

ORIGINAL ARTICLE

## The Risk Factors Associated with Handgrip Strength and Endurance in Adolescence

### Faktor Risiko yang Berhubungan dengan Kekuatan dan Ketahanan Genggam pada Remaja

Ni Putu Laksmi Ananda Martini<sup>1</sup>, Dian Mediana<sup>2</sup>

<sup>1</sup>Medical Undergraduate Program, Faculty of Medicine, Universitas Trisakti, Jakarta, Indonesia

<sup>2</sup>Anatomy Department, Faculty of Medicine, Universitas Trisakti, Jakarta, Indonesia

dianmediana@trisakti.ac.id

<https://doi.org/10.18051/jbk.310-319>

#### ABSTRACT

##### Background

Handgrip strength and endurance are some of the ways that can be done to examine the muscle quality of adolescents as well as their physical fitness. It is influenced by various internal and external factors, including body mass index, gender, age, and smoking habits. Handgrip strength can be an important parameter for health. Adolescents with lower muscle strength have an increased mortality rate in adulthood. Thus, this study aimed to determine the factors associated with handgrip strength and endurance in adolescence.

##### Methods

The study used analytic observational with a cross-sectional approach using consecutive non-random sampling on 58 adolescents between 15-23 years old. The instruments used a scale and microtoise to measure body mass index, and a hand dynamometer to measure handgrip strength and endurance. The data was analyzed by the Chi-square test using the SPSS program with  $p < 0.05$ .

##### Results

Of the 58 respondents consisting of 48.27% men, and 51.72% women, there were 58.62% normal BMI and 70.68% did not smoke. The percentage of respondents who had weak grip strength was lower (44.82%) compared to weak grip endurance (55.17%). There was no significant relationship between gender and handgrip endurance; body mass index and handgrip strength as well as handgrip endurance; cigarette consumption and handgrip strength. Moreover, there was found a significant relationship between gender and handgrip strength ( $p=0.000$ ) and between cigarette consumption and handgrip endurance ( $p=0.011$ ).

##### Conclusions

Handgrip strength and endurance were more in the weak-medium category. There was no significant relationship between gender and handgrip endurance; body mass index and handgrip strength as well as handgrip endurance; cigarette consumption and handgrip strength. Moreover, there was found a significant relationship between gender and handgrip strength and between cigarette consumption and handgrip endurance.

**Keywords:** body mass index, gender, smoking, handgrip strength, handgrip endurance

## ABSTRAK

### Latar Belakang

Kekuatan dan ketahanan genggam merupakan salah satu cara yang dapat dilakukan untuk melihat kualitas otot dan juga kebugaran pada remaja. Hal ini dipengaruhi oleh berbagai faktor internal maupun eksternal, seperti indeks massa tubuh, jenis kelamin, usia dan juga kebiasaan merokok. Kekuatan genggam dapat sebagai parameter penting bagi kesehatan, remaja dengan kekuatan otot lebih rendah memiliki peningkatan angka mortalitas di masa dewasa. Tujuan penelitian ini adalah untuk mengetahui faktor-faktor yang berhubungan dengan kekuatan dan ketahanan genggam pada remaja.

### Metode

Desain penelitian ini adalah observasional analitik dengan pendekatan *cross sectional*. Responden adalah remaja berusia 15-23 tahun, diambil dengan metode *consecutive non-random sampling*. Instrumen penelitian menggunakan timbangan dan mikrotoise untuk mengukur indeks massa tubuh dan *hand dynamometer* untuk mengukur kekuatan dan ketahanan genggam. Analisis data menggunakan program SPSS dengan uji *Chi-square* dan tingkat kemaknaan  $p < 0.05$ .

### Hasil

Dari 58 responden yang terdiri dari 48.27% laki-laki dan 51.72% perempuan, terdapat 58.62% IMT normal dan 70,68% tidak merokok. Persentase responden yang memiliki kekuatan genggam lemah lebih rendah (44.82%) dibandingkan dengan ketahanan genggam lemah (55.17%). Tidak terdapat hubungan bermakna antara jenis kelamin dengan ketahanan genggam, indeks massa tubuh dengan kekuatan genggam dan ketahanan genggam, dan merokok dengan kekuatan genggam. Terdapat hubungan yang bermakna antara jenis kelamin dengan kekuatan genggam ( $p=0.000$ ) dan merokok dengan ketahanan genggam (0.011).

### Kesimpulan

Kekuatan dan ketahanan genggam lebih banyak pada kategori lemah-sedang. Tidak terdapat hubungan bermakna antara jenis kelamin dengan ketahanan genggam, indeks massa tubuh dengan kekuatan genggam dan ketahanan genggam, dan merokok dengan kekuatan genggam. Terdapat hubungan yang bermakna antara jenis kelamin dengan kekuatan genggam dan merokok dengan ketahanan genggam.

**Kata Kunci:** indeks massa tubuh, jenis kelamin, merokok, kekuatan genggam, ketahanan genggam

## INTRODUCTION

Adolescence is a transition period between childhood and adulthood. Adolescence is an important period because a person's future can begin to be formed from adolescence. <sup>1</sup> The Ministry of Health (DEPKES) 2009 categorizes adolescents into early adolescents (12-16 years) and late adolescents (17-25 years).<sup>2</sup>

Teenagers certainly have different muscle qualities. One way to assess hand muscle strength in adolescents is to assess the strength and endurance of their grip. This measurement can use a tool called a hand dynamometer.<sup>3</sup> The prevalence of normal/moderate grip strength in adolescents aged 15-18 years is 72.3%.<sup>2</sup> Grip strength and endurance in young men and young women will be different. Men will be stronger than women because of differences in body composition, women's muscle mass is lower than men's, and conversely, women's fat mass is higher than men's.<sup>4</sup> Apart from that, it can be influenced by training factors, height, weight, Body Mass Index (BMI), smoking, and so on.<sup>3</sup>

Body mass index (BMI) is a simple indicator obtained from the correlation of a person's height and weight to determine whether the person has an ideal body weight. However, you also need to know that BMI cannot measure a person's health status or a person's fat content.<sup>3</sup> According to

Liao's research results, a correlation was found ( $r=0.000 - 0.775$ ) between BMI and handgrip strength. The high BMI group was stronger than the normal BMI group, and the normal BMI group had higher grip strength than the low BMI group.<sup>5</sup>

As we know, strength and endurance are important tools for assessing nutritional status which determines muscle quality. In individuals who are overweight or underweight, there is a possibility of changes in the quality of their muscles.<sup>5</sup> The results of research by Dhananjaya J, et al.<sup>6</sup> stated that there was a negative correlation between BMI and hand grip strength (HGS) in normal and overweight populations, while hand grip endurance (HGE) had a weak negative correlation in the group with overweight and obesity in men. They added that HGS and HGE depend on factors such as age, gender, muscle strength, arm span, and diet.<sup>6</sup> Meanwhile, research by Al-Asadi JN found that BMI had a significant correlation with grip strength assessed using a hand grip.<sup>7</sup> Therefore, by measuring muscle strength and endurance, it is hoped that the author will obtain data to determine the muscle quality for each category of BMI which can then be processed and educated to the public about the importance of having a body weight that is neither deficient nor excess to improve and improve muscle quality in adolescents.<sup>6</sup> In addition, muscle strength, which can be measured handheld, can be an important parameter for health; adolescents with lower muscle strength have increased mortality rates in adulthood.<sup>8</sup>

## METHODS

Analytical observational research design with a cross-sectional approach. Conducted at the Permata Arcadia Complex, Depok, West Java from November to December 2020. The inclusion criteria were youth groups who were in the category of teenagers aged 15-23 years, were willing to take part in the research, and had signed informed consent. The exclusion criteria are subjects who have physical disabilities and participate in sports related to hand muscle training (badminton, tennis, volleyball, plank, push-ups, pull-ups, using dumbbells, spring grip, hand grip, power wrist).

The minimum sample size is 58 people. The method used was consecutive non-random sampling. BMI measurement uses the formula  $BMI = \text{body weight}/\text{height}^2$  (kg/m<sup>2</sup>). The scale is on a flat place, the subject removes shoes and other accessories that can cause bias, then climbs onto the scale and stands straight in the middle of the scale with a straight look ahead. Body height is measured using a microtoise. The subject to be measured is to remove footwear, the subject stands under the microtoise in an upright position, looking straight ahead, both arms at the side, knees straight/not bent, and palms facing the thighs (ready position). Smoking data was obtained by interview, whether the respondent smoked actively or did not smoke (actively or passively). Grip strength and endurance were measured using a hand dynamometer: carried out on the dominant hand. Grip strength is measured by gripping the dynamometer with maximum strength, with the hand and elbow forming an angle of 90°. 9 The maximum strength of muscle contraction in approximately 3 seconds will be recorded in the form of kilograms. This is done 3 times with a break of 10 minutes and the maximum results are recorded. Meanwhile, grip endurance is measured by telling the subject to maintain 1/3 of the maximum muscle strength on a hand dynamometer, then calculating using a stopwatch how many seconds can be maintained.<sup>10</sup>

Univariate data analysis is used to explain the percentage results of the frequency distribution for each variable. Bivariate data analysis to see the relationship between factors that influence grip strength and endurance. This analysis uses the SPSS program with the Chi-square test. This research

was conducted after obtaining ethical permission from the Trisakti University Faculty of Medicine Ethics Commission number 63//KER-FK/10/2020.

## RESULTS

This research was conducted on 58 teenagers with different BMIs to determine the relationship between handgrip strength and endurance results. Several other factors such as gender and smoking habits were also studied.

**Table 1. Frequency distribution of gender, BMI, smoking, strength, and grip endurance (n=58)**

Frequency distribution	n	%
<b>Gender</b>		
Men	28	48.27%
Women	30	51.72%
<b>BMI</b>		
Underweight	13	22.41%
Normal	34	58.62%
Overweight	11	18.9%
<b>Smoking</b>		
Smoking	17	29.31%
Not Smoking	41	70.68%
<b>Strenght</b>		
Weak	26	44.82%
Moderate	22	37.93%
Strong	10	17.24%
<b>Endurance</b>		
Weak	32	55.17%
Moderate	24	41.37%
Strong	2	3.44%

Note: n= frequency; %=percentage

Of the 11 respondents who were overweight, 7 were men and 4 were women. Of the 17 respondents who smoked, 10 of them were men, 3 were underweight and 3 were overweight. The smoking habit was found in respondents aged 21-23 years, while respondents under the age of 21 years had a habit of not smoking. Most respondents have weak muscle strength, and only a small percentage have strong muscle strength. The same thing was also found in the results of grip resistance where more than half of the respondents had weak grip resistance.

Table 2 displays the relationship between gender, BMI, and smoking with grip strength. Please note that there is a merging of cells between the moderate and strong categories into one category, namely medium-strong, in order to meet the requirements for using the Chi-square test.

**Table 2. Relationship between gender, BMI, and smoking with grip strength**

Variable	Category				Total		p-value
	Weak		Moderate-strong		N	%	
	n	%	n	%			
<b>Gender</b>							
Men	4	14.3%	24	85.7%	28	100%	0.000 <sup>#</sup>
Women	22	73.3%	8	26.7%	30	100%	
<b>BMI</b>							
Underweight	8	61.5%	5	38.5%	13	100%	0.373 <sup>#</sup>
Normal	14	41.2%	20	58.8%	34	100%	
Overweight	4	36.4%	7	63.6%	11	100%	
<b>Smoking</b>							
Smoking	9	52.9%	8	47.1%	17	100%	0.424 <sup>#</sup>
Not smoking	17	41.5%	24	58.5%	41	100%	

<sup>#</sup> Chi-square test

Based on the results of grip strength studied on the gender variable, men have greater grip strength in the moderate-strong category than women. Chi-square test results showed that gender had a significant relationship with grip strength ( $p=0.000$ ).

In the group of underweight respondents, 61.5% had weak grip strength, whereas 38.5% of the group of respondents with higher nutritional status had moderate-strong grip strength. In the group with normal nutritional status, there was an almost equal ratio between the percentages who had weak and moderate-strong grip strength. The results of the Chi-square test showed that there was no significant relationship between BMI and grip strength ( $p=0.373$ ).

Another factor that was also studied was smoking habits and the results of grip strength. Respondents with a smoking habit had greater grip strength in the weak category than non-smokers, and vice versa. The results of the Chi-square test showed that there was no significant relationship between smoking and grip strength ( $p=0.424$ ).

Table 3 displays the relationship between gender, BMI, and smoking with handgrip endurance. More females have weak grip endurance compared to males. Meanwhile, the men's category had balanced results between the weak and medium-strong categories. The Chi-square test showed that there was no significant relationship between gender and grip endurance ( $p=0.444$ ).

**Table 3. Relationship between gender, BMI, smoking and grip endurance**

Variable	Category				Total		p-value
	Weak		Moderate-strong		N	%	
	n	%	n	%			
<b>Gender</b>							
Men	14	50.0%	14	50.0%	28	100%	0.444 <sup>#</sup>
Women	18	60.0%	12	40.0%	30	100%	
<b>IMT</b>							
Underweight	8	61.5%	5	38.5%	13	100%	0.868 <sup>#</sup>
Normal	18	52.9%	16	47.1%	34	100%	
Overweight	6	54.5%	5	45.5%	11	100%	
<b>Smoking</b>							
Smoking	5	29.4%	12	70.6%	17	100%	0.011 <sup>#</sup>
Not smoking	27	65.9%	14	34.1%	41	100%	

<sup>#</sup> Chi-square test

Both underweight, normal, and overweight respondents were more likely to have weak resistance. The results of the Chi-square test showed that there was no significant relationship between BMI and handgrip endurance ( $p=0.868$ ).

In the group of respondents with a smoking habit, more people had moderate-strong resistance, while more individuals who did not smoke had weak resistance. The results of the Chi-square test showed a significant relationship between smoking habits and grip endurance ( $p=0.011$ ).

## DISCUSSION

The results of BMI measurements in the normal category have the highest figure, namely 58.62%. This is slightly lower than the prevalence of teenagers in Indonesia based on the 2018 RISKESDAS which states that the normal category ranks highest at 78.3% of teenagers aged 16-18 years.<sup>11</sup>

The smoking habits of respondents were found to be 29.31% active smokers with an age range of 21-23 years. This is in accordance with the 2020 Indonesian Tobacco Atlas which states that the highest age proportion of smokers among teenagers is 20-24 years, which in 2013 was 34.1% and decreased in 2018 to 33.2%.<sup>12,13</sup>

Based on the results obtained, it was found that men had higher grip strength than women, with a value of  $p=0.000$ . This is in line with research conducted by Sandhu, et al<sup>14</sup> which states that there is a correlation between grip strength and gender, namely that men have a higher average strength than women. Research conducted on 25 men and 25 women resulted in a mean strength for men of  $34.64 \pm 7.52$  while for women it was  $24.18 \pm 5.67$  which resulted in high significance between men and women of  $p < 0.001$ . This is due to differences in muscle mass, men have a greater number of muscle fibers and especially type I, therefore when both of them exert the same effort the results will be different, men's grip strength will be greater than women's.<sup>14</sup> In this study, it was also said that individuals with strong hand, wrist, and finger muscle strength could lift and hold weights for a longer duration of time. High levels of forearm and hand flexor muscle activity are required in many sporting events and during many daily activities.<sup>13,14</sup>

The results obtained in this study showed that the relationship between gender and grip endurance was not significant ( $p=0.444$ ). This is different from research conducted by Hammed, et al<sup>15</sup> which states that men have a stronger level of resilience ( $p=0.000$ ). The testosterone hormone possessed by men helps increase muscle size and strength by increasing type II muscle fibers which have greater glycolytic activity, so they can maintain endurance for longer.<sup>15</sup> In line with Hammed, Sandhu et al<sup>14</sup> said that in women there is an increase in glycogen stores. and increased body temperature affects blood supply during the luteal phase. This is associated with greater fatigue resistance in women.<sup>14</sup>

In the results of this study, men obtained a higher percentage of grip resistance in the moderate-strong category compared to women. However, the results obtained may not be meaningful because in the men group, more people are overweight and smoke, it is possible that this could be one of the causal factors.

It was found that the relationship between grip strength and BMI was not significant ( $p=0.373$ ). This is in accordance with the research results of Dhananjaya et al which also stated that there was a non-significant relationship ( $p=0.157$ ) and there was also no correlation between BMI and grip strength. In the overweight category there should be changes in muscle strength due to accumulation of fat, plus a lack of type I muscle fibers and more type IIb muscle fibers compared to the normal category.<sup>6</sup> In this study, perhaps because there were more men in the overweight group, the grip strength was stronger.

Research conducted by Umesh, et al<sup>16</sup> also stated that the relationship between BMI and grip strength was not significant ( $p>0.05$ ). In this case, BMI, which is an indicator of body mass, does not show the percentage of fat and muscle mass which can affect the strength of the muscles themselves. In the underweight population, good muscle mass may be found, as well as in the overweight population, which may have more muscle mass than fat mass.<sup>16</sup>

In contrast to the research above, Liao K5 found that there was a positive correlation between BMI and grip strength ( $r=0.6$  and  $p<0.01$ ). However, they also said that if BMI and gender were combined, gender would have a greater influence on a person's grip strength. The journal also added that there was a positive correlation between grip strength and body height ( $r=0.7$  and  $p<0.01$ ) and body weight ( $r=0.7$  and  $p<0.01$ ). Using the ANOVA statistical test, the relationship between grip strength and the three categories of BMI showed significantly different results ( $p<0.001$ ) where the overweight category was in first place, followed by the normal category and the underweight category was in last place.<sup>5</sup>

The relationship between BMI and grip endurance results obtained in this study was not significant ( $p=0.868$ ). This is the same as the research results of Dhananjaya, et al<sup>6</sup>, there is a positive correlation that is not significant for normal BMI ( $r=0.01$  and  $p=0.896$ ), and a negative correlation that is not significant for overweight and obese ( $r= -0.06$ ,  $r= -0.27$  and  $p=0.730$ ,  $p=0.726$ ). So normal BMI has the highest grip resistance results.<sup>6</sup>

Research conducted by Umesh, et al<sup>16</sup> also stated that there was a positive correlation that was not statistically significant between BMI and grip endurance in men with underweight and normal weight. In women, the correlation was significantly positive in the group with normal weight only, whereas in women who were overweight, the correlation was negative but not significant.<sup>16</sup>

The relationship between smoking and grip strength was not found to be significant ( $p=0.424$ ). These results are not in accordance with the theory, that smoking has a risk of getting lower muscle strength values and fatigue more quickly than non-smokers. Cigarettes will be an inflammatory mediator that can cause proteolysis and inhibit protein synthesis which causes loss of muscle mass.<sup>17</sup>

The results of this study are also not in line with research conducted by ShanAi Quan<sup>18</sup>, which stated that the risk factors of smoking, low education, and low income can reduce grip strength in old age. The physiology and anatomy of the hand can change with age. Apart from reducing muscle quality, smoking habits are also reported to result in less bone mass, because the nicotine in cigarettes can be involved in the metabolism of calcium and vitamin D which affects bone health.<sup>18</sup>

The insignificant results in this study are possible because the smoking period in adolescents is still relatively short, so the side effects of smoking are not yet visible. Therefore, the grip strength produced by respondents who smoke did not show a significant relationship.

It was found that respondents who smoked had the most moderate-strong grip resistance, namely 70.6%. Meanwhile, respondents who do not smoke have the highest grip resistance in the weak category, namely 65.9%. The  $p$ -value = 0.011 means that the relationship between smoking and grip endurance is significant. It can be concluded that respondents who smoke have stronger grip resistance than those who do not smoke. Another factor that influences the results of this percentage is that the average individual who has a smoking habit is male. In the relationship between gender and grip endurance, it has been stated that men have different muscle mass from women which can cause men to have stronger grip endurance.<sup>13</sup>

In a journal written by Vaidya, et al<sup>19</sup>, it is stated that grip endurance is also related to muscle strength. Contracting muscles are influenced by the amount of blood flow that transports oxygen and energy substrates. In addition, contracting muscles also create pressure which can weaken arteries and blood vessel circulation. Therefore, many external factors can influence grip endurance results, such as smoking history and physical activity.<sup>19,20</sup>

This relationship between smoking and handgrip endurance may be significant according to a journal researched by Kovarik, et al<sup>21</sup> which stated that patients suffering from chronic obstructive pulmonary disease (COPD) had a negative correlation with their handgrip endurance. If teenagers who have this smoking habit continue into old age, they may be at risk of developing COPD which can cause weakness in their grip.<sup>21</sup>

The limitation of this research did not measure the level of physical activity in respondents, whether their physical activity was light, moderate, or heavy, which could affect muscle strength and endurance. Not measuring cigarette consumption using a cigarette index, how long and how much cigarette consumption.

## CONCLUSION

The grip strength results obtained were in the weak category as much as 44.82%, moderate 58.62%, and strong 17.24%. Grip resistance in the weak category was 55.17%, medium 41.37%, and strong 3.44%. The group that has a smoking habit is 29.31%. There is a significant relationship between gender and grip strength ( $p=0.000$ ), where men have a stronger level of strength than women. There was no significant relationship between gender and grip endurance ( $p=0.444$ ).



There was no significant relationship between body mass index and grip strength ( $p=0.373$ ). There was no significant relationship between body mass index and grip endurance ( $p=0.868$ ).

There was no significant relationship between smoking and grip strength ( $p=0.424$ ). There was a significant relationship between smoking and grip resistance ( $p=0.011$ ), where smoking habits have stronger grip resistance.

For future research, it is hoped that we can examine adolescent age groups with equal numbers of gender and BMI by categorizing the duration of smoking, measuring physical activity, and also other external factors.

## ACKNOWLEDGEMENT

Thank you to all youth respondents from Karang Taruna Depok, West Java, as well as the Faculty of Medicine, Trisakti University.

## AUTHORS CONTRIBUTION

NPLAM contributes to the collection, processing, analysis of data, and writing of the manuscript. DM contributed to the improvement of the manuscript.

## FUNDING

The costs used for this research came from the researchers themselves.

## CONFLICT OF INTEREST

All researchers have no conflict of interest regarding the results of this research.

## REFERENCES

1. Pusdatin. Infodatin Reproduksi Remaja-Ed.Pdf [Internet]. Situasi Kesehatan Reproduksi Remaja. 2017. p. 1. Available from: [https://www.kemkes.go.id/download.php?file=download/pusdatin/infodatin/infodatin\\_reproduksi\\_remaja-ed.pdf](https://www.kemkes.go.id/download.php?file=download/pusdatin/infodatin/infodatin_reproduksi_remaja-ed.pdf)
2. Andarbeni DP, Sugiarto, Prasetyo AA. Asupan energi dan protein dengan kekuatan genggam pada remaja putri. Darussalam Nutr J. 2018;2(1):11–8.
3. Nuttall FQ. Body mass index: Obesity, BMI, and health: A critical review. Nutr Today. 2015;50(3):117–28.
4. Almashaqbeh SF, Al-Momani S, Khader A, et al. The Effect of Gender and Arm Anatomical Position on the Hand Grip Strength and Fatigue Resistance during Sustained Maximal Handgrip Effort. J Biomed Phys Eng. 2022;12(2):171–80.
5. Liao K-H. Hand Grip Strength in Low, Medium, and High Body Mass Index Males and Females. Middle East J Rehabil Heal. 2016;3(1):1–7.
6. Dhananjaya JR, Veena HC, Mamatha BS, et al. Comparative study of body mass index, hand grip strength, and handgrip endurance in healthy individuals. Natl J Physiol Pharm Pharmacol. 2017;7(6):594–8.
7. Al-Asadi JN. Handgrip strength in medical students: Correlation with body mass index and hand dimensions. Asian J Med Sci. 2018;9(1):21–6.
8. Crump C, Sundquist J, Winkleby MA, et al. Interactive effects of aerobic fitness, strength and obesity on mortality in men. Am J Prev Med. 2017;52(3):353–61.
9. Tayyari F. Effects of Elbow Flexion on the Hand - Grip Strength. Ergon Int J. 2018;2(1).
10. Baxi G, Tigdi RS, Palekar JT, et al. Static and Dynamic Handgrip Endurance in Young Adults. Indian J Physiother Occup Ther - An Int J. 2017;11(4):117.

11. Riskesdes kemenkes RI 2018. Laporan\_Nasional\_RKD2018\_FINAL.pdf [Internet]. Badan Penelitian dan Pengembangan Kesehatan. 2018. p. 674. Available from: [http://labdata.litbang.kemkes.go.id/images/download/laporan/RKD/2018/Laporan\\_Nasional\\_RKD2018\\_FINAL.pdf](http://labdata.litbang.kemkes.go.id/images/download/laporan/RKD/2018/Laporan_Nasional_RKD2018_FINAL.pdf)
12. Tobacco Control Support Center-Ikatan Ahli Kesehatan Masyarakat Indonesia (TCSC-IAKMI). Atlas Tembakau Indonesia Tahun 2020 [Internet]. 2020. 1–60 p. Available from: <http://www.tcsc-indonesia.org/wp-content/uploads/2020/06/Atlas-Tembakau-Indonesia-2020.pdf>
13. Anjana Y, Reetu K. Effect of Gender Difference in Response To Sustained Isometric Exercise Using Handgrip Dynamometer. *J Evol Med Dent Sci*. 2014;3(22):6043–7.
14. Sandhu JS, Kaur V, Gupta V. A comparative study of isometric strength, endurance and gender in medical students. *IJMSIR*. 2019;4(5):185-9.
15. Hammed AI, Obaseki CO. Interdependence of body mass index with handgrip strength and endurance among apparently healthy teenagers. *Turkish J Kinesiol*. 2018;4(1):1–7.
16. Lad UP, Satyanarayana P, Shisode-Lad S, et al. A study on the correlation between the Body Mass Index (BMI), the body fat percentage, the handgrip strength and the handgrip endurance in underweight, normal weight and overweight adolescents. *J Clin Diagnostic Res*. 2013;7(1):51–4.
17. Carrasco-Rios M, Ortolá R, Fernando RA, et al. Exposure to secondhand tobacco smoke is associated with reduced muscle strength in US adults. *Aging (Albany NY)*. 2019;11(24):12674–84.
18. Quan S, Jeong J-Y, Kim D-H. The Relationship between Smoking, Socioeconomic Status and Grip Strength among Community-dwelling Elderly Men in Korea: Hallym Aging Study. *Epidemiol Health*. 2013;35:e2013001.
19. Vaidya SM, Nariya DM. Handgrip Strength as a Predictor of Muscular Strength and Endurance: A Cross-sectional Study. *J Clin Diagnostic Res*. 2021;1–4.
20. Manoharan VS, Sundaram SG, Jason JI. Factors Affecting Hand Grip Strength and Its Evaluation: a Systemic Review. *Int J Physiother Res*. 2015;3(6):1288–93.
21. Kovarik M, Joscova V, Patkova A, et al. Hand grip endurance test relates to clinical state and prognosis in COPD patients better than 6-minute walk test distance. *Int J COPD* [Internet]. 2017;12:3429–35. Available from: <http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L619594974%0Ahttp://dx.doi.org/10.2147/COPD.S144566>



This work is licensed under a Creative Commons Attribution Non-Commercial 4.0 International License