Proposal for National Standard of Elementary School based on Students' Anthropometry

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Abstract

In 2018, the National Standardization Agency of Indonesia issued the Indonesian National Standard SNI 8519:2018 and SNI 8518:2018 to define the school furniture dimension as guidelines for school authorities and manufacturers in Indonesia. The updated standard replaced the previous standards SNI 7555.4.2009 and SNI 7555.19.2011 for desks dan chairs. This study aims to evaluate the dimensions of school furniture in the SNI 8519:2018 and SNI 8518:2018 according to the up-to-date Indonesian students' anthropometry and propose the sizing and new dimensions for a national standard. The national dimensions of the chair were evaluated in terms of seat height, seat depth, seat width, and backrest height as well desk height. Anthropometric data were taken from 1,506 students, including stature, sitting shoulder height, sitting elbow height, popliteal height, buttock-popliteal length, knee height, and hip breadth. A set of criteria was used to evaluate the dimensions of school furniture according to students' anthropometry. The results showed a high percentage of mismatch between students' anthropometry and the dimension of chair and desk. The mismatched findings proved that the current national standard needs to be revised. Further, the mismatch between school furniture with students' anthropometry could lead to the occurrence of health problems for students. Five sizes were proposed to accommodate students' anthropometry from Grade 1 to Grade 6. In addition, a stature-size chart was also designed and proposed to help as practical guidelines and use so that it could help students directly and simply choose their size, which could match their anthropometry.

Keywords: anthropometry, students, national standard, primary school

1. Introduction

Applications for anthropometrics have long been used to decide ergonomic dimensions in product design and work systems. This is necessary because of the importance of comfort in conducting our daily activities that involve the

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movement of body parts. Associated with activities with a long duration of time, such as learning activities at school that can last for several hours, the design of school chairs and desk furniture is very important, which can affect students' performance in learning and body posture after they grow up (Cantin et al., 2018). Attention to school furniture has been a popular research topic in the field of ergonomics, especially for elementary or primary school, in various countries, at least from 1994 up until now (Linton et al., 1994; Knight & Noyes, 1999; Molenbroek et al., 2003; Milanese & Grimmer, 2004; Gouvali & Boudolos, 2006; Chung & Wong, 2007; Afzan et al., 2012; Rosyidi et al., 2016; Lee et al., 2018; Assiri et al., 2019).

Furniture plays a crucial part in keeping proper seating posture. Using furniture that promotes correct posture is more important for students than adults because the habit of sitting is formed at this age (Panagiotopoulou et al., 2004). Consequently, anthropometric measurements are an essential factor in designing school furniture. Specific dimensions, such as pop-liteal height, knee height, buttocks-popliteal length, and elbow height, are required to determine the dimensions of school furniture that permit good sitting posture (Knight & Noyes, 1999; Parcells et al., 1999).

The lack of anthropometric and biomechanical compatibility between chairs and their users is the main cause of poor posture among students. Although the variation in height at the same age can be as much as 200 millimeters, it is typical for all students in the same class to use the same size chair (Parcells et al., 1999; Domljan et al., 2010; Guat-Lin, 1984; Castellucci et al., 2014; Moro, 2005). Using popliteal height as a criterion, a methodology is available for determining the optimal size of a chair and table set (Milanese & Grimmer, 2004; Castellucci et al., 2016), which, when compared to height, offers a better overall fit.

Many studies on this subject are motivated by concerns about the duration of sitting (Knight & Noyes, 1999; Chung & Wong, 2007), which may increase the likelihood of a condition related to sedentary posture. Non-ergonomic product design can have short- and long-term consequences. Short-term consequences include fatigue, soreness, and back pain (Assunção et al., 2013). At the same time, the long-term effect causes kyphosis and body structure alterations (Bragança et al., 2016) and de-creases students' concentration (Sholihah, 2014). In a systematic review by Castellucci et al., (2017) to determine whether the design and/or dimensions of school furniture affect students' physical responses and/or performance, 64% offered good results or proven effects, 24% presented a negative effect or no change/effect, and 12% exhibited an unclear effect. The compatibility between the proportions of school furniture and the anthropometric characteristics of students has been found as a major component in enhancing students' physical responses. Also beneficial are tall furniture, sit-stand furniture, and sloped tables and chairs.

Standard documents are required for the manufacturing of furniture by manufacturers and the procurement of furniture by schools. This is because the standard pro-vides technical standards recognized by the stakeholders as a common reference (BSN, 2014). In Indonesia, standards are formulated by a Technical Committee and set by the National Standardization Agency (BSN). Regarding school furniture, BSN has set two Indonesian National Standards (SNI), namely SNI 8518: 2018 Furniture – Study chairs for schools (BSN, 2018a) and SNI 8519: 2018 Furniture – Study tables for Schools (BSN, 2018b). The two SNIs have several quality parameters regarding construction, safety, performance/performance, and dimensions closely related to student body anthropometry and ergonomics. The standards were prepared by the Technical Committee 97-02 for furniture made of wood, rattan, and bamboo.

Several previously cited sources indicate that it is usual for the dimension parameters of school furniture to be mismatched with the anthropometry of school users (students). For anthropometry of schoolchildren and desk and

chair furniture in Indonesia, research by Yanto et al., (2017), who evaluated the previous version of SNI, namely SNI 12-1015-1989 and SNI 12-1016-1989, revealed a significant mismatch, ranging from 63 to 99%, between the dimensions of furniture for elementary schools based on SNI and anthropometry. The percentage of this dimension mismatch reaches 99% for the chair back and table height. Currently, Yanto's research continues to measure the dimensions of existing school furniture that do not comply with SNI standards.

Due to the significance of matching the proportions of furniture to the anthropometry of its users in order to avoid short- and long-term risks and to promote activity performance, as well as the findings of prior studies conducted at the elementary school level, this study intends to determine if the size parameters of the most recent reference standards in Indonesia, namely SNI 8518:2018 about study chairs for schools and SNI 8519:2018 regarding study tables for schools, correspond to the most recent anthropo-metric data for primary school pupils (Yanto et al., 2022). To achieve this goal, approximately 1200 anthropometric data from previous studies from Yanto et al., (2017) will be used with 300 more data. This makes the total anthropometric data as many as 1500 with a sample of Grade 1 to Grade 6 students from schools in the Greater Jakarta area. The results of the processed student anthropometric data, which were translated into several sizes of main furniture dimensions, were then compared with the standard dimensions in the SNI. The percentage of mismatches will be a key factor for the evaluation. With the existing results, this study will provide conclusions and suggestions related to the strategy for elementary school desk and chair sizing as input in the maintenance of SNI, which is conducted every five years. A novelty is also proposed to correlate stature with the different furniture sizing.

2. Materials and methods

2.1 Sample and sampling method

A number of 1,509 samples were used in this study. 1,158 samples (with raw data) were taken from the 2013 Anthropometric Database of Indonesian students' anthropometry aged 6-12 years in seven primary schools in Greater Jakarta (Yanto et al., 2013). Meanwhile, 351 samples (with raw data) were taken from the 2021 Anthropometric Database of Indonesian students in 3 primary schools in West Java Province (Yanto et al., 2021). Samples distributed according to gender (Boys and Girls) and grade (Gr) were presented in **Table 1**.

Table 1. Samples used in this study, presented in grade and gender

	Gr1	Gr2	Gr3	Gr4	Gr5	Gr6	Subtotal
Boys	130	198	149	110	127	55	769
Girls	120	191	138	106	120	65	740
Subtotal	250	389	287	216	247	120	1509

2.2 SNI school furniture dimensions

National Standardization Agency of Indonesia issued SNI 8519:2018 to define the dimensions of a chair as guidelines for school authorities. Meanwhile, SNI 8518:2018 was used to define desk height for school furniture. These guidelines

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were intended for students of Grade 1-6 in primary school. The school furniture dimensions were defined according to Parcells et al., (1999), Panagiotopoulou et al., (2004), and (Gouvali & Boudolos, (2006) as follows: Seat Height (SH) is the vertical distance from the floor to the highest point on the form of the seat; Seat Depth (SD) is the horizontal distance from the back of the sitting surface of the seat to its front; Seat Width (SW) is The horizontal distance from the outer left side of the sitting surface of the seat to the outer right side; Backrest Height (B) is the vertical distance from the top side of the seat surface to the highest point of the backrest; Desk height (DH) is the vertical distance from the floor to the top of the front edge of the desk. The evaluated dimensions are illustrated in Figure 1.

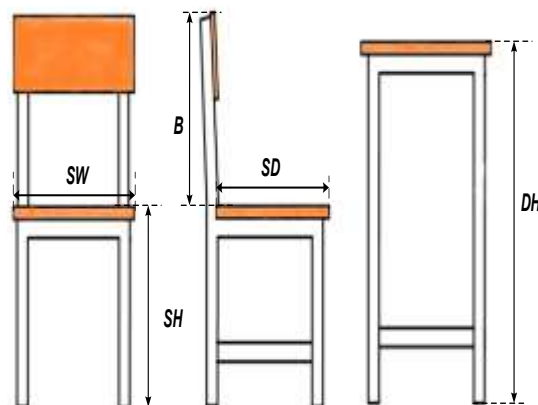**Figure 1. Illustration of dimensions of chair and desk evaluated in this study**

Table 2. Major dimensions of school furniture in the 2018 national standard
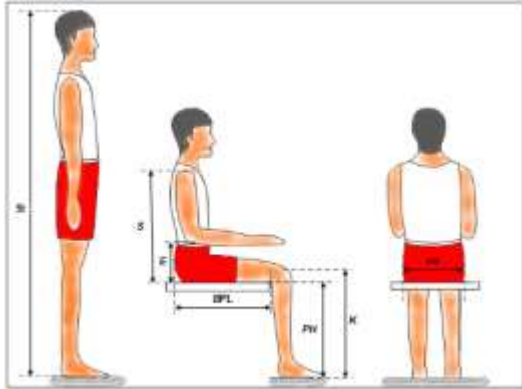
Indonesian National dard	Furniture dimensions	Size (cm)
Chair	Seat Height (SH)	34 – 38 cm
	Seat Depth (SD)	Minimum 33 cm
	Seat Width (SW)	Minimum 38 cm
	Backrest Height (B)	Minimum 28 cm
Desk	Desk Height (D)	68 – 70 cm

2.3. Anthropometric dimensions of the elementary school students

To evaluate the major dimensions of school furniture according to students' anthropometry, a few studies have been conducted (Gouvali & Boudolos, 2006; Parcells et al., 1999; Yanto et al., 2017; Castellucci et al., 2016; Castellucci et al., 2014; Castellucci et al., 2017; Carneiro et al., 2017). Studying the aforementioned studies, anthropometric dimensions include popliteal height (PH), knee height (K), Buttock-Popliteal Length (BPL), hip breadth (HB), shoulder height (S), and Elbow height (E). All dimensions, except stature (St), were taken when the subject was in a sitting posture. In addition, stature was also measured as a cross-referencing dimension for comparing population and estimating data (Pheasant and Haslegrave, 2006). An illustration of anthropometric dimensions measured in this study is presented in Figure 2.

Figure 2. Illustration of anthropometric measurements in this study

2.4. Equations to define match or mismatch

criteria to evaluate the dimensions of the current national standard of school furniture

In the last decades, a few studies have been conducted to evaluate the dimensions of school furniture according to students' anthropometry. Anthropometric dimensions of students were compared with school furniture dimensions to define a match or mismatch between them. The mismatch was defined as incompatibility between the dimensions of the furniture and the student's body (Panagiotopoulou et al., 2004; Parcells et al., 1999). A set of match criteria has been used, relating the anthropometric dimensions of students to the dimensions of chairs and desks (Castellucci et al., 2017; Yanto et al., 2017; Gouvali & Boudolos, 2006). This study defined several match criteria, as presented in **Table 3**.

Table 3. Summary of the dimensions of chair and desk through the anthropometric mis/match equations

School Furniture dimensions		Relevant students' anthropometry	(mis)/match criteria	Equation number
Chair	Seat height(SH)	Popliteal height(PH)	$(PH + 2) \, Cos \, 30^0 \leq SH \leq (PH + 2) \, Cos \, 5^0$	Equation 1
	Seat depth(SD)	Buttock-popliteal length(BPL)	$80\% \, BPL \leq SD \leq 95\% BPL$	Equation 2
	Seat width (SW)	Hip Breadth(HB)	$110\% \, HB \leq SW$	Equation 3
	Backrest height(B)	Shoulder height(S)	$60\% \, S \leq B \leq 80\% \, S$	Equation 4
Desk	Desk height (DH)	Elbow rest height(E)	$SH + EHS \leq SH \leq SH + EHS + 5$	Equation 5

Regarding **Table 3**, with regard to the Equation 1-2 and Equation 4-5 have two-way criteria, while Equation 3 has one-way criteria. For two-way criteria, a dimension of furniture was considered a "mismatch" when the such dimension is smaller than the minimum limit or greater than the maximum limit. Meanwhile, for one-way criteria, the mismatch is defined when a dimension of school furniture has a smaller value than the minimum limit.

2.5. Procedure for generating proposed standard school furniture dimensions

Characteristics of various sizes and dimensions of school furniture are generated based on the scope of student anthropometric variability; seat height is used as an initial reference. This approach agrees with other researchers (Yanto et al., 2017; Molenbroek et al., 2003; Cho, 2020; Castellucci et al., 2014). The procedure for determining the

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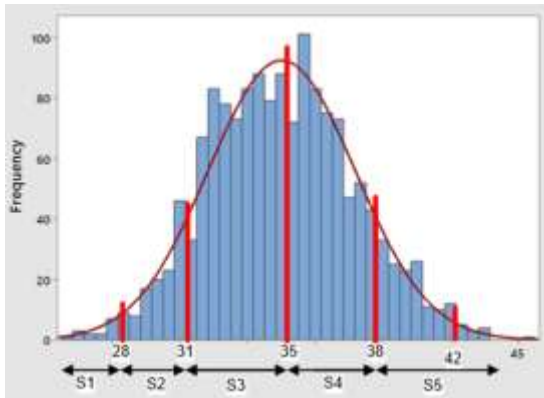
number of sizes based on students' popliteal height and seat height is as follows:

1. The starting point to determine the sizing of the set of chairs and desk is seat height (SH), defined by students' popliteal height (PH). The first set was generated and evaluated for each sample from Grade 1 to Grade 6 using Equation 1. Using Equation 1, it is possible that some students fit into two different sizes due to minimum and maximum limits. Hence, these students were assigned to the larger size, as recom-mended by Castellucci et al., (2016) and Yanto et al., (2017).

2. The size of the seat height for the first type (Size 1) is determined based on the standard deviation of the 2nd (below the average) elementary school students with a low child popliteal height – Figure 3. Based on the data of this study, a chair height of 28 cm with a popliteal height for elementary students is the best compromise and becomes the first set. The second set was determined based on the 1st first standard deviation (below average) of students' popliteal height. This value is 31 cm and becomes the second set. The value is 3 cm more than the previous size.

3. The third set was determined based on the mean value of popliteal height for all samples (with a round-up to the nearest point). This value is 35 cm, with 4 cm more than the second set. The fourth set (Size 4) was determined based on the 1st first standard deviation (above average) of students' popliteal height. This value is 38 cm, with 3 cm more than the previous size.

4. Ideally, Size 5 is intended for students whose popliteal height could not be accommodated by Size 1-4. Two options were used, first, by using the 2nd standard deviation (above average, given the value of 41 cm) or by adding 4 cm to the previous size as recommended by Castellucci et al. (2015) and given the value of 42 cm. Considering that a few students could not fit with the value of 41 cm, the fifth set was determined to be 42 cm by considering the recommendation from Castellucci et al., (2016).

5. The samples were then assigned for each set by splitting them regarding their pop-liteal height. Then the other dimensions were determined according to the equations presented in **Table 4.**

Table 4. The equation to generate proposed dimensions for the new national standard

School furniture dimensions	Equation basis for generating proposed dimensions	Equation
Seat depth	0.95 BPL from the 5th percentile of each group	Equation 6
Seat width	1.1 HB from the 99th percentile of each group	Equation 7
Backrest height	0.8 S from the 95th percentile of each group	Equation 8
Desk height	SH + 0.8517 E + 0.1493 S + table thickness (S and E from P5 of each group)	Equation 9

Figure 3. Sizing for newly proposed seat height based on the standard deviation of students' popliteal height

1. The samples have been split into different sizes of seat height according to their popliteal height (Group 1 to Group 5). For each group, the percentile values were calculated and summarized.
2. The range of stature for each group was determined based on percentile 10th for the lower limit and percentile 90th for the upper limit. A few ranges of stature could fit into two different sizes due to the maximum and minimum limits for each size. Regarding this, the students are allowed to choose their size.

3. Results and discussion

3.1 Students' Anthropometry
Table 3 and **Table 4** show the mean, standard deviation (SD), 5th percentile, and 95th percentile values of anthropometric data of the students from Grade 1-Grade 3 and Grade 4-6. In general, anthropometric measures show an increase in mean consistently from Grade 1-6.

2.5. Chart for stature sizes for guidelines
Despite the fact that popliteal height was used to define the sizing set of chairs and desks, it is practical in Indonesia to use stature as a guideline to select the set of school furniture which could fit the students. Hence, a chart that can be used as a reference to select the size of school furniture according to students' stature was made. The chart was made as follows:

Table 5. Summary of students' anthropometry from Grade 1-3 (cm).

Anthropometric dimensions	Gender	Grade 1				Grade 2				Grade 3			
		Mean	SD	P5	P95	Mean	SD	P5	P95	Mean	SD	P5	P95
Stature	Boys	121.1	5.9	112.1	131.1	126.7	6.1	117.3	136.9	133.9	8.5	120.3	149.0
	Girls	118.5	6.6	107.3	129.1	126.0	6.9	116.6	137.5	134.4	9.4	121.3	150.7
	All	119.8	6.3	109.6	130.5	126.4	6.5	116.6	137.5	134.1	9.0	120.9	149.6
Sitting shoulder height	Boys	39.9	3.6	35.7	45.3	42.1	4.1	37.2	48.7	44.8	3.5	38.7	51.3
	Girls	39.2	3.9	33.3	44.4	41.7	4.1	37.0	46.9	45.3	3.9	38.9	51.7
	All	39.6	3.7	34.3	44.7	41.9	4.1	37.1	47.7	45.0	3.7	38.8	51.4

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		Mean	SD	P5	P95	Mean	SD	P5	P95	Mean	SD	P5	P95
Sitting elbow height	Boys	15.4	3.4	11.3	18.7	16.7	3.5	12.8	20.2	16.9	2.7	12.8	21.8
	Girls	15.4	2.1	12.1	18.7	16.6	3.0	13.0	21.2	17.5	2.5	13.4	21.5
	All	15.4	2.8	11.6	18.7	16.6	3.3	12.8	21.0	17.2	2.6	13.1	21.6
Popliteal height	Boys	31.2	1.9	28.3	34.7	33.2	2.0	30.4	36.5	35.8	3.2	30.6	40.9
	Girls	30.7	2.3	27.1	34.2	32.9	2.3	28.7	36.5	35.8	3.0	31.5	40.5
	All	31.0	2.1	27.3	34.5	33.0	2.1	29.7	36.5	35.8	3.1	31.2	40.7
Buttock-knee height	Boys	36.0	2.5	32.6	40.2	38.6	2.8	34.1	43.4	41.5	4.2	35.8	48.7
	Girls	35.5	2.5	31.4	39.6	38.3	3.3	33.4	43.9	40.8	4.1	34.7	47.6
	All	35.8	2.5	32.1	40.0	38.5	3.0	34.0	43.6	41.1	4.2	35.3	48.4
Buttock-popliteal length	Boys	34.1	3.0	29.4	38.9	35.2	2.4	31.5	39.0	38.1	3.1	32.6	43.1
	Girls	33.3	3.2	28.1	37.8	35.5	2.6	30.7	39.4	38.5	3.0	33.5	43.6
	All	33.7	3.1	28.7	38.0	35.3	2.5	31.0	39.2	38.3	3.0	32.9	43.5
Hip Breadth	Boys	22.2	2.8	18.0	27.8	23.2	3.0	19.4	28.5	25.7	3.7	21.3	32.9
	Girls	21.0	2.8	16.5	25.9	23.1	2.57	19.6	27.8	25.0	3.8	19.3	31.4
	All	21.6	2.9	17.1	27.1	23.1	2.8	19.5	28.3	25.4	3.8	19.8	32.1

Table 6. Summary of students' anthropometry from Grade 4-6 (cm).

Anthropometric dimensions	Gender	Grade 4				Grade 5				Grade 6			
		Mean	SD	P5	P95	Mean	SD	P5	P95	Mean	SD	P5	P95
Stature	Boys	135.9	6.7	126.0	147.9	138.7	6.9	128.8	151.0	148.8	7.5	138.2	159.9

	Girls	137.1	8.4	124.4	151.9	142.0	7.3	131.9	153.0	146.5	6.6	136.3	156.7
	All	136.5	7.6	124.5	149.3	140.3	7.3	129.1	152.3	147.5	7.1	136.7	159.8
Sitting shoulder height	Boys	46.5	3.3	41.2	51.8	47.3	4.1	41.3	53.5	51.6	3.7	46.0	57.8
	Girls	47.3	3.7	41.6	53.2	49.0	3.7	43.1	55.1	51.5	4.1	44.9	57.0
	All	46.9	3.5	41.3	52.5	48.1	4.0	41.9	54.4	51.6	3.9	45.8	57.8
Sitting elbow height	Boys	17.5	2.2	14.3	21.3	18.4	2.6	14.4	22.7	19.6	2.4	15.6	23.2
	Girls	18.6	2.7	14.8	23.1	19.4	2.4	15.8	23.7	19.6	2.4	15.5	22.7
	All	18.1	2.5	14.4	22.9	18.8	2.6	14.5	23.5	19.5	2.4	15.5	23.2
Popliteal height	Boys	35.7	2.5	31.8	39.9	35.9	2.2	32.4	40.3	38.4	2.2	35.6	42.2
	Girls	35.6	3.0	30.2	41.3	36.5	2.4	32.6	40.6	37.7	2.3	34.1	41.2
	All	35.6	2.8	31.2	40.4	36.2	2.3	32.4	40.4	38.0	2.3	35.1	41.9
Buttock-knee height	Boys	41.6	3.3	36.9	47.4	41.7	2.9	36.9	46.7	44.0	3.3	39.3	49.7
	Girls	41.8	3.4	37.0	46.7	42.0	3.0	38.0	47.8	43.0	2.5	39.4	46.9
	All	41.7	3.3	37.0	46.9	41.8	2.9	37.7	46.8	43.5	2.9	39.4	49.2
Buttock-popliteal length	Boys	39.0	2.7	34.9	43.8	40.0	3.4	34.9	46.3	42.3	3.0	37.3	46.5
	Girls	39.4	2.9	34.3	44.3	41.2	3.3	36.6	46.6	42.3	2.8	38.5	47.8
	All	39.2	2.8	34.5	43.9	40.6	3.4	35.0	46.5	42.3	2.9	37.6	47.3
Hip Breadth	Boys	24.9	3.4	21.0	31.2	24.8	4.3	19.8	32.9	27.9	3.8	23.6	33.8

Girls	25.5	3.6	20.6	31.8	26.0	3.9	20.6	33.0	27.4	3.7	22.9	34.5
All	25.2	3.5	20.9	32.0	25.4	4.1	20.3	33.0	27.6	3.7	23.1	34.2

The stature and popliteal height were also analyzed for differences between boys and girls within the same grade (t-test) and among students across different grades (ANOVA). The results showed that there were no significant differences between boys and girls for stature in Grade 2 (t=1.06; p-value= 0.289), Grade 3 (t=-0.47; p-value= 0.636), Grade 4 (t=-1.16; p-value= 0.246) and Grade 6 (t=1.80; p-value= 0.077), except for Grade 1 (t=3.29; p-value= 0.001) and Grade 5 (t=-3.65; p-value= 0.00). As for popliteal height, results showed that there were no significant differences between boys and girls in Grade 1 (t=1.88; p-value= 0.061), Grade 2 (t=1.37; p-value= 0.170), Grade 3 (t=0.00; p-value= 1.00), Grade 4 (t=0.27 p-value= 0.79), Grade 5 (t=-2.05; p-value= 0.041) and Grade 6 (t=1.70; p-value= 0.093). To investigate the differences among students in all grades, an ANOVA test was conducted. Results showed significant differences were found among students from Grade 1-6 for stature (F=375.1; p-value=0.00) and for popliteal height (F=226.9; p-value=0.00).

3.3 Match and Mismatch between students' anthropometry and the dimensions in the national standard

The percentage of students whose body dimensions matched or did not match the chair dimensions is shown in **Figure 4**. Respectively, **Figure 4** shows the percentage of mismatch for seat height (a), seat depth (b), seat width (c), and backrest height (d) for students in Grade 1-6 for boys and girls. Meanwhile, the percentage of mismatch for desk height is shown in **Figure 5**.

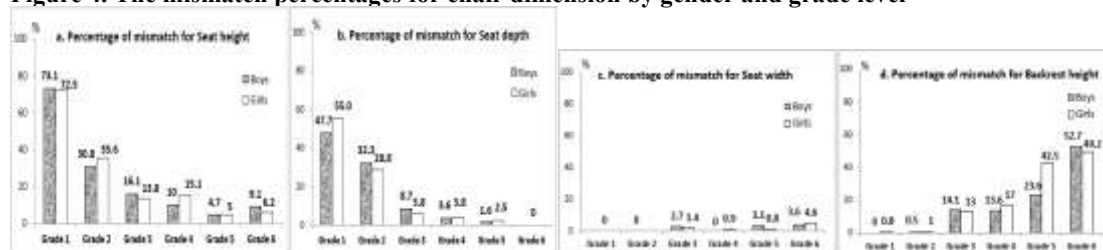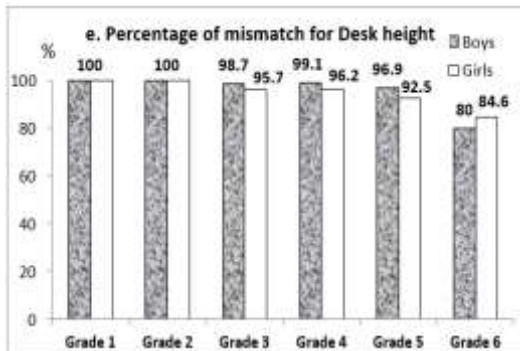**Figure 4. The mismatch percentages for chair dimension by gender and grade level**

Figure 5. The match/mismatch percentages for dimensions of the desk height by gender and grade level

Studying **Figure 4**, the mismatches were found for seat height, seat depth, seat width, and backrest of the chair. For seat height and depth, the mismatches were highest among Grade 1 and decreased steadily in higher grades (73.1% in Grade 1 to 6..2% in Grade 6 for seat height, and 55% dun Grade 1 and 0% in Grade 6). Regarding the desk, the height is too high for all students in Grade 1-2, and the mismatches decreased from Grade 4-6 (from 98.7% in Grade 3 to 80.0% in Grade 6). Considering that the most critical dimensions for school furniture design are seat height and table height (Evans et al., 1988), the mismatches between students' anthropometry and seat and desk height, as found in this study,

provided evidence that the current national standard needs to be revised.

3.4 The proposed dimensions for the new national standard

The one-size policy, as used by the current national standard, proved that dimensions did not match with students' anthropometry. This was supported by the ANOVA test, which showed significant differences in students' popliteal height among students from Grade 1 to Grade 6 (p=0.00). Considering this, having furniture of different sizes will be a more real and cheaper solution, as mentioned by Castellucci et al., (2014). As mentioned in Section 2.4, the procedure to generate different sizes and dimensions for school furniture used seat height as starting point (as recommended by Castellucci et al., 2016; Yanto et al., 2017). Using the equation given in Table 3 and the procedure to generate the number of sizing as mentioned in Section 2.4, some 5 sizes were obtained to accommodate the differences among students' anthropometry from Grade 1-6. The proposed dimensions of the chair and desk for national standards are presented in Table 6.

Table 7. Proposed standard dimensions of chair and desk sizes (in cm)

School furniture	Furniture dimensions	Size 1	Size 2	Size 3	Size 4	Size 5
Chair (Proposed dimensions)	Seat Height (SH)	28.0	31.0	35.	38.0	42.0
	Seat Depth (SD)	25	28	0	34	37
	Seat Width (SW)	31	33	31	40	43
	Backrest Height (B)	36	38	37 41	44	46
Desk	Desk Height (DH)	45	50	55	60	64

Regarding **Table 4**, the first size seat height is 28.0 cm. The proposed standard began with seat height and was based on a bottom-up approach. The second size was determined to be 31.0 based on the 1st standard deviation below the average of popliteal height. The third size is taken from the mean of all popliteal heights with a round-up

(35.0 cm). This is also relevant to the suggestion from some authors (Castellucci et al., 2014; Gutiérrez & Apud, 1995) that a 4 cm can be added to the previous value to generate the next size of school furniture. The fourth size was based on the 1st standard deviation above the average 38.0 cm. For the fifth size, 4 cm was added to the

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previous size (38 cm) since it could fit the biggest range of the popliteal height of students.

Once seat heights for Sizes 1-5 were obtained, the samples were split according to their popliteal height limit. Finally, the dimensions of the seat depth, seat width, backrest height, and desk height were obtained by applying Equations 2-6 in **(Table 3).**

4. Discussion

4.1 The current national standard and potential health problem

The results showed a substantial mismatch between students' anthropometry and the dimensions of chairs and desk in the national standard. The majority of the students did not match the seat height, with the percentage ranging from 4.7 to 73.1%. The percentage of mismatch decreases at higher grades with age and body growth. The mismatch showed that the dimension of seat height in the national standard is too high for the majority of students in the lower level (i.e., Grade 1 and Grage 2). The field observation in one of the schools showed that the seat height is too high for students in the lower grade (**Figure 7). Figure 7** shows that one student in Grade 1 could not even get her feet on the ground, causing her feet to hang. Sitting with the feet hanging caused the thigh to become compressed. Sitting in such a position may lead to increased tissue pressure on the posterior surface of the thighs (Milanese & Grimmer, 2004) as well as serious discomfort or possible injury (Agha, 2010) and restriction in blood circulation (Parcells et al., 1999).

Figure 6. Students sit in the chair and desks which did not match their anthropometry

As for desk height, the dimension is too high for students from Grade 1-6. **Figure 7** also shows students whose body dimensions did not match desk height. The students have to raise their shoulders and arms at shoulder level to read and write during their activity. The desk height is not the right height causing students to spend most of their time with awkward neck and shoulder posture (Yanto et al., 2017), as it is a known risk factor for musculoskeletal disorders (MSDs). This sitting posture also causes muscle workload, discomfort, and pain in the shoulder region (Garcia-Molina et al., 1992; Szeto et al., 2002). Moreover, discomfort and bad postures associated with badly designed chairs and tables used may affect the academic performance and physical development of schoolchildren (Evans et al., 1988).

To corroborate potential health problems, as mentioned above, a few clinical studies have shown that there were indeed musculoskeletal disorders due to the use of desk and chair which did not match their users (Panagiotopoulou et al., 2004; Yanto et al., 2008; Saes et al., 2015; Gheysvand et al., 2019; Loredan et al., 2024). Loredan et al. (2024) reported that a high student-furniture mismatch was found for seat and desk height. The neck, lower back, shoulders, and

upper back were the most affected body parts. Based on study by Saes et al. (2015) regarding prevalence of musculoskeletal pain and its association with inadequate school furniture, it was found that greater musculoskeletal pain (MSP) prevalence was found in the neck/cervical region and lumbar region in students using totally inadequate desk. Another study of Gheysvandi et al. (2019) regarding neck and shoulder pain among elementary school students with 693 students, it was found that the prevalence of neck and shoulder pain was high (more than 30%), with unsuitability of school furniture among the significant factors which are related to this health problem. Improper sitting positions, as well as physical factors such as the school furniture, caused one-third of the students had at least one of shoulder and neck pain problems.

Panagiotopoulou et al. (2004) reported that 18.3% of the 2nd grade, 20% of 4th grade and 45% of 6th grade students have suffered from recurrent or continuous back pain due to the poor fit of school furniture. Lastly based on the first clinical study in Indonesia, Yanto et al. (2008) found that due to inappropriate dimensions of school furniture (i.e. chair) with students' anthropometry, most students experienced pain in the area of buttock protrusion (88.9% in Grade 1, 82% in Grade 2, and more than 50% in Grade 3-6), thigh, popliteal, and acromion (more than 30%), and waist (more than 50%). Meanwhile, due to the desk height which is too high, Yanto et al. (2008) found that the students experienced pain in the area of neck (more than 80% in Grade 1-3, and more than 40% in Grade 4-6).

Due to mismatched findings in this study, the potential health problems, plus evidence from clinical studies, the current national standards SNI 8519:2018 and SNI 8518:2018 need to be revised. One size, as issued in the guidelines of national standards, was proved to be inappropriate for implementation in Indonesia. The National Agency for Standardization needs to consider a few sizes policy to accommodate different anthropometry of students.

Apart from safety and stability requirements, the main purpose of setting standard for school furniture is to define a series of increasing sizes which will accommodate children with different body heights (Molenbroek et al., 2003). A few sizes could be useful to accommodate variability of students' anthropometry from Grade 1-6. It will provide students with the natural and best sitting posture, improve comfort use, reduce the negative impact of their health, and further improve focus and achievement of students. In term of health issues, it could avoid students from long-term health effect due to sitting with higher desk and chair which can lead to increased discomfort in the neck, shoulder, and lower back, leg fatigue, and contribute the occurrence of musculoskeletal pain. A five-size model, as results of this study, would give long-term benefits not only for students but also for school authorities. It can reduce medical costs and improve students' achievement.

4.2 Proposed national standard and stature-size chart for sizes allocation guidelines
Most schools in Indonesia use the single size for students from Grade 1-Grade 6. The single size, as used by many schools in Indonesia, proved unable to accommodate the range dimensions of students from Grade 1-6. Considering this, different sizes with 5 levels in this study could accommodate these. This study proposed a number of 5 sizing to define the dimensions of chairs and desks for national standards **(Table 6)**. These five levels of school furniture are to fit a population of students from Grade 1-6 with ages ranging from 6 to 13 years old. An optimal fit is obtained when students of all sizes can be accommodated. The findings are similar to those of Hongkong recommendation with five categories (Evans et al., 1988) to accommodate Hongkong school students from primary and secondary. Compared to the previous study by Yanto et al., (2017), which recommended 4 sizes, this study proposed 5 sizes to accommodate students' anthropometry from Grade 1 to Grade 2. Nevertheless, this study

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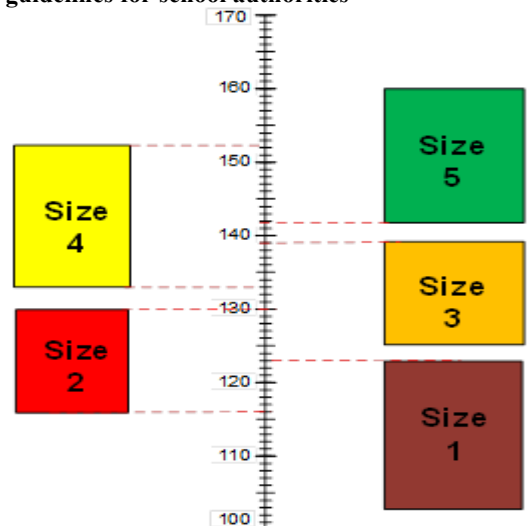
covers more samples and geographical areas of schools. In addition, a five-level of different sizes, as proposed by this study, could cover a broader age range (6-13 years old), whereas the previous study Yanto et al., (2017) could cover the age range of 6-12 years old.

Although 5 sizes, as recommended through this study, are not common in Indonesia (either from the cultural or practical point of view), we believe this recommendation could be successfully implemented. A different size policy has been implemented successfully in many countries. For instance, New Zealand has shown high success in implementing such different-sizes policies for school furniture (Macedo et al., 2015). Furthermore, six different sizes are used in Australian schools (Standard Australia, 1995). In Korea, eleven sizes were used (Cho, 2020). Meanwhile, in Japan, nine sizes have been implemented (Hibaru & Watanabe, 2020). Moreover, these different sizes are intended to accommodate a range of students' anthropometry.

With 5 levels of school furniture, the findings are reasonable for Indonesian schools considering the cost, safety, maintenance, and practical consideration. There is a high need for low-cost and long durability school furniture, so non-adjustable chairs of different sizes will be the best option. Considering that differences in physical characteristics (i.e., anthropometry) among Indonesian elementary school students are highly significant, "a different sizes school furniture" is the best option. Furthermore, again, 5 levels, as recommended by this study, could be applied by school authorities in Indonesia.

In order to help school authorities, teachers, and students, a stature-size chart was designed in this study. Considering the lack of knowledge from school authorities and teachers about the measurement and use of popliteal height for school furniture selection is absent; we choose stature as the basis to design a stature-sizes chart as guidelines **(Figure 6).** Providing the school with the guidelines could give the school authority and students the chance to choose their size

according to body height **(Figure 5).** Using the chart could give students to choose their size correctly so that it could match their anthropometry.

Figure 7. Proposed body height-size chart as guidelines for school authorities

4.3 Proposed national standard and possible implementation

A few sizes policy, as result from this study, is certainly very different from the one size policy which is widely applied in Indonesia today. Either ergonomically or economically, this policy is actually more beneficial for school authorities. Based on the results of a study by Yanto et al. (2022), 93.7% of Indonesian elementary schools use chairs which are larger than those of the current national standard (larger than those of Size 1-3 in the proposed standard, Table 7). Meanwhile, 81.1% of the Indonesian schools use desks which are larger than those of the current national standard (larger than those of Size 1-3 in the proposed standard, Table 7). Hence, regarding the results of this study, school authorities can later replace desks and chairs with smaller sizes. Using smaller and a few sizes (i.e. recommended

Size 1-5, Table 7), it can not only accommodate users of various body sizes, increase comfort and health of the users, but also reduce production costs due to more efficient materials. This means that the five-size model of school furniture can be practically implemented in all types of schools, even schools with limited budgets. In addition, the five-sizes model can generally also increase the capacity of the classroom, especially classroom for the lower grade students (Grade 1-3).

For the implementation of the proposed standard, joint involvement between academics in the field of ergonomics, school authorities, and education government officials from the Minister of Primary and Secondary Education of Indonesia is needed. The results of this study need to be proposed formally and then their implementation needs to be integrated into public health policies under the relevant ministries. Researchers in this study consist of cross-disciplinary and cross-institutional researchers, including researchers from Research Center for Testing Technology and Standards, the National Research and Innovation Agency of the Republic of Indonesia who can provide formal proposal to the government. Subsequently, it is necessary to make a team consisting of various elements, namely academics, government officials, and school authorities to prepare and issue guidelines related to the implementation of this new policy.

5. Conclusion

This study has evaluated the dimensions of school furniture in the national standard SNI 8519:2018 and SNI 8518:2018 according to students' anthropometry using a set of anthropometric criteria. The results showed that the dimensions of the chair did not match with the majority of students in the lower grade (Grade1 and Grade 2). Meanwhile, the desk height did not match all students in Grade 1-2 and the majority in Grade 3-6, ranging from 80.0% to 98.7 80.0%. With the percentage of mismatch decreasing from lower grade to upper grade, these results proved that the chair and desk are too high majority of students in the lower grade. The findings from field observation also supported the mismatch findings, where students sit in chairs dan desks unsuitable for them. Furthermore, the mismatch between school furniture with students' anthropometry could lead to the occurrence of health problems for students. Furthermore, again, these results provided evidence that the current national standard SNI 8519:2018 and SNI 8518:2018 need to be revised. Five sizes were proposed to accommodate students' anthropometry from Grade 1 to Grade 6. In addition, a stature-size chart was also designed and proposed to help as practical guidelines and use for School principals, teachers, and students to choose chairs and desks suitable for students. The chart could help students choose their size, matching their anthropometry. This study also suggests that joint involvement between academics, school authorities, and education government officials from the Minister of Primary and Secondary Education of Indonesia is needed to implement the results.

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