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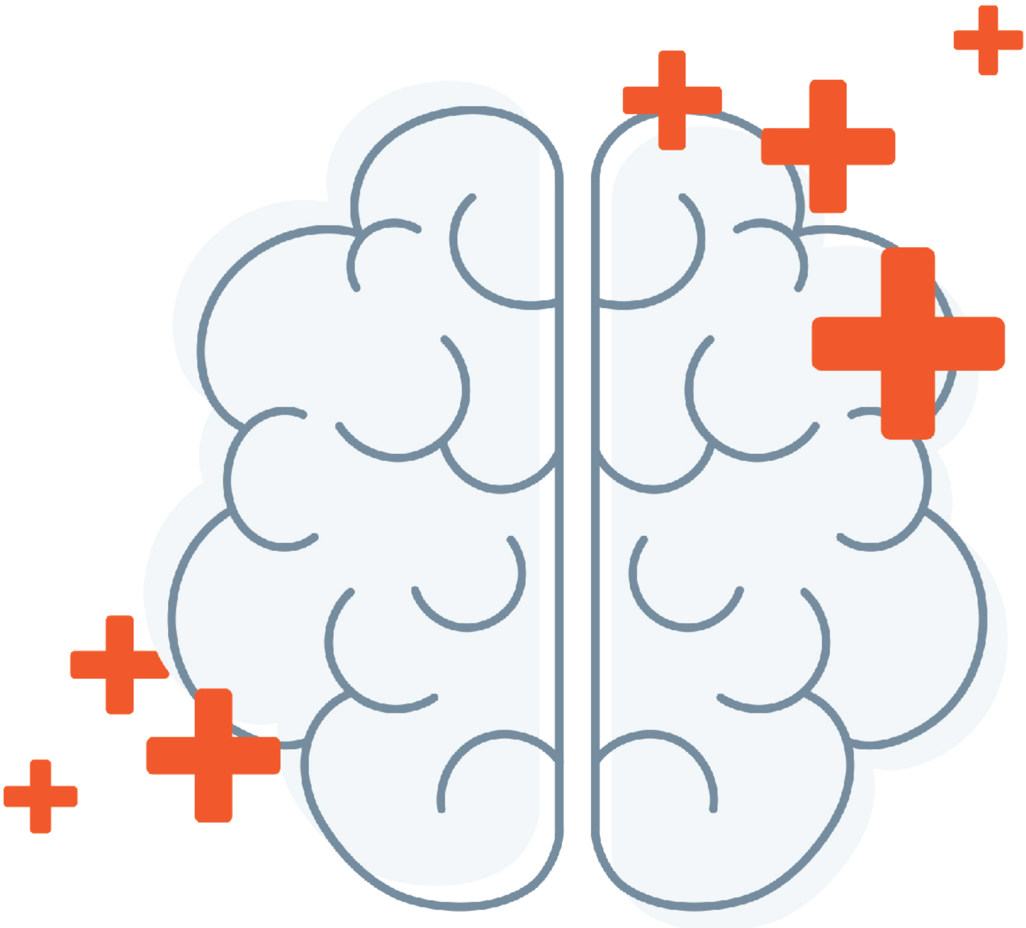

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Two-dimensional analysis of gait parameters on normal and overweight children – an observational study

Dwuwymiarowa analiza parametrów chodu dzieci zdrowych i dzieci z nadwagą – badanie obserwacyjne

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Abstract

Background. Gait analysis is a systematic study of human locomotion that involves evaluating body motions, body mechanics, and muscle activity. Objective. To analyze spatiotemporal and kinematics variables among overweight children and normal children. Methodology. Non-Experimental study, convenient sampling, sample size was 30. Both boys and girls with 12 to 14 years of age were included in the study. Procedure. Participant were selected according to BMI for analyzing the normal and overweight children, based on these two groups were divided. GROUP A – Normal children and GROUP B – Overweight children. Outcome measures. Spatiotemporal and kinematics variables were assessed by using 2D gait analysis with software from Auptimo technologies. Results. Gait analysis of normal children shows significant difference in ankle plantar flexion, knee flexion and hip flexion in lateral view and in anterior view shows knee adduction, in posterior view shows ipsilateral pelvic drop and rear foot eversion at $p < 0.05$. In overweight children shows that ankle dorsiflexion, knee hyperextension, hip extension in lateral view, and in anterior view shows knee adduction and in posterior view shows that contralateral pelvic drop and rear foot eversion. In spatiotemporal parameters of overweight children shows reduced cadence and gait cycle compare to normal children at $p < 0.05$. Conclusion: This study concludes the normal and overweight children shows marked changes in ankle, knee and hip joint, knee abduction/adduction, pelvic drop, rear foot angle and spatiotemporal parameters.

Keywords

lower limb, pelvic drop, rear foot angle, knee adduction/adduction, spatiotemporal, gait analysis, 2-dimensional

Streszczenie

Wprowadzenie. Analiza chodu to systematyczne badanie lokomocji człowieka, które obejmuje ocenę ruchów ciała, mechaniki ciała i aktywności mięśni. Cel. Analiza zmiennych czasoprzestrzennych i kinematycznych wśród dzieci z nadwagą i dzieci zdrowych. Metodologia. Badanie nieeksperymentalne, próba okolicznościowa, wielkość próby wynosiła 30. Do badania włączono zarówno chłopców, jak i dziewczęta w wieku od 12 do 14 lat. Procedura. Uczestników wybrano na podstawie BMI i podzielono na dwie grupy. GRUPA A – Dzieci zdrowe i GRUPA B – Dzieci z nadwagą. Miary wyników. Zmienne czasoprzestrzenne i kinematyczne oceniono za pomocą analizy chodu 2D przy użyciu oprogramowania firmy Auptimo Technologies. Wyniki. Analiza chodu zdrowych dzieci wykazała istotną różnicę w zgięciu podeszwowym, zgięciu stawu kolanowego i biodrowego w widoku bocznym, a w widoku przednim w zakresie przywiedzenia kolana, w widoku tylnym w zakresie opadania miednicy po tej samej stronie i nawracania stopy na poziomie $p < 0,05$. U dzieci z nadwagą zaobserwowano zgięcie grzbietowe w stawie skokowym, przeprost w stawie kolanowym, wyprost w stawie biodrowym w widoku bocznym, w widoku przednim przywiedzenie kolana, a w widoku tylnym opadanie miednicy po stronie przeciwnej i nawracanie stopy. W parametrach czasoprzestrzennych u dzieci z nadwagą wykazano zmniejszone tempo i cykl chodu w porównaniu z dziećmi zdrowymi na poziomie $p < 0,05$. Wniosek: Niniejsze badanie podsumowuje, że dzieci z prawidłową masą ciała i z nadwagą wykazują znaczne zmiany w stawie skokowym, kolanowym i biodrowym, odwodzeniu/przywiedzeniu kolana, opadaniu miednicy, nawracaniu stopy i parametrach czasoprzestrzennych.

Słowa kluczowe

kończyna dolna, opadanie miednicy, nawracanie stopy, przywiedzenie/odwodzenie kolana, parametry czasoprzestrzenne, analiza chodu, 2-wymiarowe

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Introduction

Excess body weight for a certain height is referred to as overweight. Obesity and overweight occur mostly as a result of excessive calorie intake, insufficient physical activity, or both [1]. According to WHO, Overweight is defined as having a BMI for age that is more than one standard deviation higher and obesity is defined as having a BMI for age that is more than two standard deviations higher than the WHO Growth Reference median. Overweight children has become one among the most pressing public health concerns in the 21st century. Over the last three decades, the global prevalence of childhood overweight or obesity has risen dramatically [2]. Based on BMI, the prevalence of overweight and obesity is 18% and 6%, respectively [3]. The BMI of children and adolescents is measured in comparison to other children of the same gender and age. According to the Asian criteria of classification the body mass index cut off for overweight ranges from 23–25 and the pre-obese cut off range from 25–29.9 which also comes under the category of the overweight. The main cause for overweight of an individual as overeating, lack of physical exercise, poor nutrition, poor quality of sleep, sedentary life style and hormonal imbalance etc. According to the CDC, Obesity is defined as being in the 95th percentile or higher, while overweight is defined as being in the 85th to 95th percentile. Because children's BMI varies substantially with age, age-specific cut-off points are necessary. The 85th and 95th percentiles have been chosen as the cutoffs for overweight children [4].

Human locomotion is a sophisticated biomechanical process requiring an intricate interplay between muscular and inertial forces that results in the body moving through space smoothly (Winter, 1980) [5]. Walking is a movement that involves the coordination of the neuromuscular and skeletal systems. Gait analysis is a thorough examination of human movement that includes bodily motions, mechanics, and muscle activity [6]. The GaitON motion analysis programme (Auptimo Technologies LLP, India) [7] allows a clinician to reliably and rapidly diagnose while also allowing detailed observation and control of an intervention/treatment in an objective manner. To establish spatiotemporal gait parameters and kinematics factors, 2-dimensional clinical gait analysis is used. The designed system includes a high-speed video camera, markers, a computer, and technical computing software were used to track markers attached to the human body while it was moving. Obese children's gait features are currently being studied in contrast to children of the same age who are of normal weight.

Because children are in the process of maturing, their gait features will be influenced by their age, particularly in overweight and obese youngsters. However, there are few studies on how overweight and obese children of various ages modify their gait features. Despite the rising prevalence of childhood obesity, few research have looked into gait parameters in overweight children, including spatiotemporal and kinematic factors. Hence, The goal of this research is to look at how normal and overweight children walk.

Materials and methodology

The observational study included data from Tamil Nadu school children between 12–14 years of age. A total 150 children were screened in that 15 normal and 15 overweight children (both boys and girls) from 7th grade to 9th grade of secondary school was incorporated based on inclusion criteria include for normal children BMI less than 85th percentile of age and sex, both boys and girls for overweight children BMI greater than 85–95th percentile of age and sex and both boys and girls. The exclusion criteria include Recent surgeries in lower extremity, Recent fractures in lower extremity, Any severe Cardiovascular illness, Any severe lower limb deformity in this assessment. The research was approved on (5.4.2021) by the Institutional Ethical Committee (Ethical clearance number 2894) of SRM Institute of Science and Technology and obtained permission from school principal. The children were chosen based on the criteria for inclusion and exclusion. The procedure was described to the children/parents/guardians, and their informed consent was acquired. Children were undergone BMI percentile checking, for analyzing the normal and overweight children, based on they were split into two groups. Group A consists of normal children while Group B consists of overweight children. The gait of the subject was captured using a Nikon D3300 camera that captures video at 60 frames per second in 1080p in MPEG-4 format, and the gait analysis was performed using GaitOn Software. GaitOn is a motion analysis programme with a built-in gait reference protocol. This set of reference values is based on J. Perry's model (RLA medical center, California). Children were asked to wear loose clothing or shorts. The following landmarks were marked with colored tapes: in posterior aspects bilateral PSIS, midpoint of calf, midpoint of Achilles tendon, insertion point of Achilles tendon at calcaneum, in lateral aspects greater trochanter, lateral femoral condyle, lateral malleoli on both right and left side of limbs, and one marker in front of the calcaneum in the lateral aspect of the foot. In anterior aspects marker were placed midpoint of patella and 2nd toe of foot on both right and left side of limbs and they were asked to walk in a 5-meter track.

Result

Table 1. Demographic data of normal children

Age	Gender		Height	Weight	BMI
	Boys	Girls			
12	3	2	145	38	17
13	2	1	152	43	18
14	3	4	166	56	22

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Table 1. shows the mean value of height, weight and BMI of 12–14 years of normal children and also gender distribution of boys and girls.

Table 2. shows the mean value of height, weight and BMI of 12–14 years overweight children and also gender distribution of boys and girls.

Table 2. Demographic data of overweight children

Age	Gender		Height	Weight	BMI
	Boys	Girls			
12	4	4	140	43	21
13	2	1	154	56	23
14	4	-	170	70	27

Table 3. Kinematic parameters of ankle joint in normal and overweight children

Kinematic parameter		IC	LR	MS	TS	PS	IS	MS
Reference value		**93 ± 3**	**92.5 ± 2**	**82 ± 4**	**80 ± 4**	**104 ± 5**	**99 ± 5**	**90 ± 3**
Normal children (right)	Mean	96	96.4	93	95.6	100	92	92.8
	SD	20.5	20.7	12.8	17.5	12	9	10.9
	p-value	0.28^{NS}	0.23^{NS}	0.00^{S}	0.00^{S}	0.11^{NS}	0.00^{S}	0.17^{NS}
Normal children (left)	Mean	94	100	94.5	95.5	102	93	91
	SD	21.7	21.7	13.8	19.7	17	12	12.6
	p-value	0.42^{NS}	0.09^{NS}	0.00^{S}	0.00^{S}	0.33^{NS}	0.04^{S}	0.36^{NS}
Overweight children (right)	Mean	85.5	82.8	87.6	88	87.7	86.9	86.5
	SD	27.6	21	19.8	23	24.6	9	14.7
	p-value	0.16^{NS}	0.04^{S}	0.14^{NS}	0.10^{NS}	0.01^{S}	0.00^{S}	0.18^{NS}
Overweight children (left)	Mean	88.5	91.3	87.8	92.7	89.8	88.8	91.3
	SD	25.8	17.9	16.7	12	15.6	17	12
	p-value	0.26^{NS}	0.40^{NS}	0.00^{NS}	0.00^{S}	0.00^{S}	0.01^{S}	0.33^{NS}

Foot note: IC – initial contact, LR – loading response, MS – mid stance, TS – terminal stance, PS – preswing, IS – initial swing, MS – mid swing.
NS – not significant, S – significant

Table 3 shows the value of normal children's kinematic parameters of ankle joint. The mean value of mid stance, terminal stance and initial swing found to be significant on right side.
The mean value of mid stance, terminal stance and initial swing found to be significant < 0.05 on left side.

Table 3 shows the value of overweight children kinematic parameter of ankle joint. The mean value of initial contact, preswing, and initial swing found to be significant on right side.
The mean value of mid stance, terminal stance, pre-swing and initial swing found to be significant < 0.05 on left side.

Table 4. Kinematic parameters of knee joint in normal and overweight children

Kinematic parameter		IC	LR	MS	TS	PS	IS	MS
Reference value		**173 ± 5**	**160.5 ± 4.5**	**172.5 ± 4.5**	**167 ± 4**	**141.5 ± 5.5**	**121 ± 5**	**151.5 ± 5.5**
Normal children (right)	Mean	180	176.9	176.6	172.5	165.5	160.7	171
	SD	9	15	9	30	59	53	29
	p-value	0.00^{S}	0.00^{S}	0.05^{S}	0.24^{NS}	0.07^{NS}	0.00^{S}	0.01^{S}
Normal children (left)	Mean	184.7	186	182.8	181	200.7	199	194.7
	SD	11	13	9	31.7	53.7	46.5	25.7
	p-value	0.00^{S}	0.00^{S}	0.00^{S}	0.05^{S}	0.00^{S}	0.00^{S}	0.00^{S}
Overweight children (right)	Mean	179	180.6	182	183	186.6	187.6	186
	SD	7.8	17	9	33.9	58	51	35.8
	p-value	0.00^{S}	0.00^{S}	0.00^{S}	0.04^{S}	0.04^{S}	0.00^{S}	0.00^{S}
Overweight children (left)	Mean	182	187	185	180	186.9	183.8	182
	SD	13	17.6	12	32.6	56.5	50.7	29.8
	p-value	0.00^{S}	0.00^{S}	0.00^{S}	0.04^{S}	0.00^{S}	0.00^{S}	0.00^{S}

Foot note: IC – initial contact, LR – loading response, MS – mid stance, TS – terminal stance, PS – preswing, IS – initial swing, MS – mid swing.
NS – not significant, S – significant

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Table 4 shows the value of normal children's kinematic parameters of knee joint. The mean value of initial contact, loading response, mid stance, initial swing and mid swing found to be significant < 0.05 on right side.
The mean value of initial contact, loading response, mid stance, terminal stance, preswing, initial swing and mid swing found to be significant < 0.05 on left side.

Table 4 shows the value of overweight children kinematic parameter of knee joint. The mean value of initial contact, loading response, mid Stance, terminal Stance, pre-swing, initial swing and mid swing found to be significant < 0.05 on right side.
The mean value of initial contact, loading response, mid Stance, terminal stance, preswing, initial swing and mid swing found to be Significant < 0.05 on left side.

Table 4. Kinematic parameters of knee joint in normal and overweight children

Kinematic parameter		IC	LR	MS	TS	PS	IS	MS
Reference value		**23.5 ± 3.5**	**22.5 ± 3.5**	**3 ± 3**	**19 ± 4**	**11 ± 4**	**13 ± 4**	**26 ± 4**
Normal children (right)	Mean	27.7	21.5	−5	−12	−9.6	23	25
	SD	5.8	6.8	3.5	7	6	8	7
	p-value	0.00S	0.30NS	0.21NS	0.00S	0.21NS	0.00S	0.29NS
Normal children (left)	Mean	27.4	20	−4.4	−11.9	−11.5	21	25.9
	SD	6	6.8	3	9	8	7.9	8
	p-value	0.01S	0.09NS	0.34NS	0.00S	0.39NS	0.00S	0.48NS
Overweight children (right)	Mean	26.5	20.7	−4	−9.5	−11	21.5	27
	SD	5	6	5.6	5.5	5.7	5	4.6
	p-value	0.11NS	0.15NS	0.20NS	0.00S	0.42NS	0.00S	0.20NS
Overweight children (left)	Mean	23	18.5	−4.5	−11	−8	18	18.9
	SD	7	8.6	3.6	4.8	5	5.6	7
	p-value	0.44NS	0.04S	0.06NS	0.00S	0.08NS	0.00S	0.00S

Foot note: IC – initial contact, LR – loading response, MS – mid stance, TS – terminal stance, PS – preswing, IS – initial swing, MS – mid swing.
NS – not significant, S – significant

Table 5 shows the value of normal children's kinematic parameters of hip joint. The mean value of initial contact, terminal stance and initial swing found to be significant < 0.05 on right side.
The mean value of initial contact, terminal stance and initial swing found to be significant < 0.05 on left side.

Table 5 shows the value of overweight children kinematic parameter of hip joint. The mean value of terminal stance, and initial swing found to be significant < 0.05 on right side.
The mean value of loading response, terminal stance, initial swing and mid swing found to be significant < 0.05 on left side.

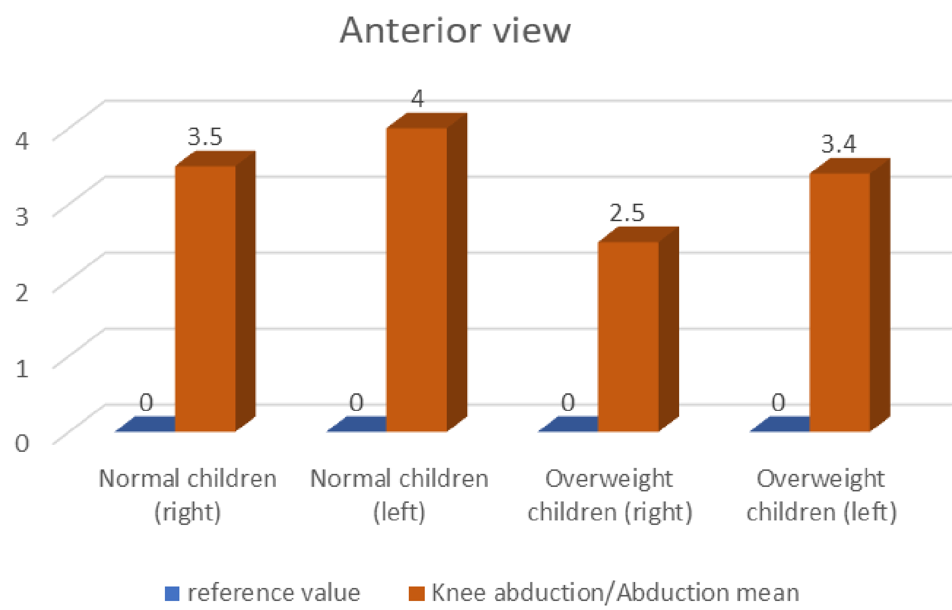

Figure 1. Kinematic parameters of anterior view in normal and overweight children

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Figure 1 shows the value of anterior view of kinematic parameter of knee abduction and adduction in normal and overweight children found to be significant < 0.05 in both right and left side.
Figure 2 shows the value of posterior view of kinematic parameter. The mean value of pelvic drop on right side of normal children found to be significant < 0.05.
The mean value of rear foot angle on right side of normal and overweight children found to be significant < 0.05.

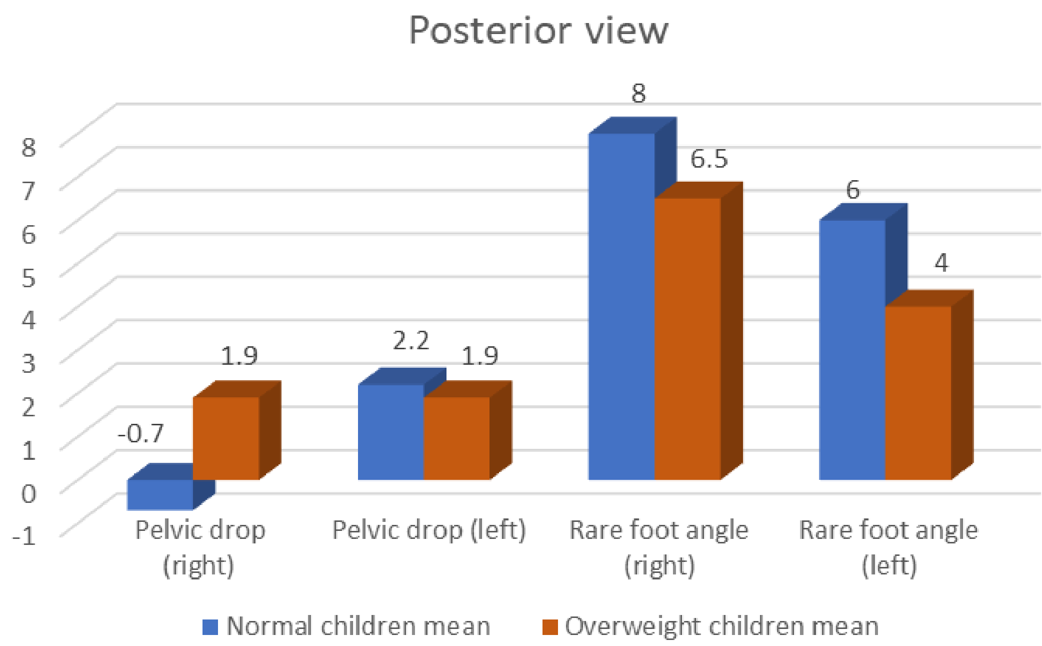

Figure 2. Spatiotemporal parameters of normal and overweight children – cadence

Figure 3 shows the value of spatiotemporal parameters of normal an overweight children. The mean value of cadence shows significant difference < 0.05 in normal and overweight children but overweight children shows decreased cadence compare to normal weight children.

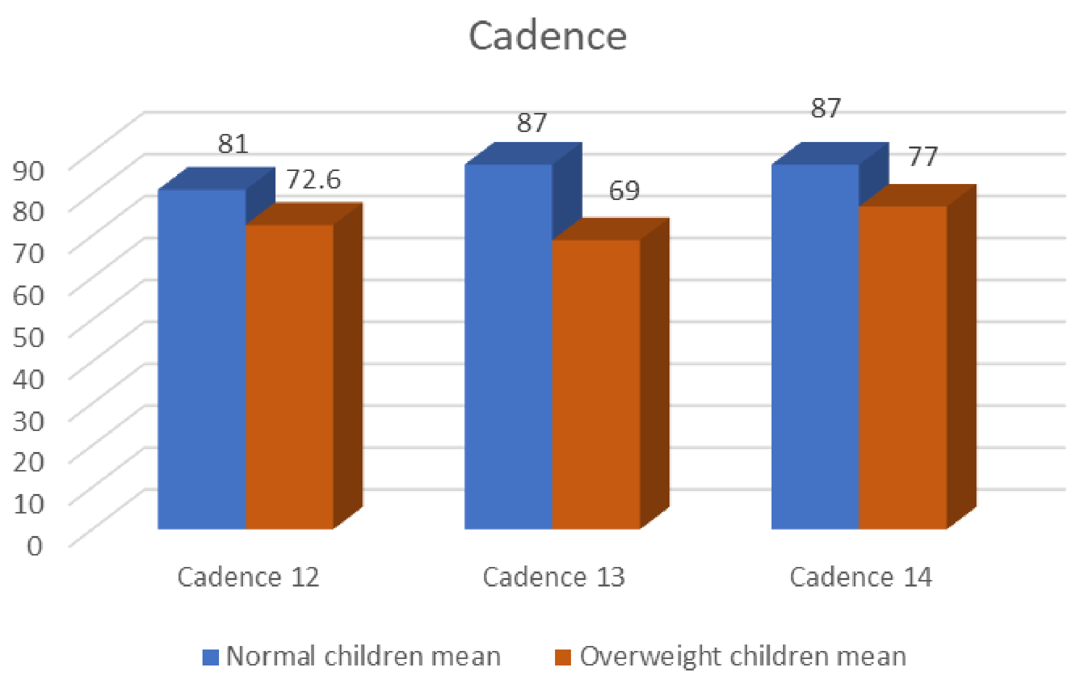

Figure 3. Kinematic parameters of anterior view in normal and overweight children

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Figure 4 shows the value of spatiotemporal parameters of normal and overweight children. The mean value of right and left single limb support, double limb support, right and left stance and swing phase, gait cycle found to be significant difference < 0.05 but gait cycle duration is increased compare to normal weight children.

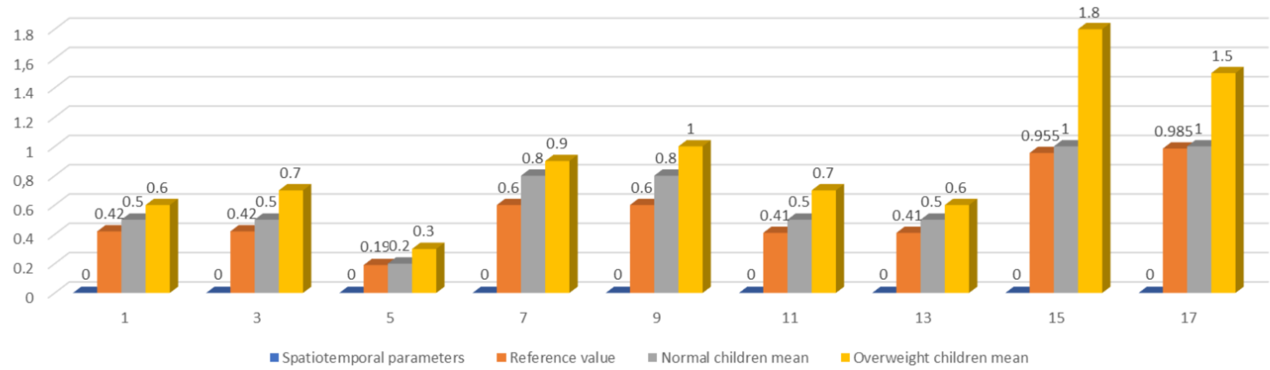

Figure 4. Spatiotemporal parameters of normal and overweight children

Discussion

The purpose of this study is to analyze spatiotemporal and kinematics variables among overweight children and normal children. The findings of this study were related to gait kinematic analysis and spatiotemporal factors in normal and overweight children aged 12 to 14.

Kinematic analysis of ankle joint

Comparing with the reference value, the results shows that 2D analysis of ankle joint kinematic variables of normal children reveal that increased plantar flexion motion in midstance, terminal stance and initial swing in both right and left side due to overaction of plantar flexors. In overweight children, on right side it shows that increase dorsiflexion motion in initial contact, preswing and initial swing. On left side increase dorsiflexion motion occurs in terminal stance, pre-swing and initial swing due to inactivation of plantar flexors.

McMillan et al. (2010) reported that obese and overweight adults have less plantarflexion motion in late stance, which they assume is due to relative plantar flexor muscle weakness, as these muscles contribute to ankle joint moments in the sagittal plane [8].

Kinematic analysis of knee joint

Comparing with the reference value, the results shows that 2D analysis of knee joint kinematic variables of normal children reveals that hyperextension occurs at left side initial contact, loading response, midstance, terminal stance and pre-swing. In overweight children both right and left side shows increased hyperextension during stance phase of gait.

McMillan et al., 2010, In obese and overweight children observed alterations in the knee joint during walking, including reduced knee flexion amplitude due to possible knee extensor weakness [8].

Kinematic analysis of hip joint

Comparing with the reference value, the results shows that 2D analysis of hip joint kinematic variables of normal children reveals that increased hip flexion occurs at initial contact and initial swing in both right and left side and increased hip extension shows in terminal stance in both right and left side. In overweight children increased hip flexion occurs at right side initial swing and left side loading response, initial swing and mid swing. Increased hip extension seen in terminal stance in both right and left.

Fabina et al. 2018. In the sagittal plane, overweight subjects demonstrated changes in hip freedom. According to visual inspections between groups, hip flexion was minimized at heel strike and mid swing stride phases, as well as hip extension during push off [9].

According to Fabina et al. (2018), during the push-off phase, hip joint (lower) extension was noted, and this disparity was linked to decreased plantar flexor muscular endurance. As a result, muscle weakness may clarify whether obese people have reduced plantarflexion and hip extension during push-off [9].

McMillan et al. 2010 observed reduced hip flexion has been linked to a compensatory technique for probable hip extensor muscle weakening [8].

Kinematic analysis of anterior view

Comparing with the reference value, the results shows that 2D analysis of knee abduction/adduction (frontal plane) kinematic variables reveals that both normal and overweight children has a significant difference in knee abduction/adduction movement.

Gushue et al, presumed that the Overweight children during stance phase maintained knee adduction (varus), necessitating knee abduction phases to maintain balance [10].

Kinematic analysis of posterior view

Comparing with the reference value, the results shows that 2D analysis of rear foot angle kinematic in normal and overweight children revelas that significant difference in rear foot angle (eversion). pelvic drop kinematic analysis in normal and overweight children shows that contralateral pelvic drop during mid stance.

McMillan et al. 2010 suggested that overweight subjects have more rearfoot eversion during gait, based on clinical observations of midfoot pronation during static posture. Throughout the stance, overweight children kept their backfoot inverted. During initial contact and push-off, when ankle stability was in its lowest, this increase is likely to impose additional load on the peroneal muscles. However, there was more rear foot eversion during mid-stance [8].

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Spatio-temporal parameters

Comparing with the reference value, the results shows that 2D analysis of Spatiotemporal parameters of normal children reveals that significant reduced in cadence, gait cycle, single and double limb support, stance and swing duration but in compare to overweight children cadence and gait cycle was increased in normal children. In overweight children shows that significant reduce in cadence and gait cycle but increase in stance phase than swing and single and double limb support.

Stephen David cousins 2014 observed that children of normal weight, they spend much more time in double-support. Other temporal differences included longer cycle time, lower cadence, lower relative velocity, and broader stride width. These findings were the first to demonstrate that obese children walk slower, safer, and more tentatively than children of normal weight. Obese children's altered temporal-spatial characteristics may reflect a locomotor approach to preserve midline balance during stride, suggesting that the gait pattern of obese children is altered to make up for the enhanced insecurity [11].

The authors advised that overweight children be examined and treated early for improved gait and lower foot pressure to reduce the chance of developing musculoskeletal diseases connected to excess body mass [12].

Conclusion

This 2D analysis provide normative value of gait parameters that compare with the normal and overweight children gait. This study finding concluded that the mean value of normal and overweight children shows marked changes in ankle joint (normal children show plantarflexion, overweight children show dorsiflexion during gait), in knee joint (normal children shows knee flexion, overweight children show knee hyperextension during gait), in hip joint (normal children shows flexion, overweight children shows hip extension), in anterior view knee abduction and adduction shows notable changes seen in both normal and overweight, in posterior view marked changes shows on right side ipsilateral pelvic drop in normal children and contralateral pelvic drop seen in overweight children. In spatiotemporal parameter apparent changes shows in overweight children cadence and gait cycle than normal children. There will always be some limitation in this study they are Small sample size, Limited age 12–14 years was analyzed, Due to covid many parents were denied to participate in the study, This 2D analyses didn't find rotational movements of lower extremity and the future study include Study can be done with large sample size, all school going children (underweight, normal, overweight, obesity), Forthcoming studies can be done with backpack, Long term studies can be concentrate on intervention program for biomechanical deviation in ambulation along with gait analysis.

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