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MEDIATING ROLE OF PRENATAL ANDROGENS, MUSCLE STRENGTH AND PHYSICAL ACTIVITY ON AGGRESSION IN OBESE AND OVERWEIGHT CHILDREN AND ADOLESCENTS

POSREDNIŠKA VLOGA PRENATALNIH ANDROGENOV, MIŠIČNE MOČI IN TELESNE DEJAVNOSTI PRI AGRESIVNOSTI DEBELIH IN PREKOMERNO TEŽKIH OTROK TER MLADOSTNIKOV

ABSTRACT

Obesity in children and adolescents is a global health problem associated with behavioral issues like aggression which can lead to developmental problems. High levels of prenatal androgens may play a role between obesity and aggression. This study examined the relationship between obesity, aggression and the mediating role of prenatal androgens, muscle strength and physical activity in children and adolescents. 118 healthy boys ages 9 to 17 participated and researchers measured their height, weight, body composition, muscle strength, second to fourth finger ratio, physical activity level using PAQ, and aggression using BPAQ. Chi-square test, Pearson's correlation, stepwise linear regression, and Sobel's test were used to examine relationships between variables and test mediation, seeking to identify factors affecting aggressiveness. The study found that aggression is directly related to weight, BMI, muscle mass, body fat and WHR. Obese people were more likely to be aggressive compared to non-obese people. Regression analysis showed that 2D:4D ratio, muscle mass and BMI can predict aggression. The results also showed that only muscle strength mediates the relationship between body mass and aggression. The study found a direct link between aggression and body mass in boys which may be because muscle strength mediates this relationship. The findings agree with the idea that prenatal androgens affect aggression in boys. Obese children with low 2D:4D ratios may need education to change views, values, and increase physical activity.

Keywords: aggression, prenatal androgens, physical activity, strength, obesity

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IZVLEČEK

Debelost pri otrocih in mladostnikih je globalni zdravstveni problem, povezan z vedenjskimi težavami, kot je agresivnost, ki lahko vodijo do razvojnih težav. Visoke ravni prenatalnih androgenov lahko igrajo pomembno vlogo pri povezavi med debelostjo in agresivnostjo. Ta študija je preučevala odnos med debelostjo, agresivnostjo in posredniško vlogo prenatalnih androgenov, mišične moči in telesne dejavnosti pri otrocih in mladostnikih. V raziskavo je bilo vključenih 118 zdravih dečkov, starih od 9 do 17 let, pri čemer so raziskovalci izmerili njihovo višino, maso, telesno sestavo, mišično jakost, razmerje med drugim in četrtim prstom, raven telesne dejavnosti z uporabo PAQ in agresivnost z uporabo BPAQ. Za preučevanje odnosov med spremenljivkami in testiranje mediacije so uporabili hi-kvadrat test, Pearsonov korelacijski koeficient, postopno linearno regresijo in Sobelov test, s ciljem prepoznati dejavnike, ki vplivajo na agresivnost. Študija je pokazala, da je agresivnost neposredno povezana z maso, indeksom telesne mase (ITM), mišično maso, telesno maščobo in razmerjem med obsegom pasu in bokov (WHR). Debeli posamezniki so bili bolj verjetno agresivni v primerjavi z normalno težkimi posamezniki. Regresijska analiza je pokazala, da lahko razmerje 2D:4D, mišična masa in ITM napovedujejo agresivnost. Rezultati so pokazali, da samo mišična moč posreduje odnos med telesno maso in agresivnostjo. Študija je odkrila neposredno povezavo med agresivnostjo in telesno maso pri dečkih, kar je lahko posledica tega, da mišična moč posreduje ta odnos. Ugotovitve se strinjajo z idejo, da prenatalni androgeni vplivajo na agresivnost pri dečkih. Debeli otroci z nizkimi razmerji 2D:4D morda potrebujejo izobraževanje za spremembo pogledov, vrednot in povečanje telesne aktivnosti.

Ključne besede: agresivnost, prenatalni androgeni, telesna dejavnost, mišična jakost, debelost

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https://doi.org/10.52165/kinsi.30.2.18-38

INTRODUCTION

Obesity and overweight are gradually increasing as a global health challenge across all age groups, with a particularly concerning impact on children and adolescents. In 2016, approximately 17% of children and adolescents worldwide were classified as overweight or obese (Cheng et al., 2022). Using body mass index (BMI) as a measure, roughly 1 out of every 5 individuals globally falls into the obese or overweight category. Among adolescents aged 12 to 19 years, severe obesity has seen a slight increase, affecting over 9% of this age group in the last two decades (Ogden et al., 2016).

In Iran, a meta-analysis conducted by Khazaei et al. (2017) estimated the prevalence of obesity among boys to be approximately 6.85%, while in girls, it was approximately 5.13% (Khazaei et al., 2017). However, recent meta-analysis studies have reported a higher percentage of obesity and overweight, ranging from 9.4% to 13.7%, in Iranian children (Akbari, & Mohammadi, 2022).

The physical and psychosocial consequences of obesity in childhood and adolescence are widespread. Some of the adverse physical consequences of obesity/overweight are well documented, such as cardiovascular diseases, metabolic syndrome, type II diabetes, hypertension, hyperlipidemia, orthopedic disorder, sleep apnea, asthma, and fatty liver (Andrade & Alves, 2019). However, research on the psychological, social, and behavioral consequences of obesity in childhood and adolescence is still underway. Research findings, in this case, have shown that children with obesity are at risk of low self-esteem, increased body dissatisfaction, depression, and social isolation and discrimination (Cheng et al., 2022).

Obesity is a circumstance that can create diverse unruly behaviors in children and teenagers. One of the prevalent antisocial behaviors that result from corpulence is aggression. Aggression can cause unsafe environment for other children and can show forthcoming issues like delinquency, depression, drug abuse misuse, and scholastic failure (Motlagh, Ahmadi, Jalilian, Mirzaei, Aghaei, & Karimzadeh, 2013). Aggression can be a forerunner to diverse developmental complications such as physical and mental health distortions, including temper disorders, anxiety, and psychosis (Tso, Rowland, Toumbourou, & Guadagno, 2018). Studies conducted in both Australia and the United States have found that approximately 18 to 33% of children and adolescents display physically aggressive behaviors (Tso et al., 2018). Similarly, studies directed in Iran have announced that between 30-50% of children and teenagers display aggression (Motlagh et al., 2013). While research has been led on the relationship between

overweight/obesity and aggression in children, the results have been contradictory. Some studies have announced an important relationship between obesity and aggressive behavior, while others have not found any important connection. Furthermore, gender differences have brought about mixed results. However, studies conducted on both boys and girls show that there is an important association between excess weight/obesity, and aggressive behaviors in girls only, while others found an important association between overweight/obesity and aggression in boys only (Tso et al., 2018). The contradictory results may be due to other environmental and genetic factors affecting aggression. Generally, the correlation between obesity and aggression in children is a complex issue that requires further investigation. It is important to recognize the negative impact of obesity on a child's behavior and take appropriate actions to address it.

Various elements, including biological, social, and cultural factors influences can lead to aggressive behaviors that continuously influence one another. Thus, to mitigate aggressive behaviors, interventions may need to address the biological, environmental, and sociocultural aspects together. Among the biological factors, testosterone has been extensively studied (Vigil, Del Río, Carrera, ArÁnguiz, Rioseco, & Cortés, 2016). Another gender characteristic that has been linked to aggressive behavior is the second-to-fourth digit ratio (2D:4D), which is typically higher in women than in men (Mikac, Buško, Sommer, & Hildebrandt, 2016). This ratio is established around the fourth month of pregnancy under the influence of prenatal sex hormones. The higher the testosterone-to-estrogen (T/E) ratio, the smaller the 2D:4D ratio, leading to more masculine characteristics. Conversely, a larger ratio of 2D:4D indicates female typicality (Fink, Neave, Laughton, & Manning, 2006). As a result, the 2D:4D ratio can help determine the levels of progenitor androgens (Mikac et al., 2016). Prenatal sex hormones create morphological and neurological differences that can affect sex differences in behavior (Marina Butovskaya, Burkova, Karelin, & Fink, 2015). The brain's sexual differentiation follows a similar pattern with morphological characteristics, such that the presence of testosterone makes the tissue more masculine, while its absence makes it more feminine. These differences can also be noticed in personality traits (Fink et al., 2006). Therefore, there appears to be a probable relationship between the 2D:4D ratio and aggressive behavior. Many studies have shown such a connection among young men (Bailey & Hurd, 2005), black men and women (Marina Butovskaya et al., 2015), children and adolescents (M. Butovskaya, Burkova, Karelin, & Filatova, 2019), and pre-pubescent boys (Babarro et al., 2022). Additionally, a meta-analysis by Turanovic et al. (2017) found a weak but significant relationship among fetal testosterone, 2D:4D ratio, aggression,

and violent behavior (Turanovic, Pratt, & Piquero, 2017). However, other studies did not find a relationship between prenatal testosterone and aggressive behavior (Hilgard, Engelhardt, Rouder, Segert, & Bartholow, 2019; Joyner & Beaver, 2021).

Recent studies have examined the relationship between obesity and the second-to-fourth digit ratio as an indicator of prenatal androgens. Manning et al (2022) found an association between BMI and decreased prenatal testosterone, as well as increased prenatal estrogen levels. A similar link between the 2D:4D ratio and BMI was also found (Manning, Fink, Mason, & Trivers, 2022). Furthermore, this association has been established in other investigations with fat percentage (Bagepally, Majumder, & Kotadiya, 2020). Considering this dual relationship involving aggression with obesity and prenatal androgens, examining the mediating part of prenatal androgens, in this case, may be exceptionally valuable. These relationships grow to be more difficult when the interaction effect of some other factors in obesity, aggression, and prenatal androgens such as muscle strength and physical activity are also considered. The relationship between muscle strength and physical activity with the 2D:4D ratio and obesity has been well explained in two new studies (de Dios Benítez-Sillero, Corredor-Corredor, Portela-Pino, & Raya-González, 2022; Pasanen, Tomkinson, Dufner, Park, Fitzgerald, & Tomkinson, 2022). The relationship between physical activity and aggression has also been investigated in some studies, which show a significant and inverse relationship between aggression and physical activity. Additionally, some studies suggest that people with lower levels of physical activity tend to display more aggressive behaviors. The biological mechanisms behind this link are complex and may involve changes in endorphin and serotonin levels, as well as symptoms of depression and anxiety that can coincide with sedentary lifestyles. Furthermore, there is evidence to suggest that the correlation between aggression and delinquency is moderated by physical activity. Specifically, at high levels of physical activity, instrumental aggression is not associated with delinquency, whereas at low levels of physical activity, active aggression is positively correlated with delinquency. Therefore, physical activity may be an important factor in moderating the relationship between aggression and other Criminal behaviors (Fite & Vitulano, 2011; Ubago-Jiménez, Cepero-González, Martínez-Martínez, & Chacón-Borrego, 2021). The role of muscle strength, especially grip strength, has also been investigated in relation to aggression and the 2D:4D ratio, and the findings indicate a positive relationship between muscle strength and aggression and their relationship is a lower 2D:4D ratio (Ribeiro Jr et al., 2016).

Given the complex relationships between obesity, aggression, and factors like prenatal androgens, strength, and physical activity, investigating the potential mediating role of the 2D:4D ratio in the link between obesity and aggression is needed. While positive associations between obesity and aggression have been found, the influence of prenatal androgens as measured by the 2D:4D ratio has yet to be examined.

We hypothesize that specific biological and behavioral factors may help explain the link between being overweight and exhibiting aggressive behaviors. First, we will evaluate the correlation between aggression scores and measures of body composition, including body mass index, percentage of body fat, and waist circumference in our youth participants. If a significant relationship is found, we will then investigate whether and how much of this correlation can be attributed to one of three potential mediating factors: 2D:4D digit ratio, a proxy for prenatal hormone exposure; physical strength and muscle mass; and levels of physical activity. Answering these questions could uncover valuable new insights into the health risks facing overweight youth, aid in identifying those at risk of being both overweight and aggressive, and inform the design of effective intervention and prevention programs.

METHODS

Study participants

This study was cross-sectional correlational research. All male students in Iran (Mazandaran province) between the ages of 9 and 17 in the academic year 2019-2020 were included in the statistical population of this study, and the sample size was based on the average value of r obtained from past research (Tso et al., 2018) using G-Power software for correlational research. Male children and adolescents (0.24) and a significance level of 0.05, 218 people were considered. Sampling was done in a cluster-random manner (based on region and level) from three schools in the province. At first, in coordination with education, the necessary permission was issued to carry out work in schools. Following a visit to the school and agreement with the head teacher, an invitation to take part in the research was then sent to the parents of the students. After filling out the consent form and medical information questionnaire by the parents, the selected students were invited for evaluation according to the schedule.

Study instruments

All measurements were based on the international anthropometric standards provided by the International Society of Anthropology (ISAK)(Norton & Eston, 2019).

Obesity status: The subjects' height was measured using an AntroFlex wall-mounted studio meter with an accuracy of 0.1 m. To measure the weight, the subjects were asked to stand without shoes and in light sports clothes (sports shirt) and in a balanced position with their hands next to the body on a digital scale with an accuracy of 0.01 kg (BRISK, Germany) until the number fixed by the scale to show the subject's weight correctly. Body mass index (BMI), was calculated using the following formula:

BMI=(Weight (kg))/([Height]^2 (m))

BMI values were divided into underweight, normal, overweight (pre-obesity), and obese groups based on the three classifications of cut points proposed by IOTF (Kelishadi et al., 2008).

Waist to hip ratio (WHR): a flexible 1.5-meter tape measure was used to measure this ratio. First, waist circumference was measured in the smallest diameter (usually 2.5 cm above the navel). Then the hip circumference was measured in the largest diameter of the hip area parallel to the ground. WHR was the ratio of waist circumference to hip circumference in cm.

Body composition: The two-point skinfold method of Slater et al. (1988) was used to evaluate body composition (Slaughter et al., 1988). For this purpose, the subcutaneous fat of the triceps and triceps (legs) was marked according to the measurement guide and measured three times by a trained examiner using a NUMED digital caliper (England). The average value of three measurements was considered in the calculation. Then, using the formula of Slaughter et al. (1988) for boys, the values of the percentage of procrastination were calculated.

% Body Fat=0.735 (Triceps+Calf)+1.0

2D:4D ratio: The length of the fingers was measured using the indirect measurement technique of Wisnapu et al. (2007). For this purpose, a trained examiner repeated the measurements twice for each subject (after practicing the measurement technique and reproducibility of the results several times). For the measurement, the subject was first asked to sit on a comfortable chair and place his hands on the grid paper placed on the table with the fingers extended and extended (in full abduction). Most of the subjects were asked to cut their nails completely. If needed, this was done by the researcher before the measurement. In this situation, the shape of the fingers was drawn by the examiner using a pen that was placed vertically on the paper. From the

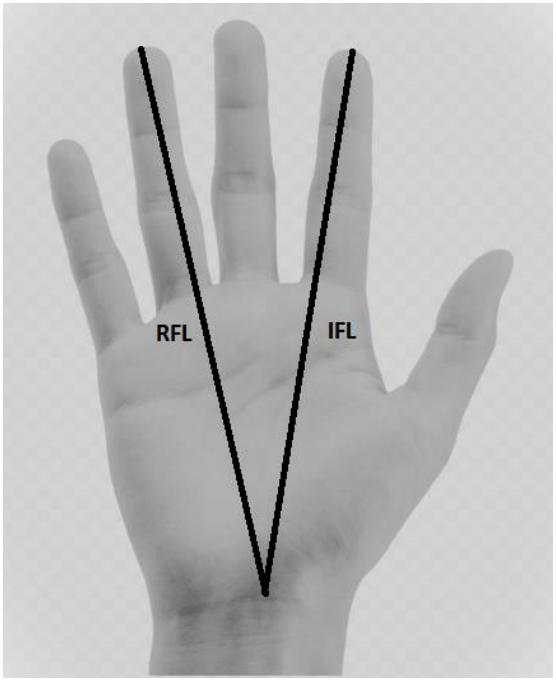
mentioned figure, finger length was measured using a caliper with 0.1 cm accuracy (Visnapuu & Jürimäe, 2007). The measurement method is shown in Figure (1):

The length of the index finger (2D): from the fold of the wrist, which is tangential to the horizontal line of the checkerboard as much as possible, to the tip of the forefinger.

The length of the ring finger (4D): from the crease of the wrist, which is tangential to the horizontal line of the checkerboard as much as possible, to the tip of the ring finger.

By dividing the average length of the second to the fourth digit, the 2D:4D ratio was calculated. The reliability of this measurement technique was calculated using the interclass correlation coefficient (ICC) to measure this ratio in two measurements 0.95 for the dominant hand and 0.94 for the non-dominant hand.

Figure 1. Measuring the length of the second and fourth digits.



Grip strength: A grip dynamometer (model SH5001, Saehan, South Korea) was used to evaluate grip strength. The movement of the handle in this dynamometer is not noticeable and uses a closed hydraulic system to activate the force indicator during muscle static action. Considering that the results of new research show that the values of the maximum power of the claw are higher in the standing position with outstretched hands(Xu, Gao, Xu, Zhou, & Guo, 2021), the measurement was done according to the standard method in this position(Xu et al., 2021). First, the dynamometer was adjusted according to the size of the subject's hand, so that the middle joint (second joint) of the middle finger (third finger) is almost at a right angle. Then the subject

was in a standing position, the head was in a vertical position (looking straight ahead); the arm was between 0 to 180 degrees of flexion; the elbow was in full extension and the wrist and forearm were in 90 degrees of pronation. In this situation, after hearing the examiner's command, the subject applied his maximum force for 3 to 5 seconds. During this time, the examiner verbally encouraged the subject with stronger words and more pressure. The subject repeated the test three times with a one-minute rest between them. The highest value obtained from three times of the test was considered as the value of the subject's hand grip strength(Xu et al., 2021).

Maturity status: The Iranian version of the maturity self-assessment questionnaire was used to determine maturity levels (Rabbani, Noorian, Fallah, Setoudeh, Sayarifard, & Abbasi, 2013). This questionnaire contained two series of illustrations depicting stages of genital development and patterns of pubic hair growth, evaluated as self-reports. Puberty was clinically diagnosed based on Tanner stages, which divides puberty among boys into five stages according to primary and secondary sexual characteristics, including changes in the penis and growth of pubic and axillary hair. In previous studies, this questionnaire had an acceptable reliability coefficient(Rabbani et al., 2013). To ensure the accuracy of the questionnaire results, some subjects were also examined by a general practitioner.

Physical activity: To measure the level of physical activity in this research, the Physical Activity Questionnaire of Children and Adolescents (PAQ-C) was used. This questionnaire includes 9 five-point Likert scale questions designed by Kowalski et al. (1997). The score of this questionnaire ranges from 1 to 5, where 1 indicates the lowest level of physical activity and 5 indicates the highest level of physical activity (Hajinia, Hamedinia, Haghighi, & Davarzani, 2013). The internal consistency of this test was reported as ranging from 0.79 to 0.89 using Cronbach's alpha, and its reliability ranged from 0.75 to 0.82 using test-retest. The criterion validity of this questionnaire shows favourable values when compared to other similar questionnaires(Crocker, Bailey, Faulkner, Kowalski, & McGrath, 1997). This questionnaire has previously been administered to Iranian children aged 12 to 16 (Hajinia et al., 2013).

Aggression: Bass and Perry's (1992) Standard Aggression Questionnaire (AGQ) was used as a self-report measure to measure aggression in this research. This questionnaire has 29 statements in which the subject evaluates his situation on a five-point Likert scale for each statement. People whose score is lower than the average in this scale will have low aggression and the higher the score of people in this test, the higher their aggression. The aggression questionnaire

has high internal consistency. In past studies in Iranian society, Cronbach's alpha coefficient for the total scores of the questionnaire was reported as 0.88, and for the subscales of physical aggression, verbal anger, and hostility between 0.72 and 0.84 (Amirkhanloo, Dousti, & Donyavi, 2022). The retest coefficient (retest) of the questionnaire was also reported in previous research as 0.8 (Amirkhanloo, Dousti, & Donyavi, 2022). In this study, Cronbach's alpha coefficient for the total score of the questionnaire was 0.85. The cut-off point of this questionnaire was 78 points, which is more or equal to this number as aggressive, and less than that is considered non-aggressive.

Statistical analyses

Descriptive statistics (mean and standard deviation) were used to classify and summarize the data. In order to determine the clinical relationship between obesity and aggression, initially, both variables were grouped based on the cut points suggested in previous studies, thereafter chi-square test was utilized to examine the relationship between them. Prior to inferential statistics, the distribution of each variable was checked. Owing to the normality of data distribution, Pearson's correlation coefficient and stepwise linear regression were used in two stages (while excluding the constant value and its associate) to investigate the relationship between the research variables. Moreover, Sobel's test was applied to check the mediating role of variables. For this purpose, the third version of the PROCESS plugin was added to the SPSS software package. This plugin designed by Hayes has the ability to calculate p-value for the Sobel test. Significance level considered $p \leq 0.05$.

RESULTS

Table 1 shows the descriptive indices of the key variables. These include mean, standard deviation, skewness and kurtosis. There was no significant violation of the normal condition (all skewness and kurtosis values were within ±2). Therefore, Pearson correlation coefficient and linear regression were used to check the association between predictor variables and aggression.

Table 1. Descriptive indices of variables (n=218)

Variables	Mean	SD	Skewness	Kurtosis
Age (year)	13.77	2.4	-	-
Height (m)	1.59	0.16	-0.16	-0.92
Weight (Kg)	61.88	16.03	0.51	0.18
BMI (kg/m^2)	24.21	3.15	0.63	1.24
FFM (Kg)	47.27	11.69	0.17	-0.89
Body fat (%)	22.77	10.00	0.63	-0.63
WHR	0.87	0.082	0.56	-1.14
Grip strength (Kg)	40.36	10.49	0.35	-0.40
2D:4D ratio right	0.9928	0.0123	-0.69	0.36
2D:4D ratio left	0.9925	0.0124	-0.67	0.33
Physical activity	2.88	0.74	-0.39	-0.76
Aggression	72.29	11.42	0.31	-0.22

Note. BMI: Body mass index; FFM: Fat free mass; WHR: waist-to-hip ratio

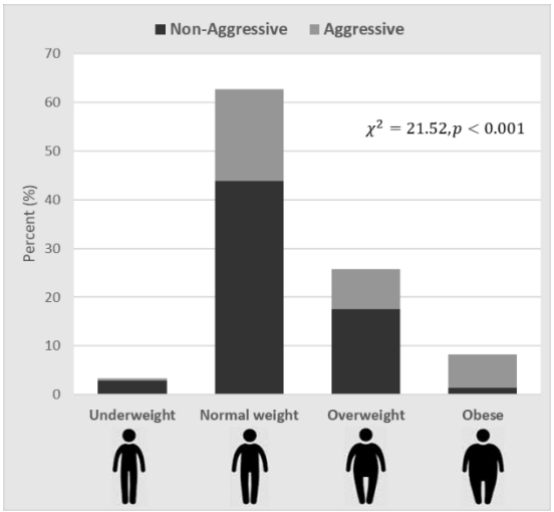
Table 2. Correlation matrix of the research variables (n=218)

Variables	Weight	BMI	FFM	Fat percent	WHR
Aggression	.321**	.303**	.238**	.152*	.165*

Note. BMI: Body mass index; FFM: Fat free mass; WHR: waist-to-hip ratio

Figure 2 displays the relationship between weight status and aggression based on cut off points according to BMI percentile levels. As seen in the figure, there is a significant positive association between weight status and aggression among the children ($p<0.05$, chi-square test). The odds for aggression increased with increasing weight status. The odds were highest among the children who were obese.

Figure 2. Relationship between weight status and aggression based on cut off points



The outcomes of Pearson's test in investigating the correlation between aggressiveness and body weight factors, body mass index, lean body mass, body fat percentage and the waist-to-hip ratio (WHR) are presented in Table 2. The findings demonstrate that all variables related to body composition possess a significant and direct association with aggressiveness. The strongest correlation is relevant to weight and the weakest correlation is relevant to body fat percentage and WHR.

Table 3. Summary of aggression prediction models

Model	R	R2	SEE	F	df	Sig.
A. with considering the constant value	.437	.191	10.74	16.85	3	.0001
B. without considering the constant value	.989	.977	11.18	3092.9	3	.0001

Note. R: correlation coefficient; R2: R-squared; SEE: standard error of estimate; F: F-test; df: Degrees of Freedom; Sig: Statistical significance

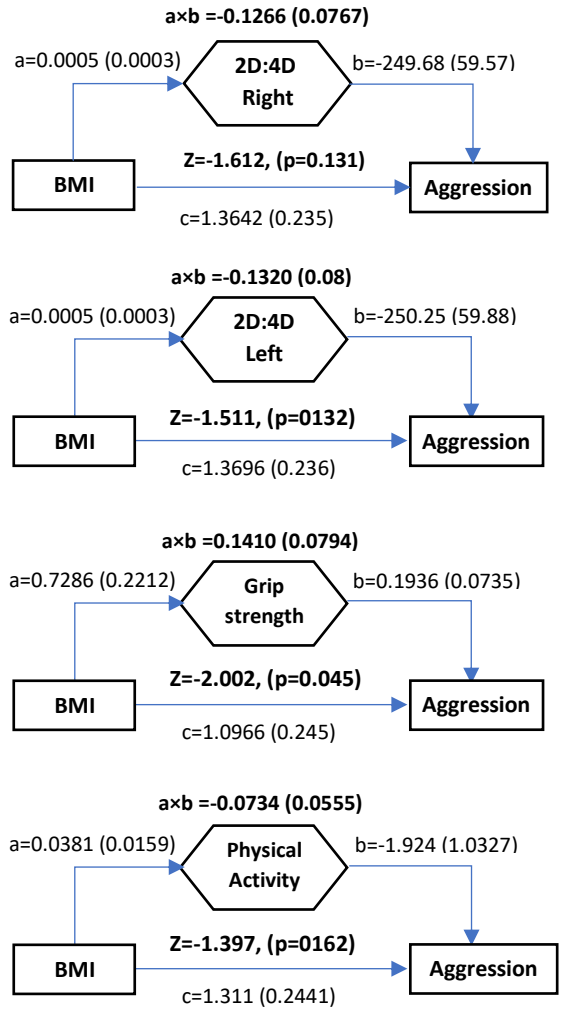
The results of the stepwise regression model are given in Tables 3 and 4. The F test results show the fit of the model A. This model can correctly predict up to 19% of aggression values. Predictive variables in this model included body mass index (BMI), the ratio of the second to the fourth digit of the right hand (2D:4D-R) and fat-free mass (FFM), all of which had a significant effect in the mentioned model ($p \leq 0.05$). Also, the F test results show the fit of the model B (without considering the constant value). This model can correctly predict up to 97% of aggression values. Predictive variables in this model included body mass index (BMI), the ratio of the second to the fourth digit of the left hand (2D:4D-L) and fat percentage, all of which had a significant effect in the mentioned model ($p \leq 0.05$).

Table 4. Selected predictive variables to predict aggression based on stepwise regression

Model	Predictors	B	SE	Beta	t	Sig.
A	constant	261.99	59.55	-	4.4	.000
	BMI	1.23	0.24	0.33	5.12	.000
	2D:4D-R	-227.16	60.13	-0.24	-3.78	.000
	FFM	.14	0.06	0.13	2.05	.041
B	2D:4D-L	25.59	7.85	0.34	3.26	.001
	BMI	2.32	0.41	0.77	5.66	.000
	BFP	-0.38	0.13	-0.13	-3.02	.003

Note. B: Beta coefficient; SE: Standard Error of the Regression; t: t test; Sig: Statistical significance; BMI: Body mass index; FFM: Fat free mass; 2D:4D-R: second-to-fourth digit ratio of right hand; 2D:4D-L: second-to-fourth digit ratio of left hand; BFP: body fat percentage

Figure 3. The path model of the relationship between body mass index and aggression and the mediating role of variables



As can be seen in Figure 3, the mediating role of the variables of 2D:4D of the right and left hands, physical activity and hand grip strength in the relationship between body mass index and aggression have been investigated. According to the results of the Sobel test, among the mediating variables, only hand grip strength has a significant mediating effect on the relationship between body mass index and aggression ($p \leq 0.05$). Z values in the Sobel test in other variables are lower than the critical value.

DISCUSSION

Obesity and overweight are two of the most significant health problems in today's societies, garnering significant attention due to their links with physical and mental health issues. There is an established relationship between obesity/overweight and mental health problems like depression, obsessive-compulsive disorder, bullying victimization, and aggression. However, it remains unclear exactly how this relationship forms and whether manipulating factors within either group could mitigate the effects for individuals in the other group.

The results of the present study showed that aggression is significantly and directly related to weight, body mass index, muscle mass, body fat and WHR. Among the above variables, weight, BMI and muscle mass respectively showed the highest correlation with aggression. These associations are relatively weak, with correlation coefficients ranging from 0.152 to 0.321. These correlation coefficients have been reported to vary in previous studies, depending on factors such as gender, age, and geographical region. The reported ranges of correlation coefficients have been weak to moderate (Tso et al., 2018). The findings of past researche in this case are contradictory. The results of a meta-analysis study by Tso et al. (2018) by examining different studies with a large number of participants, a wide range of ages and geographical locations has supported the view that there is a fundamental link between being overweight or obese and being aggressive. In their study, combined effect sizes were highly significant, strengthening evidence that obesity may be a risk factor that contributes specifically to physical aggression (Tso et al., 2018). These evidences highlight the importance of studying the physiological and psychological mechanisms that might help to explain why this occurs. It is possible that being overweight or tall can lead to aggressive behavior in the future, or that a child or adolescent who behaves aggressively may later become overweight or obese (Tso et al., 2018). Results from previous longitudinal studies show that obesity or large body size is a predictor of future physical aggression, and that overweight/obesity precedes physical aggression (Tso et al., 2018). Children with a higher BMI at 12 months were significantly more likely to engage in violent behavior as adults (Ikäheimo et al., 2007). Raine et al (1998) also demonstrate that there is a relationship between body mass index at the age of three and aggression at the age of 11 (Raine, Reynolds, Venables, Mednick, & Farrington, 1998). In contrast, some researchers found evidence that aggression precedes BMI, and Physical aggression at ages 10 and 11 significantly predicts BMI at age 12 (Tremblay et al., 1998). Therefore, the mutual relationship between obesity/overweight and aggression can basically have common determinants. Several theoretical processes may be somehow involved in this

connection. One of the most important models presented is socio-economic theory. Previous studies have shown that having a poor socio-economic status is related to obesity and overweight in children and adolescents (Wu et al., 2015). It is believed that this issue can be related to poor nutrition or malnutrition in less well-off families. On the other hand, some studies have also found a link between low socio-economic status and aggression in childhood (Najman, Clavarino, McGee, Bor, Williams, & Hayatbakhsh, 2010; Santiago, Wadsworth, & Stump, 2011). In these researches, the hypothesis has been proposed that young people who experience chronic family poverty, eventually choose a type of rebellion, delinquent and aggressive behavior due to their inability to join a middle-class section and the mainstream of society. Especially if their social exclusion becomes a more obvious feature of their daily life (Najman et al., 2010). However, this theory is unlikely to fully explain the common association between overweight/obesity and aggression. In the meta-analysis study by Tso et al. (2017), when this variable was controlled, the relationship between overweight/obesity and aggression was still significant. Another theory that has been proposed is that the relationship between being overweight or obese and aggression in young people is an evolutionary tool. The social dominance perspective suggests that, over time, increasing height and weight will increase the use of violence as a strategy for winning social disputes, as well as for securing material resources and gender choice, and sometimes it may be a means to reduce the fame and attractiveness of same-sex couples so that they are less desirable for the opposite sex (Gallup & Wilson, 2009; Tso et al., 2018). An alternative theory is that overweight/obese youth experience more negative peer interactions (in the form of being rejected and/or victimized by peers), which might contribute to later physical aggression. They rely heavily on physical cues to interact and are likely to be influenced by stereotypes associated with such cues (such as obese people being teased, fighting, or selfish and mean) and subsequently behave in the same way (Gunnarsdottir, Njardvik, Olafsdottir, Craighead, & Bjarnason, 2012). In addition to conforming to negative self-stereotypes, overweight individuals may also avoid physical activity to avoid exposure to ridicule and social rejection by others. Therefore, by reducing opportunities for social interaction, they start a vicious cycle. Obese children may be more susceptible to sarcasm and social rejection due to low social competence and social skills (Gunnarsdottir et al., 2012). In future interactions, individuals could acquire knowledge from these exchanges and opt for aggressive conduct towards others, particularly if it is reinforced by helping them achieve certain goals like gaining social standing (Tso et al., 2018). When children transition into adolescence, attaining a prominent social position among their peers becomes significantly crucial, and their sensitivity towards stressors that they perceive as

degrading or shameful intensifies. At the same time, their coping skills undergo significant changes and they acquire emotion-focused coping strategies that may be less adaptive than others (Tso et al., 2018).

The results of the present study showed that in both aggression prediction models, the ratio of 2D:4D was proposed as an effective predictive variable. According to previous research findings, it has been demonstrated that in men, there exists a notable correlation between aggression and a reduced 2D:4D ratio. Bailey and Hard (2005) suggest that this issue is probably due to the role of prenatal testosterone organizer in physical aggression in men(Bailey & Hurd, 2005). But the amount of this relationship is lower than many other physical and physiological factors such as low heart rate and smoking by the mother during pregnancy with aggression (Pratt, Turanovic, & Cullen, 2016). On the other hand, past studies have reported that body mass index (BMI) is significantly associated with lower prenatal testosterone levels and a higher 2D:4D ratio (Manning et al., 2022). However, despite the significant relationship between aggression and 2D:4D ratio in the present study, the 2D:4D ratio of right and left hand did not show an effective mediating role in the relationship between BMI and aggression. One of the reasons for these findings is the strengthening or lack of strengthening of this relationship in some psychological conditions and situations. Kilduff et al. (2013) played a violent video to men and found that those with a lower 2D:4D ratio exhibited more aggressive behavior after watching the video. Interestingly, testosterone levels increased more in men with a lower 2D:4D ratio than men with a higher 2D:4D ratio after playing a violent video (Kilduff, Hopp, Cook, Crewther, & Manning, 2013). Ribeiro et al. (2016) observed a significant increase in strength and moderate increases in testosterone levels, emotional stability, and physical aggression by showing violent tackles to 89 young men. This increase was correlated with a lower 2D:4D ratio in subjects. Interestingly, there was no significant correlation between these indicators and the 2D:4D ratio after playing an ineffective movie (blank screen). Probably, the relationship between these two variables may be due to exposure to prenatal testosterone and self-control mechanism, which can be considered as primary factors of aggression.

In addition to the presented social theories, many psycho-physiological theories have also been proposed in this field. Both being overweight or obese and displaying aggression are linked to prevalent mental health issues like depression and anxiety (Sanders, Han, Baker, & Cobley, 2015). Children and teenagers experiencing anxious and depressive symptoms often turn to eating as a means of seeking emotional solace or utilizing stress eating as an emotional defense mechanism or coping strategy (Sanders et al., 2015). According to the researchers, stress-

induced elevation in cortisol levels could potentially play a part in stress-related eating habits. When individuals find themselves amidst high levels of stress, it is quite common for them to turn to delectable foods, particularly those with a high fat and sugar content (often packed with calories), in an attempt to alleviate their unease. Interestingly, chronic stress and depressive symptoms are also associated with sedentary behavior due to a decrease in the level of motivation to participate in physical activities, which may lead to an imbalance between energy intake and energy expenditure and increase the likelihood of overweight or obesity in these people (Tso et al., 2018). The findings of the present study show that the amount of physical activity cannot be considered as a strong and independent variable in predicting aggression. Also, the amount of physical activity cannot be an effective mediating variable in the relationship between obesity and aggression. The findings of past studies are contradictory in this regard. Fite and Vitolano's (2011) study shows a significant and inverse relationship between instrumental aggression and physical activity, but physical activity was not related to reactive aggression. Furthermore, the correlation between active aggression and peer delinquency was influenced by physical activity. Specifically, when engaging in high levels of physical activity, instrumental aggression did not show any association with peer delinquency. However, when involvement in physical activity was minimal, active aggression exhibited a positive relationship with peer delinquency. Therefore, physical activity may be an important factor for moderating the relationship between aggression and other problem behaviors. Another study also shows that physical activity helps to reduce aggressive behaviors (Ubago-Jiménez et al., 2021). Engaging in physical activity is also connected to higher levels of self-efficacy and improved social integration. These skills are crucial in safeguarding individuals against manifestations of depression and anxiety (Tso et al., 2018). Physical activity increases self-efficacy and body satisfaction. Dissatisfaction with the body is an important factor that can mediate between obesity and aggression (Sans et al., 2018).

The findings of this study about muscle strength show interesting results about the prediction of aggression according to muscle strength and its mediating role in the relationship between BMI and aggression. Probably, due to the higher body mass, obese people have higher absolute power than their peers, and based on previous social and psycho-physiological theories, they act violently. Higher absolute power can be a reinforcing factor for a person to use physical aggression and increase the possibility of aggression in the person's subsequent interactions. Interestingly, higher fat-free mass (FFM), which is highly correlated with muscle strength, was also identified as a significant predictor of aggression in this study. Therefore, it can be said

that the weight or body mass index of people who have higher aggression may also have a higher lean mass, which will lead to an increase in the absolute muscle strength of the person. These findings clarify the established relationship between muscle strength, prenatal testosterone and the amount of physical activity based on previous researches. According to a meta-analysis conducted by Pasanen et al. (2022), the results indicate that prenatal testosterone, specifically the ratio between the second and fourth finger, holds the potential to serve as a lasting indicator of well-being. This is achieved by enhancing physical activity levels and bolstering strength. It is likely that prenatal testosterone affects the regulation of several skeletogenic genes responsible for the growth and development of several body systems (eg, musculoskeletal), thereby leading to potential increases in strength. Also, prenatal testosterone may affect muscle strength by influencing physical activity behaviors (Pasanen et al., 2022). In their study, Tomkinson and Tomkinson (2017) discovered a noteworthy correlation between grip strength and the 2D:4D ratio. They took into account various factors like weight, age, and BMI to establish this relationship. They suggested that the level of physical activity of the subjects was probably influential in this connection (Tomkinson & Tomkinson, 2017). This suggests that the possible interaction of prenatal testosterone (lower 2D:4D ratio) and obesity is a potential factor in increasing aggression by increasing muscle strength enhancing factor. On the other hand, the moderating role of physical activity on aggression, which is related to a lower 2D:4D ratio based on past research, can affect and moderate the mediating role of prenatal testosterone in the relationship between obesity and aggression. The relationship between prenatal testosterone and physical activity probably occurs due to more excitement in people with a lower 2D:4D ratio, which itself is caused by the action of some genes effective in neural processing and metabolic functions such as ACE, TPH2 and SNAP25 (Minkwitz et al., 2016). Excitement levels can be a potential genetic factor for problematic behaviors in childhood and adolescence, and engaging in sports activities can be a prominent moderator of this relationship (Wilkinson et al., 2013). Therefore, if the obese child has a lower ratio of 2D:4D, participating in physical activity to moderate the potential aggression of these children seems very necessary.

CONCLUSION

The findings of this research indicate a substantial direct link between aggression and body mass index in children, and adolescent males that may be partially explained by the individual's muscular strength. Factors like prenatal testosterone exposure, obesity, and lean body mass can

forecast aggression in boys to a certain degree. Therefore, focusing efforts on obese children and teenagers who have a lower 2D:4D ratio as a key target group for interventions like attitude changes, social values development, and increasing physical exercise should be considered very crucial. The results of this research could help in needs assessment and planning efforts aimed at reducing aggression in boys as well as determining the need to counsel them with psychologists.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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