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Screen Time, Anthropometric Parameter, Insulin and Homa IR in Adolescents

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Abstract

Introduction: The rapid integration of digital technology into daily life, particularly among adolescents, has generated increased screen time exposure. This study investigates the effect of screen time on anthropometric parameters, insulin levels, and HOMA IR in adolescents, regarding the increasing concerns about its potential health implications. Methods: A cross-sectional study involving 131 healthy adolescents (aged 12-18) was conducted to assess an anthropometric measurements, blood investigations (lipid profile, fasting blood glucose, fasting insulin), blood pressure, and screen time assessments. Screen time was categorized as recommended, moderate, and heavy. Results and Discussion: The moderate screen time was associated with a higher risk of overweight (OR=5.643), obesity (OR=3.737), insulin resistance (OR=4.116), and metabolic syndrome (OR=2.185). Heavy screen time showed higher risks for being overweight and metabolic syndrome (OR=32.421), but did not correlate significantly with overweight or obesity. The findings suggest a significant association between screen time and adverse health outcomes in adolescents, particularly for moderate and heavy screen time. Heavy screen time demonstrated substantial risks, emphasizing the need for interventions to mitigate potential health consequences. Conclusion: Screen time has noteworthy implications on the health of adolescents, with significant associations observed on anthropometric parameters, insulin resistance, and metabolic syndrome

Introduction

Technology makes human life easier, especially in digital technology. Digital technology and devices have become habitual tools and must-haves in all human life nowadays (Konca, 2022), especially with the development of communication technology, marked by the development of *the interlinked computer networks* (Internet), which diminished physical barriers for the users (Petcu and Gherheş, 2010). These digital technology developments have made young children use this technology regularly in their daily lives, even in school life (Konca, 2022). This technology development has exposed humans, especially children, to longer screen time on electronic or digital devices, including computers, laptops, smartphones, tablets, or other devices with a screen as the medium of communication, virtual interaction, and connected with people (Pandya and Lodha, 2021).

Screen time is time spent on screen devices, including smartphones, tablets, television, video games, computers, or wearable technology (Canadian Pediatric Society, 2019). Nowadays, young children have been exposed to digital devices from birth, and the use of digital media from an early age has increased rapidly (Neumann, 2015). Even educational sites encourage their students to use digital technology (Straker *et al.*, 2018). This phenomenon is also experienced by adolescents, with screen time as the common activity. They spend screen time at least 3 hours

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per day, such as watching television (57% of them spend an average time of 109 minutes) (Haghjoo *et al*., 2022). Growing evidence notes that screen time is one of the causes of overweight/obesity in modern technology (Priftis and Panagiotakos, 2023). Screen time has a serious impact, including the increase of the obesity pandemic, reduced physical activity, and sleep disturbances (Goswami and Parekh, 2023). The highest risk was cardiovascular disease (Takagi *et al*., 2019). Screen time activity recommendation for children and adolescents was limited to less than 2 hours per day. Yet, more than 50% adolescents access screen time more than that (Haghjoo *et al*., 2022).

Screen time affects body composition, particularly BMI, via sleep, diet, and physical activity (Zhang *et al*., 2022). Screen time is one of the sedentary behaviour with low energy expenditure (<1.5 metabolic equivalents), which increase the risk factor of metabolic disease (Haghjoo *et al*., 2022). However, population studies still result in inconsistent outcomes in investigating the correlation between screen time and overweight/obesity. A literature review noted that the highest screen time category had 0.7 kg/m^2 higher BMI than lower screen time in children and adolescents, and those with obesity had higher screen time than non-obese by 0.313 hours (Wu *et al*., 2022). The relationship between high and low screen time and the blood pressure, BMI, and waist-to-hip ratio (WHR) was confirmed in adolescents (Oto *et al*., 2021). Another meta-analysis study noted that screen time had no relationship with central obesity, even though the subjects with the highest screen time had a higher waist circumference by 1.23 cm than lower screen time subjects (Ghasemirad *et al*., 2023). Objectives: to investigate the effect of screen time on anthropometric parameters, insulin, and HOMA IR in adolescents.

Methods

A cross-sectional study was conducted in adolescents aged 12-18 years old in Surabaya and Sidoarjo from September 2019 to January 2020, involving healthy adolescents (normal, overweight, and obese) aged 13-18 who studied in Sidoarjo and Surabaya. The subjects in this study should be healthy, not smokers, not consume alcohol or drugs, not have dyslipidemia medication or undergo hormonal therapy, or autoimmune disease, and not have chronic diseases or infectious diseases. Before the study was performed, the researchers must have the head master's permission and clarify the importance of this study in front of the subject's parents. The subjects would participate in this study only when the parents sign informed consents without any coercion, as this study needs blood withdrawal. This study is an open-label one, without any randomization.

The anthropometric measurements included: body height (Seca stadiometer 213®, Seca, Germany), body weight (Seca Robusta digital scale 815®, Seca, Germany), waist circumference (Seca 201 measuring tape®, Seca, Germany), and hip circumference (Seca 201 measuring tape®, Seca, Germany). All the procedures were done when the subjects wore light clothes, without accessories (belt, hairpin, watch, hat, or ponytail) in a standing position. Body weight was measured using a weighing device. When the weighing device reads 00.00, ask the child to stand in the center of the weighing device. Make sure the child is standing upright, eyes/head straight ahead, legs not bent. The interviewer can help the child to stand properly on the scale and reduce unnecessary movements that may affect the weighing result. After the child stands correctly, the weighing device will automatically show the digital weighing result. Ask the child to get off the scale first, and the interviewer should immediately record the result.

Body height measurements were taken using a stadiometer. After the stadiometer is assembled and ready for use, the subject to be measured is asked to remove shoes, sandals, and hats. Then the subject to be measured stands upright on the base with straight legs, heels closed, buttocks and back of the head against the stadiometer, and face straight with a forward gaze. Lower the head slider until it is tight against the top of the head, and then read the number on the scale visible on the stadiometer. The number indicates the height of the subject. The waist and hip circumference measurements were taken using a measuring tape. A measuring tape was wrapped around the waist in a standing straight position without pulling the stomach. Waist circumference is measured halfway between the lower ribs and the iliac crest. Hip circumference is measured at the largest circumference around the buttocks. Measurement error occurs if the tape is pulled too tight or loose (Eaton-Evans, 2005).

The blood test was taken via the vena cubiti. Before the blood was taken via the vena cubiti in the morning, the subjects were asked to fast for 12 hours (did not have a meal or snack, or sweet beverage after the last supper, except drinking water). The blood was taken by a laboratory technician. After the blood was taken, it was placed in a labelled non-EDTA tube (the label included name, sex, birth date, the date the sample was taken, and the schools' name) as much as 5 ml, and then it was placed in a cooling box for transportation to the laboratory (Kedung Doro Laboratory). The blood investigation includes: lipid profile, fasting blood glucose (FBG), and fasting insulin. Blood pressure was measured in a relaxed sitting position. If the subject is doing physical activity, ask to rest for 10 minutes before the measurement is taken.

1. Use the cuff on the upper arm on the left side.
2. The cuff should be about 2-3 cm above the elbow. Place the cuff directly on the skin, as clothing may cause a weak pulse and result in measurement errors.
3. Tighten the cuff.
4. Place the subject's hands on the table and relax the subject's posture.
5. The cuff should be at the level of the subject's heart.
6. Press the START button to start the measurement.
7. Remain still until the measurement is complete, i.e. the pressure and pulse values are displayed on the monitor.

Screen time was assessed using the World Health Organization-Global School Health Survey (WHO-GSHS), to confirm the duration of screen time activity. The subjects were divided into 3 groups. Recommended screen time (> 2 hours/day), moderate screen time (3-6 hours/day), and heavy screen time (> 7 hours/day). Insulin resistance (IR) was determined using homeostatic model assessment for insulin resistance (HOMA IR), calculated using:

$$HOMA - IR \equiv \left[Fasting\ blood\ glucose\ \left(\frac{mg}{dL}\right) \times insulin\ \left(\frac{\mu u}{L}\right)\right] \div 405$$

The cut-off value to determine IR was $\geq$ 5.22 for boys and $\geq$ 3.82 for girls in pubertal periods (Kurtoglu *et al.*, 2010). The subjects were determined as hyperinsulinemic when the fasting insulin ≥ 15 μU/mL (Güemes *et al.*, 2020). Metabolic syndrome (MetS) assessment based on the International Diabetes Foundation (IDF) criteria, namely central obesity (waist circumference > 90th percentile or adult cut-off value) accompanied by at least 2 other component: glucose intolerance (fasting blood glucose or FBG > 100 mg/dL), triglycerides > 150 mg/dL, and HDL-c (high density lipoprotein cholesterol) < 40 mg/dL, hypertension (systole blood pressure > 130 mmHg or diastole blood pressure > 85 mmHg) (Magge *et al.*, 2017; Zimmet *et al.*, 2007).

This study has been reviewed and registered ethically and was approved by the Ethical Committee of the Faculty of Medicine, Airlangga University, Number 65/EC/KEPK/FKUA/2020. After a test of normality (Kolmogorov-Smirnov) was conducted, one-way ANOVA or Kruskal-Wallis was conducted, followed by a post hoc test (LSD or Mann-Whitney). The correlation between screen time and other variables was conducted using Pearson's or Spearman's Rho correlation. While the categorical parameters were analyzed using multinomial logistic regression to determine the odds ratio, the correlation were analyzed using Cramer's V or Phi.

Results and Discussion

A total of 131 adolescents were recruited after their parents signed the informed consent and received approval from their school. 61.83% adolescents had screen time more than 2 hours/day. However, a study in Malaysia found that the prevalence of excessive screen time in children was 91.4%, which was higher than this study, with an average time of 3.00 h/day(Raj *et al.*, 2022). Excessive screen time is strongly associated with friends' screen time (Suchert *et al.*, 2016), parents' screen time during weekdays (Ishii *et al.*, 2022), higher education, and BMI

Table 1. Subject's Characteristics

Variables	x ± SD (n=131)	Recommended screen time x ± SD (n=50)	Moderate screen time x ± SD (n=66)	Heavy screen time x ± SD (n=15)	p
Age, months old	185.58 ± 16.50	174.56 ± 15.03[a*]	191.35 ± 13.65[a]	196.93 ± 11.94[a]	0.000[1]
Body height, cm	161.76 ± 7.71	158.93 ± 7.592[a*]	163.63 ± 6.81[a]	162.95 ± 9.40	0.004[1]
Body weight, kg	86.61 ± 20.32	80.54 ± 14.96[a*]	90.08 ± 22.72[a]	91.55 ± 20.97	0.025[1]
Body mass index, kg/m^2	33.17 ± 6.78	31.81 ± 4.44	33.64 ± 7.60	35.63 ± 8.72	0.116[1]
BMI-for-age z-score	2.66 ± 1.19	2.67 ± 0.72	2.62 ± 1.46	2.75 ± 1.22	0.097[2]
Height-for-age z-score	-0.64 ± 0.81	-0.58 ± 0.92	-0.66 ± 0.67	-0.79 ± 1.02	0.670[1]
Hip circumference, cm	107.41 ± 13.76	104.83 ± 9.60	108.45 ± 15.46	111.41 ± 16.69	0.182[1]
Waist circumference, cm	98.75 ± 17.00	99.02 ± 12.89	98.63 ± 18.09	98.34 ± 24.15	0.660[2]
LDL-c, mg/dl	117.50 ± 29.13	112.08 ± 28.49	121.65 ± 29.41	117.33 ± 28.92	0.216[1]
Total cholesterol, mg/dl	7.27 ± 5.66	168.34 ± 33.27	181.03 ± 37.42	175.67 ± 34.71	0.168[1]
HDL-c, mg/dl	45.02 ± 9.07	44.00 ± 8.29	45.14 ± 8.96	47.93 ± 11.77	0.337[1]
Triglyceride, mg/dl	110.64 ± 57.45	103.16 ± 55.23	118.06 ± 62.11	102.93 ± 39.25	0.332[1]
Fasting blood glucose, mg/dl	82.75 ± 7.68	80.60 ± 7.69[b*]	83.29 ± 7.31[b]	87.53 ± 7.07[b]	0.006[1]
Systole blood pressure, mmHg	127.82 ± 15.21	123.72 ± 13.44	130.58 ± 15.58	129.33 ± 17.09	0.050[1]
Diastole blood pressure, mmHg	82.05 ± 10.80	82.46 ± 9.22	81.27 ± 11.57	84.13 ± 12.49	0.619[1]
Insulin, µU/mL	23.89 ± 17.76	18.55 ± 15.68[b*]	26.05 ± 16.32[b]	32.18 ± 25.16[b]	0.002[2]
HOMA IR	5.01 ± 4.13	3.85 ± 3.89[b*]	5.42 ± 3.55[b]	7.09 ± 6.04[b]	0.000[2]
Sleep duration, hours/day	6.95 ± 1.27	7.50 ± 1.27[b*]	6.62 ± 1.06[b]	6.59 ± 1.57[b]	0.000[2]

[1]Oneway anova, post hoc LSD; [2]Kruskal Wallis, Post hoc Mann Whitney; [a]Significant between groups (p<0.05), post hoc LSC; [b]Significant between groups (p<0.05), post hoc Mann Whitney.

(Kurniasanti *et al.*, 2019). Parents play a crucial role in their children's screen time activity (Raj *et al.*, 2022; Xu *et al.*, 2015). TV screen time activity decreased in 2002 and 2010. Yet people tend to switch this activity to the computer (Przybylski, 2019). For adolescents now, screen time means social media usage, which could entertain and build connections with others (Ganson *et al.*, 2023).

No significant difference in BMI, BMI-for-age z-score, hip circumference, waist circumference, fasting lipid profile, and blood pressure (p>0.05). A study conducted in adolescents produced a contradictory result, as screen time performed a positive dose-response relationship with BMI (percentile), waist circumference, and body fat (Suchert *et al.*, 2016). Others stated a positive association between screen time and BMI, skinfold thickness, waist circumference, and physical activity (Dumith *et al.*, 2012). However, another study highlighted gender-related findings, in which screen time of more than 6 hours/day was associated with waist circumference in males, not females (Singh *et al.*, 2023).

While age, body height, body weight, fasting blood glucose, fasting insulin, HOMA IR, and sleep duration showed at least one pair of groups with significance (p<0.05). Subjects with recommended screen time were younger than subjects with moderate screen time (p=0.000) and heavy screen time (p=0.000). A systematic review showed that screen time correlated positively with children's age, and the increment in screen time by 60 min/day from the age of 11 to 15, or the mid-adolescent phase (Dumith *et al.*, 2012). The gender correlation also shows that moderate screen time was prevalent in male adolescents. However, the results seemed contradictory (Shalani *et al.*, 2021). Others also found the gender-related aspect of excessive screen time, in which longer screen time was seen in males than females, and the younger ones (14-15 years old) had excessive screen time (De Lucena *et al.*, 2015). Trang *et al.* (2013) stated that the average screen time in female adolescents aged 16 years old was 69 minutes/day (min-max 34-95), while male adolescents had longer screen time activity by 78 minutes/day (min-max 48-104) (Trang *et al.*, 2013). However, a study in children showed that screen time did not differ by gender (Belton *et al.*, 2021). Gender based differences also found that females had longer screen time than males. Yet, found that the older the subjects, the longer the screen time (Dahlgren *et al.*, 2021). A study found that school grade was correlated with screen time. Students in the 6th grade had a higher risk for longer screen time by 1.44-fold than other grades, and being in the 7th grade increases screen time exposure by 1.53-fold (dos Santos Farias *et al.*, 2021).

Adolescents with recommended screen time were shorter than subjects with moderate screen time (p=0.001) as they were younger than moderate screen time, and lighter (p=0.012). A study conducted in children aged 2-14 found that children with more than 3 hours//day tend to have excess body weight by 1.20-fold (Cartanyà-Hueso *et al.*, 2022), which is in line with these findings. However, adolescent studies found no correlation between screen time and body weight status. Yet, it correlated with age, gender, and type of school (Myszkowska-Ryciak *et al.*, 2020). Subjects with recommended screen time also had lower systolic blood pressure compared to moderate screen time (p=0.016). Screen time showed no correlation with blood pressure. However, a study conducted in obese children showed a mild correlation with screen time (Stabouli, 2022), which is in line with this result. But other studies contradicted this finding, as screen time for more than 6 hours/ day did not correlate with hypertension (Singh *et al.*, 2023). We suspect that the contradictory result of screen time in adolescents is due to specific social media usage by adolescents, as a finding stated that screen time, especially social media use, was associated with attempts to gain weight and lose weight. These behaviour changes were platform-dependent (Ganson *et al.*, 2023), resulting in a negative association in which screen time reduced body weight. As for those with a positive association between screen time and body weight gain due to overeating, desire to drink, satiety responsiveness, and reduced physical activity, resulting in a positive effect in BMI (Semar and Bakshi, 2022).

Subjects with recommended screen time also had lower fasting blood glucose (FBG) than subjects with moderate screen time (p=0.048) and heavy screen time (p=0.002). A meta-analysis found that subjects with the highest screen time had a 1.64-fold risk of MetS compared to those with the lowest screen time. Others also found a linear association between screen time and MetS risk, in which every 2 hours of screen time increment will increase the risk of MetS by 1.29-fold (Jahangiry *et al.*, 2022). A cohort study found that screen time more than 2 h/day (average screen time of 2.86 ± 0.08 h/ day) increase the BMI by 8 points (22.57 ± 0.13 kg/m^2 to 30.27 ± 0.18 kg/m^2) during 24-year of follow-up, with 43.4% had obesity, 8.4% had diabetes, 31.8% had hypertension, and 14.9% had hyperlipidemia (Nagata *et al.*, 2023). This finding is also supported by the statement that childhood screen time at the ages of 5 and 15 years old was associated with the presence of MetS at the age of 45 years old (OR=1.30, 95% confidence interval: 1.08 to 1.58; *p*=0.006), and also associated with low cardiorespiratory fitness (MacDonell and Hancox, 2023).

Subjects with recommended screen time had lower fasting insulin than subjects with moderate screen time (p=0.022) and heavy screen time (p=0.008). On the basis of HOMA IR value, subjects with recommended screen time also had smaller HOMA IR value than subjects with moderate screen time (p=0.001) and heavy screen time (p=0.002). A study conducted in adults showed the highest prevalence of insulin resistance in subjects with long screen time, and correlated with HbA1C (Nightingale *et al.*, 2017). However, the study in adolescents showed no significant difference between recommended screen time (2-4 h/day) and the incidence of diabetes mellitus (>4h/ day). Adolescents with >4h/day had higher risk of being T2DM by 2.06-fold than adolescents with recommended screen time (Scandiffio and Janssen, 2021). A study found a stronger effect of screen time in boys than girls, in which excessive screen time increases the risk of elevated insulin levels by 2.73-fold and HOMA IR value by 2.42-fold (Hardy *et al.*, 2010). The correlation between screen time and insulin resistance was a dose-response in the adult population, which increased HOMA IR value in low, moderate, and high screen time (0.37 ± 0.008, 0.40 ± 0.012, and 0.43 ± 0.012). Waist circumference mediates the effect of screen time and insulin resistance (Parker *et al.*, 2023). However, this phenomenon was not evident in this study. No correlation was seen between screen time and waist circumference, as seen in Table 2.

A cohort study in children with a 2-year follow-up showed that adiposity is a central predictor of insulin dynamics; every 1% increment of body fat will be accompanied by a decrease of insulin sensitivity by 2.9%. This evidence also predicted the 0.5% enhancement in oral glucose tolerance 2 years later (Hardy *et al.*, 2010). Screen time was associated with body composition in adolescents; the additional hour screen time per day increase BMI, abdominal subcutaneous fat index, and visceral fat mass (Wu *et al.*, 2023). Others found the effect of screen time on percent body fat was evidence in boys, not in girls (Barnett *et al.*, 2010). However, we can conclude that screen time increases the risk of insulin resistance via body composition, especially fat distribution. A study conducted in Semarang gave another view as screen time was associated with sugar-sweetened beverage (SSB) consumption in female adolescents, as they had excessive screen time more than 8 hours/day, with an average consumption of SSB by 5 times/week. Types of SSW were powdered drinks, packaged milk, yoghurt, packaged coffee, and carbonated drinks. Those SSW were associated with percent body fat (Setyawati *et al.*, 2023).

Subjects with recommended screen time also had shorter sleep duration than subjects with moderate screen time (p=0.000) and heavy screen time (p=0.017). It was stated that excessive screen time is associated with poor quality of sleep and duration via several pathways: displace other activities, suppression of melatonin production due to exposure of bright which lead to circadian disruption, sympathetic regulation which lead to a psychophysiological arousal, and electromagnetic radiation delayed the melatonin production in the pineal gland as it sensed as light (Lissak, 2018; Priftis and Panagiotakos, 2023). Screen time has been proven to disrupt nighttime sleep and lower the sleep consistency in children (Przybylski, 2019).

Table 2. The Correlation Between Screen Time Duration with Anthropometric and MetS Components

Variables	**Correlation**	
	R	**P**
Age	0.519	0.000[1]
Body height, cm	0.255	0.003[1]
Body weight, kg	0.173	0.049[1]
BMI, kg/m^2	0.134	0.127[1]
BMI-for-age z-score	0.194	0.026[2]
Hip circumference, cm	0.198	0.023[2]
Waist circumference, cm	-0.039	0.655[1]
LDL-c, mg/dl	0.112	0.201[1]
Total cholesterol, mg/dl	0.135	0.125[1]
HOMA IR	0.298	0.001[2]
Insulin, μU/mL	0.263	0.002[2]
Fasting blood glucose,mg/dl	0.271	0.002[1]
HDL-c, mg/dl	0.109	0.215[1]
Triglyceride, mg/dl	-0.023	0.791[1]
Systole blood pressure, mmHg	0.094	0.285[1]
Diastole blood pressure, mmHg	-0.006	0.946[1]
Height-for-age z-score	-0.088	0.315[1]
Sleep duration, hours/day	-0.317	0.000[2]

Table 2 summarizes the correlation between screen time and anthropometric measurements and MetS components. Screen time was correlated positively with body height (r=0.255, p=0.003), body weight, BMI-for-age z-score and hip circumference. A study in children found a positive correlation between screen time and BMI-for-age z-score and waist circumference, in which the addition of screen time by 1 hour will be accompanied by an increment of BMI-for-age z-score by 0.06 points and 0.4 cm waist circumference (Lee *et al.*, 2015).

Screen time correlated positively with HOMA IR value (r=0.293, p=0.001), fasting insulin (r=0.263, p=0.002), and FBG (r=0.271, p=0.002), which means that screen time correlated with the possibility of T2DM. A similar result was also seen in Korean teenagers, in which students with moderate screen time (>2 hours/day) increased the risk of pre-diabetes (blood glucose parameters) by 9.17% (OR=1.942) (Wu *et al.*, 2018). In another investigation, the risk of diabetes was increased by 2.06-fold in adolescents with screen time > 4 hours/day (Scandiffio and Janssen, 2021). It seems that there was a change in dietary pattern toward western food during screen time than the Korean healthy diet, which leads to insulin resistance (Lee *et al.*, 2013). Screen time duration had a negative correlation with sleep duration (r=-0.317, p=0.000) but performed a positive correlation with age (r=0.519, p=000). A similar result was reported with r_S=- 0.42, p<0.001) for sleep duration, and age (r_s = 0.60, p< 0.001), and screen time became the predictor of sleep disturbance (β =- 0.26, p< 0.001) along with age (β =- 0.20, p< 0.001) (Sourtiji *et al.*, 2018).

Table 3. The Correlation Between Screen Time Groups with Anthropometric and MetS Components

Variables	Recom mended Screen Time (n=50)	Moderate Screen Time (n=66)	Logistic Regression	Heavy Screen Time (n=15)	Logistic Regression	Correlation	
						Cramer V/ Phi	P
Gender			2.685*		2.243	0.161	0.183
- Male	22 (44%)	40 (60.60%)		7 (46.67%)			
- Female	28 (56%)	28 (42.42%)		8 (53.33%)			
BMI-for-age z-score categories					-	0.489	0.000
- Normal	5 (0.10%)	15 (22.72%)	-	3 (20%)			
- Overweight	30 (60%)	12 (18.18%)	5.643*	0 (0%)			
- Obesity	15 (30%)	39 (59.09%)	3.737*	12 (80%)			
Waist circumference categories			0.651		-	0.130	0.330
- Abdominal obesity	44 (88%)	51 (77.27%)		12 (80%)			
- Normal	6 (12%)	15 (22.72%)		3 (20%)			
Sleep categories			3.296*		2.548	0.278	0.006
- Insufficient	24 (48%)	50 (75.76%)		11 (73.33%)			
- Sufficient	26 (52%)	16 (24.24%)		4 (26.67%)			
HOMA IR categories			4.116*		7.458*	0.277	0.007
- IR	10 (20%)	27 (40.91%)		9 (60%)			
- Non-IR	40 (80%)	39 (59.09%)		6 (40%)			
Insulin categories			1.042		1.566	0.221	0.041
- Hyperinsulinemia	23 (46%)	44 (66.67%)		11 (73.33%)			
- Normal insulin	27 (54%)	22 (33.33%)		4 (26.67%)			
Fasting blood glucose categories			0.221		-	0.244	0.020
- Hyperglycemic	-	-		1 (6.67%)			
- Normal	50 (100%)	66 (100%)		14 (93.33%)			

Variables	Recom mended Screen Time (n=50)	Moderate Screen Time (n=66)	Logistic Regression	Heavy Screen Time (n=15)	Logistic Regression	Correlation	
						Cramer V/ Phi	P
Triglyceride level categories			0.716		0.089	0.109	0.461
- Hypertriglyceridemia	18 (36%)	24 (36.36%)		3 (20%)			
- Normal triglyceride	32 (64%)	42 (63.64%)		12 (80%)			
HDL-c level categories			0.668		0.051	0.107	0.471
- Low HDL-c	18 (36%)	31 (46.97%)		7 (46.67%)			
- Normal HDL-c	32 (64%)	35 (53.03%)		8 (53.33%)			
Blood pressure categories			1.181		1.392	0.129	0.336
- Hypertension	27 (54%)	42 (63.64%)		11 (73.33%)			
- Normal	23 (46%)	24 (36.36%)		4 (26.64%)			
The presence of MetS			2.185*		32.421*	0.125	0.358
- MetS	20 (40%)	32 (48.49%)		9 (60%)			
- Non-MetS	30 (60%)	34 (51.51%)		6 (40%)			

*p value<0.05

Table 3 summarizes the correlation between screen time categories and the prevalence of overweight/obesity, MetS, IR, and MetS components. Males had higher risk for moderate screen time by 2.685-fold than females. It is similar to another study with the lower risk, 1.69-fold (dos Santos Farias *et al*., 2021). Other found higher risk in male by 3.6-fold at the age of 16 years-old (Trang *et al*., 2013).

Subjects with moderate screen time had a higher risk for being overweight by 5.643-fold, and being obese by 3.737-fold than recommended screen time (p<0.05). But heavy screen time did not correlate with the incidence of overweight and obesity, as the prevalence of obesity was dominant. A study found that screen time of more than 2 hours/day increases the risk of being overweight by 1.06-fold, and obesity by 1.10-fold (de Souza *et al*., 2020), which was lower than this result. The underlying mechanism of screen time could be contributing to obesity via: the increment of sedentary activity, unhealthy diet stimulated by the advertisement of unhealthy foods, the frequency of snacking while viewing, and sleep duration and quality (Strasburger *et al*., 2011). The moderate screen time increases the risk for abdominal obesity by 0.651-fold (p>0.05), which contradicts other findings, in which long screen time (>3 hours/day) had a higher risk for abdominal obesity by 2.5-fold in post-puberty adolescents (de Oliveira *et al*., 2023). However, others found a smaller risk for overweight, 1.51-fold (dos Santos Farias *et al*., 2021).

Moderate screen time increases the risk of IR by 4.116-fold in this study, which is in line with the findings that boys with excessive screen time (>2 hours/day) are more likely to have IR (OR=2.42) and hyperinsulinemia (OR=2.73) (Nightingale *et al*., 2017). However, the odds ratio did not perform well in this study, due to different cut-off values. Others also found that the possibility of IR was increased along with screen time duration; those with screen time > 3 hours/day had the possibility of IR by 16.4% (Nightingale *et al*., 2017). Moderate screen time increased the risk of MetS by 2.185-fold, and 32.421-fold in heavy screen time. This finding was in line with the findings that screen time had a positive association with MetS; each hour screen time addition increased the risk of MetS by 21% (OR = 2.20-fold) (Khan *et al*., 2019). Other also found the increment risk of MetS was a dose-response, in which 2 h/day (OR=1.21, 95% CI=0.54–2.73), 3 h/day (OR=2.16, 95% CI= 0.99–4.74), 4 h/day (OR=1.73, 95% CI=0.72–4.17) and ≥5 h/day (OR=3.07, 95% CI=1.48–6.34) (Mark and Janssen, 2008).

Conclusion

Adolescents with screen time more than 3 hours/day were older, heavier, and experienced shorter sleep duration than adolescents with recommended screen time, and had higher fasting blood glucose, fasting insulin, and

HOMA-IR value. Screen time more than 3 hours/day increases the risk of overweight/ obesity, IR, MetS, and causes insufficient sleep duration in adolescents.

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