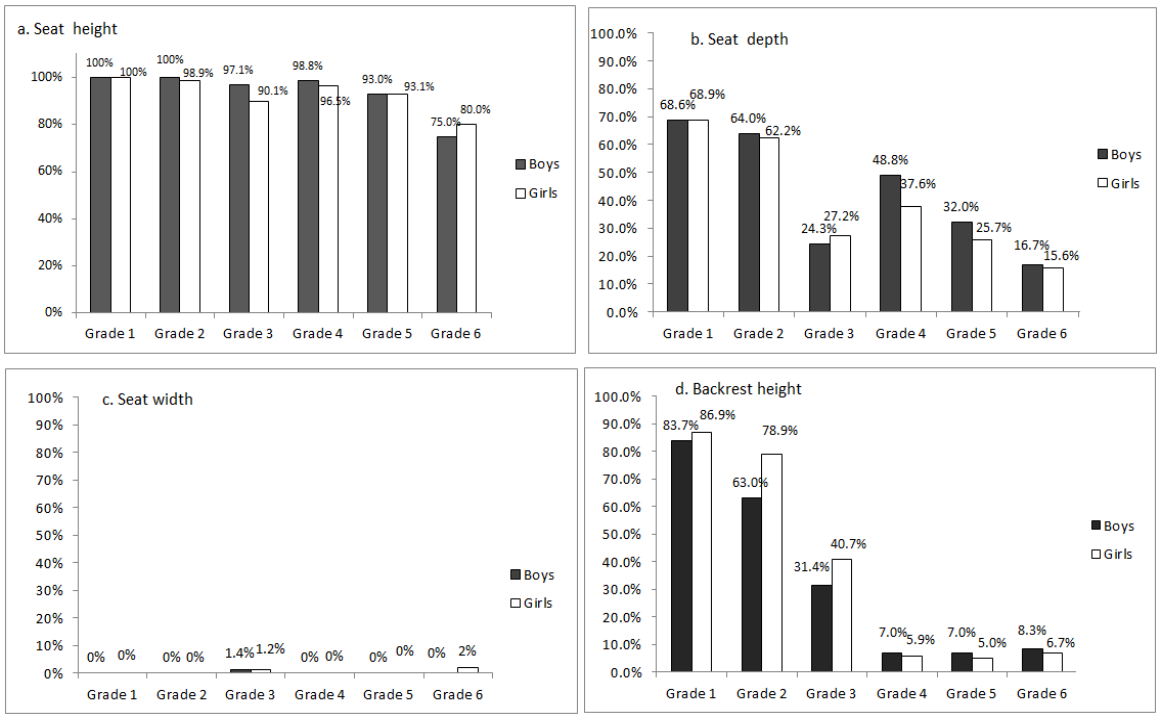

Figure 3. The mismatch percentages for seat dimensions by gender and grade level

The results indicated mismatch between student's anthropometry and the school furniture dimensions. The percentage mismatch showed that majority of the elementary school students did not match with the current school furnitures for seat height, seat depth and backrest height. The seat height for both types presented the highest mismatch with percentage are ranging from 90.1% to 100% for small type and 75% to 98.8% for large type. For small desk, mismatch were found for almost all students in Grade 1, Grade 2 and Grade 3. Similar findings were found for large desk where the desk height was inappropriate for all students in Grade 4, Grade 5 and Grade 6.

Mismatch between seat height and student's anthropometry causes students feet were unable to reach the ground (See Figure 5b). This situation may lead to increased tissue pressure on the posterior surface of the thighs (Milanese and Grimmer, 2004). The desk height exceeds most of the student's elbow rest height so that when reading and writing, they are forced to lift their arms and shoulders (as illustrated in Figure 5a). Sitting position with a too-forward inclination of the head or elevated shoulders contributes to neck and shoulder pain (Szeto et al., 2002).

Findings in this study showed that the current elementary school furniture dimensions were not appropriate for majority of the students and hence these are recommended to be revised.

4.2 The proposed design and number of size

To overcome mismatch problems between anthropometric dimensions of the student and the school furniture dimensions, this study proposed school furniture available in many sizes. To generate the characteristics of the different sizes and dimensions of school furniture which will cover the variability associated with student's anthropometry, seat height could be used as the starting point (Molenbroek et al., 2003; Castellucci et al., 2010). The first size of seat height was based on the percentile 5 of student's popliteal height (girls) in Grade 1. By added 4 cm to the previous value, the second size was generated and the 4 cm more for the subsequent level (Castellucci et al., 2015). According to the obtained data, it is necessary to develop 4 different sets of school furniture to cover the variability associated with anthropometric of the students from Grade 1 to Grade 6 (Table 5). Regarding Table 5, we also highlight that the recommended seat height have similar dimensions with the European standard EN 1729 and Castellucci et al. (2010) for Portuguese children aged 7 to 10 years.

Table 5. Proposed seat height dimensions compared to others (cm)

Source	Size 1	Size 2	Size 3	Size 4
EN 1729	26.0	31.0	35.0	38.0
Castellucci et al. (2010)	28.0	32.0	36.0	40.0
This study	27.4	31.4	35.4	39.4

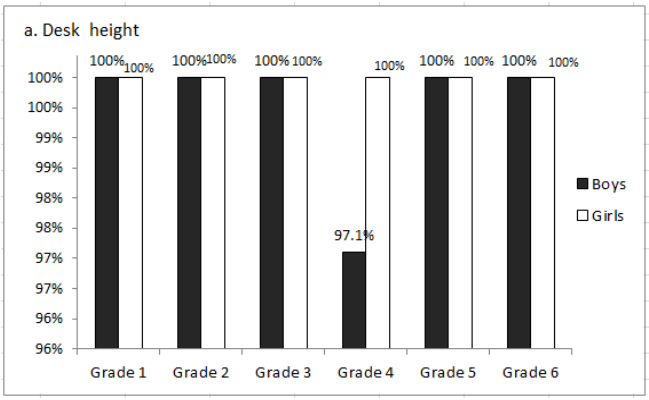

Figure 4. The mismatch percentages for desk dimensions by gender and grade level

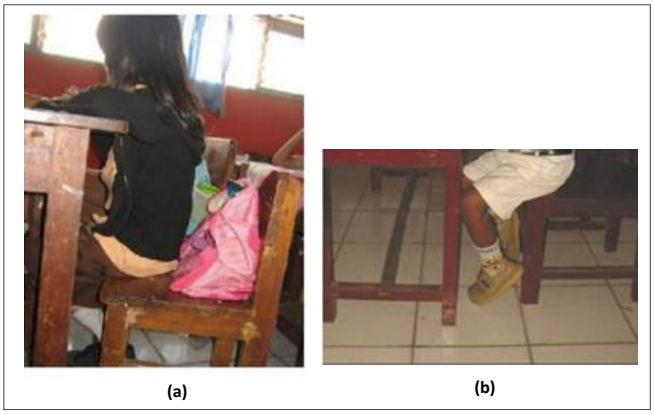

Figure. 5. Student sit in an inappropriate seat height dimensions and desk height.

5. CONCLUSION

Findings in this study showed mismatch between the school furniture dimensions and anthropometric dimensions of Indonesian elementary school children. The percentage mismatch showed that majority of the elementary students did not match with the current school furniture dimensions.

Findings in this study suggested that it is necessary to develop 4 different sets of school furniture instead of 2 sets to cover the variability associated with anthropometric of the students from Grade 1 to Grade 6.

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