Gait Parameters in Children with Different Weight Abnormalities

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Abstract: The purpose of this study was to evaluate the effect of different categories of weight abnormalities on gait parameters in children. Two hundred children of both sexes (100 boys and 100 girls) divided into four groups of equal number, fifty children in each group (fifty obese, fifty overweight, fifty underweight and fifty normal weight children), their ages ranged from twelve to fourteen years old, and recruited from outpatient clinic of National Nutrition Institute. Gait parameters were evaluated by using the Biodex gait trainer treadmill and compared with gait parameters of normal weight children. The results of this study revealed statistically significant differences in the measured variables between four groups. In conclusion, the obese children walked little distance with significantly slower gait speed by taking shorter steps with decrease in average step cycle than the other subjects when compared to normal weight children. While the results of the underweight children were better than the other groups but still less than the normal weight group.

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1. Introduction

Healthy weight is a part of overall good health. Someone in good healthy weight feels well, usually thinks clearly and has energy. Another one who weighs too little or too much often lacks energy and tires easily. Healthy weight actually is a range that's statistically related to good health. Being above or below that range increases the risk of health problems, or decreases the likedhood of good health [1].

The adverse effects of overweight and obesity on health are well established and serious. Overweight and obesity increase the risk of many serious health conditions that involve most systems of the body. Even in the absence of complications and comorbidities, obesity increases the risk of early mortality. In addition to medical complications, obesity is associated with psychological and social problems that may overshadow the medical problems in the quality of life for many obese people [2].

Overweight and obesity are associated with major mobility problems and a range of musculoskeletal pain that reduce quality of life. Thus mobility problems appear to be most common in women and increase with age [3].

People who are underweight have too little body fat, or less than 12% body fat in adult female and 5% body fat in males. World Wide, underweight due to inadequate diets is much more common than obesity and more life-threatening [4].

Gait is the manner in which we transfer or move our bodies across the surface of our environment. It is the way we travel using the body's own means [5]. Gait is a complex activity. It requires control system, an energy source, levers providing movement and forces to move the levers. The normal gait consists of an alternating rhythmical swinging forward of the leg and foot strike that involves almost all the joint and muscle of the human body. The cycle of each step can be divided into a swing phase (39%) and a stance phase (61%) [6].

The normal gait cycle is broken down into stance phase (40 % in the initial and terminal, 10 % of stance both feet are in contact with the ground (double support), whereas during the middle 40 % single-limb stance occurs (single support).Stance phase accomplished the functions of load acceptance, joint segment, length modulation, forward progression of the body over a stable plantigarde foot, and propulsion of the limb into swing phase. It allows for the advancement of the limb forward, while maintaining clearance of the foot in the face of gravity. The phases of the gait cycle have been further divided into loading response, midstance, terminal stance, pre swing and initial swing, mid swing and terminal swing [7].

Each limb blends the patterns of motion, passive force, and muscular control into a sequence of activity (called a gait cycle or astride), which is repeated endlessly until the desired destination is reached. The two limbs perform in reciprocal manner, offset by 50% of the gait cycle. The head, neck, trunk, and the pelvis are self-contained passengers on the limb's locomotor system [8].

One possible reason for deficient performance during aerobic tasks is the greater metabolic cost of locomotion in physiologic term, obese children require a higher Oxygen uptake to perform submaximal task, such as walking or running [9].

Loss of lean body mass is associated with greater compromise in physical functioning. Women who lost at least 2.5 kg of lean mass had slower walking velocity, loss muscle strength and more time double support [10].

Obese individuals experience increased loading on major joints but also, increased energy expenditure for the same movement task when compared with lighter counterparts [11]. Excess weight reduces the mechanical effectiveness of gait because of the shorter amplitude of movements, discomfort, early fatigue [12].

The major joints of the lower extremity are exposed to considerable loads during normal locomotion; the persistent loading of the musculoskeletal system during walking has been implicated in the predisposition to a range of orthopedic conditions that include knee osteoarthritis. It may be reasonable to hyposis that obese individuals may experience greater loads at these joints than normal individuals, particularly when attempting to move at speeds that vary from the normal [13].

Increased weight of lower extremities result in requirement for increased propulsive forces during gait. This constitutes an extra challenge for locomotor system of obese subjects[14].

If an object in motion is seen (a man walking) it is obvious that it is moving because a force has acted on it. It is well known, that the force must be significantly greater to overcome the object inertia, such inertia is definitely larger in obese individuals, so the acting force must be adequately higher in obese individuals [15].

Excessive amount of adipose tissue increases energy output due to increased body inertia making locomotion of obese less efficient [16]. For an obese individual, the difficulties associated with increasing age, along with the lack of regular physical activity, are capable of making the gait dysfunctions even more severe[17].

Obese subjects have greater sagittal knee moments than normal weight subjects and slower walking in obese reduces ground reaction forces and net muscle moments and may be a risk lowering strategy for obese adults who wish to walk for exercise [18].

Statement of the problem. Can weight abnormalities affect gait parameters in children?

Purpose of the study

To investigate the effect of different categories of weight abnormalities on gait parameters in children.

2.Subjects, Materials And Procedures

This study was conducted at isokintec lab at the Faculty of Physical Therapy, Cairo University to evaluate gait parameters in children with different weight abnormalities. Written informed consent from all participant families was sort prior to their enrolment into the study.

I) Subjects

Two hundred children from both sexes (100males, 100females) participated in this study. Children were assigned randomly into four groups of equal number according to BMI, fifty children in each group (fifty obese, fifty overweight, fifty underweight and fifty normal weight children). They were recruited from National Nutrition Institute according to the following criteria:

Inclusion criteria:

1-Their ages were ranged from 12 to 14 years.
2-They had no visual or auditory problems.
3-They were able to understand order and follow commands given to them.
4-All children were selected according to (BMI-for-age) Z score growth chart for boys and girls which indicate, obese child >+2SD,over weight child>+1SD,under weight child > -2SD.
5-Parent of each child signed an informed consent form before the children participated in the evaluation.

Exclusion criteria

1-Children with orthopedic or neurological problems affecting gait.
2- Children with visual and auditory problems.
3-Children who suffer from any uncontrolled conditions (pulmonary diseases, cardiovascular diseases).

II) Materials

Materials for this study included the following:

Material for child selection.

Materials for evaluation.

1) Materials for child selection

A. weight and height scale

A valid and reliable weight and height scale was used to measure each child's weight and height to calculate BMI.

B.BMI-for-age Z score

New growth charts from World health organization (WHO) include an age and sex-specific BMI reference for children aged 2-20 y [19] (WHO, 2007). At a BMI-for-age that falls in the range from (+1SD to + 2SD) Z score youths may be classified as over weight. > +2SD are obese. Range from (-2SD to -3 SD) Z score youth may be classified as underweight [20] (Kuezmarski and Flegal, 2000).

2) Materials for evaluation

Biodex gait trainer 2 treadmill:

The biodex gait trainer 2 designed specifically for assessment, rehabilitation and retraining of gait for all patients. In the assessment mode, the therapist is able to print out objective measurements about various components of the gait pattern.

Children were evaluated by asking them to walk at biodex gait trainer treadmill for six minute. Gait parameters measured included the following; total distance (m), Average walking speed (meter/sec), Average step cycle (cycle/sec), Average step length Rt/Lt) (meter/sec) and Time of each foot contact Rt/Lt (%).

This study was limited by the following factors: Small sample size.

Co-operation of the child and their relatives may affect the results of the measurements.

3.RESULTS

The collected data of this study showed the statistical analysis of gait parameters in children with different categories of weight abnormalities.

General characteristics of the subjects:

In this study, 200childern (100boys and 100girls) were assigned into to 4 groups with 50 subjects in each group.

Group (A):

Fifty obese subjects were included in this group. The mean age was (13.06±0.84) years, the mean values of their weight was (75.32±17.46) kilograms, the mean values of their height was (152.72±9.56) centimeters, and the mean values of their BMI was (32.14±5.64) Kg/cm2 as shown in table (1).

Group (B):

Fifty overweight subjects were included in this group. The mean age was (13.18±0.83) years, the mean values of their weight was (52.86±8.05) kilograms, the mean values of their height was (151.31±9.06) centimeters, and the mean values of their BMI was (22.87±1.34) Kg/cm2 as shown in table (1).

Group (C):

Fifty normal weight subjects were included in this group. The mean age was (13.04±0.83) years, the mean values of their weight was (40.85±7.14) kilograms, the mean values of their height was (149.62±8.89) centimeters, and the mean values of their BMI was (18.13±1.68) Kg/cm2 as shown in table (1).

Group (D):

Fifty underweight subjects were included in this group. The mean age was (13.05±0.87) years, the mean values of their weight was (32.48±5.11) kilograms, the mean values of their height was (148.59±9.77) centimeters, and the mean values of their BMI was (14.6±0.58) Kg/cm2 as shown in table (1).

As shown in table (1), there was no significant difference between the 4 groups in their ages, and heights where *P*-value was>0.0001. While There was a significant difference between the 4 groups in their weights, and BMI where their *P*-values was<0.0001

Table (1): Mean and standard deviation of the age, weight, height, and BMI of the four groups.

Items	Group A		Group B		Group C		Group D		comparison	
	Obese		Overweight		Normal		Underweight			
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	P-value	S
Age (yrs)	13.06	± 0.84	13.18	±0.83	13.04	±0.83	13.05	±0.87	0.83	NS
Weight (Kg)	75.32	± 17.46	52.86	±8.05	40.85	±7.14	32.48	±5.11	0.0001	S
Height (cm)	152.72	± 9.56	151.31	±9.06	149.62	±8.89	148.59	±9.77	0.12	NS
BMI (Kg/m^2)	32.14	±5.64	22.87	±1.34	18.13	±1.68	14.6	±0.58	0.0001	S

*SD: standard deviation, P: probability, S: significance, NS: non-significant

Sex distribution among the four groups:

The data in table (2) represented the number and percentage of males and females of the four groups. In Obese the number of males was 24 with a percent of 48% and the numbers of females was 26 with a percent of 52%. In Overweight the number of males was 25 with a percent of 50% and the numbers of females was 25 with a percent of 50%. In Normal the number of males was 26with a percent of 52% and the numbers of females was 24 with a percent of 48%. In Underweight the number of males was 24 with a percent of 48% and the numbers of females was 26 with a percent of 52%.

Table (2): The number and percentage of males and females of the four groups.

Sex	Obese		Overweight		Normal		Underweight	
	NO	%	NO	%	NO	%	NO	%
Males	24	48%	25	50%	26	52%	24	48%
Females	26	52%	25	50%	24	48%	26	52%

Gait parameters

1) Distance:

Mean values of distance parameter for four groups.

ANOVA test was used to compare mean values of distance parameter for four groups.

As shown in tables (3, 4), the results revealed significant difference among four groups on *P* value was (0.0001).

Table(3):ANOVA test of distance parameter mean values for four groups

Distance	SS	MS	*P* value	S
Between Groups	922431.735	307477.245		
Within Groups	204390.140	1042.807	0.0001	S
Total	1126821.875			

ss: Sum of Square, MS: Mean Square, P: probability, S: significance, S: Significant

Table (4): Post hoc test among the four groups for distance.

Distance	Mean difference	*P* value	S
Normal vs. Obese	187.62	0.0001	S
Normal vs. Overweight	79.26	0.0001	S
Normal vs. Underweight	58.26	0.0001	S
Obese vs. Overweight	108.36	0.0001	S
Obese vs. Underweight	129.36	0.0001	S
Overweight vs. Underweight	21.0	0.0001	S

2) Average walking speed:

Comparison between the four groups:

ANOVA test was used to compare mean values of average walking speed for four groups.

As shown in tables (5, 6) the results revealed significant difference among four groups on *P* value was (0.0001).

Table (5): ANOVA test of average walking speed parameter mean values for four groups.

Average walking speed	SS	MS	*P* value	S
Between Groups	10.801	3.600		
Within Groups	2.721	0.014	0.0001	S
Total	13.522			

ss: Sum of Square, MS: Mean Square, P: probability, S: significance, S: Significant.

Table (6): Post hoc test among the four groups for average walking speed.

Average walking speed	Mean difference	*P* value	S
Normal vs. Obese	0.65	0.0001	S
Normal vs. Overweight	0.37	0.0001	S
Normal vs. Underweight	0.31	0.0001	S
Obese vs. Overweight	0.28	0.0001	S
Obese vs. Underweight	0.33	0.0001	S
Overweight vs. Underweight	0.05	0.02	S

3) Average step cycle:

Mean values of average step cycle parameter for four groups.

ANOVA test was used to compare mean values of average step cycle for four groups.

As shown in tables (7, 8), the results revealed signification difference among four groups on *P* value was (0.0001).

Table (7): ANOVA test of average step cycle parameter mean values for four groups.

Average step cycle	SS	MS	*P* value	S
Between Groups	4.689	1.563		
Within Groups	3.457	0.018	0.0001	S
Total	8.146			

*SS: Sum of Square, MS: Mean Square, P: probability, S: significance, S: Significant.

Table (8): Post hoc test among the four groups for average step cycle.

Average step cycle	Mean difference	*P* value	S
Normal vs. Obese	0.4	0.0001	S
Normal vs. Overweight	0.32	0.0001	S
Normal vs. Underweight	0.26	0.0001	S
Obese vs. Overweight	0.08	0.002	S
Obese vs. Underweight	0.14	0.0001	S
Overweight vs. Underweight	0.05	0.03	S

4) Average step length

Mean value of average step length parameter for four groups:

ANOVA test was used to compare mean values of average step length parameter for four groups.

As shown in tables (9, 10, 11), the results revealed significant difference among four groups on *P* value was (0.0001).

Table (9): ANOVA test of average step length parameter mean value for four groups.

Average step length		SS	MS	*P* value	S
Right Leg	Between Groups	0.585	0.195		
	Within Groups	0.977	0.005	0.0001	S
	Total	1.562			
Left Leg	Between Groups	0.698	0.233		
	Within Groups	1.146	0.006	0.0001	S
	Total	1.844			

*SS: Sum of Square, MS: Mean Square, P: probability, S: significance, S: Significant.

Table (10): Post hoc test among the four groups for average step length of right leg.

Average step length of right leg	Mean difference	*P* value	S
Normal vs. Obese	0.14	0.0001	S
Normal vs. Overweight	0.1	0.0001	S
Normal vs. Underweight	0.07	0.0001	S
Obese vs. Overweight	0.03	0.007	S
Obese vs. Underweight	0.06	0.0001	S
Overweight vs. Underweight	0.02	0.03	S

Table (11): Post hoc test among the four groups for average step length of left leg.

___Average step length of left leg	Mean difference	*P* value	S
Normal vs. Obese	0.16	0.0001	S
Normal vs. Overweight	0.1	0.0001	S
Normal vs. Underweight	0.07	0.0001	S
Obese vs. Overweight	0.05	0.0001	S
Obese vs. Underweight	0.08	0.0001	S
Overweight vs. Underweight	0.03	0.02	S

Table (12): ANOVA test of time of each foot contact parameter mean values for four groups.

Time of foot contact		SS	MS	*P* value	S
Right Foot	Between Groups	1.215	0.405		
	Within Groups	1038.66	5.299	0.97	NS
	Total	1039.875			
Left Foot	Between Groups	10.340	3.447		
	Within Groups	1035.16	5.281	0.58	NS
	Total	1045.5			

*SS: Sum of Square, MS: Mean Square, P: probability, S: significance S: Significant.

5) Time of foot contact:

Mean values of time of each foot contact parameter for four groups:

ANOVA test was used to compare mean values of time of each foot contact for four groups.

As shown in table (12), the results revealed no significant difference among four groups on *P* value was (0.97, 0.58).

4. Discussion

The goal of the study was to provide a base line data of gait parameters of children with different weight abnormalities. Such information may provide a clear understanding of the movement-related difficulties of such children and provide insight to the differences displayed by obese, overweight and underweight children versus normal weight children. The evaluation of gait may also provide an indication of potential problems with the persistence of these weight abnormalities.

All weight abnormalities result from energy imbalance. Obese and overweight children have consumed more food energy than they have expended and have banked the surplus in their body fat. To reduce body fat, obese and overweight children need to expend more energy than they take in from food. In contrast, underweight children have consumed too little food energy to support their activities and so have depleted their bodies' fat stores and possibly some of their lean tissues as well. To gain weight, they need to take in more food energy than they expend [21].

Increased body fatness in obese and overweight children has a negative influence on children's physical performance that there is inverse relationship between body fat and the ability to move total body weight. This is due to the fact that body fats adds to the mass of the body without making a contribution to force generating capacity, subsequently becoming addition weight to be moved during tasks like walking and running [22].

Underweight children adapt to energy storage by decreasing body mass and energy expenditure related to activity. Body energy stores are diminished, basal metabolic rate (BMR) and resting metabolic rate (RMR) are diminished so. Physical activity and motor performance are reduced [23].

The gait parameters evaluated through using Biodex gait trainer treadmill were total distance, average walking speed reported in Meters/Seconds, average step cycle reported in Cycle/Seconds, average step length and time of each foot contact.

The mean age of the obese children equal (13.06 ± 0.84) years, for overweight children equal (13.18±0.83) years, for underweight children equal (13.05± 0.87) years and for normal weight children equal (13.05± 0.87) years which revealed non significant difference.

This comes in agreement with the finding of Gech and Marti (2005) [24]who reported that between the ages of seven to ten years as the child grows, body structure changes, increases in strength, neurologic maturation and walking experience all likely play a part in improvement of stability and decrease the base of support, dynamic balance and strength have also increased. So the age of children representing in the sample of this study ranged from twelve to fourteen years to make a good use of this feature during the application of the evaluation procedures, also, their mentality was more suitable for the requirements of the evaluation program.

Total distance

There was a decrease in the total distance that the obese and overweight children walked when comparing with distance that normal weight child walked and this may lead to the presence of a significant difference between normal and obese children as the mean difference value was (187.62) and *P* value was (0.0001) and the presence of a significant difference between normal and overweight children as the mean difference value was (79.26) and *P* value was (0.0001).

This decrease in the total distance that the obese and overweight children walked may be attributed to the greater metabolic cost of locomotion as a result of the heavier legs of obese and overweight children, they walked with greater step width and have greater lateral leg swing (hip circumduction).

This is supported by the idea of Peyrot *et al.,* (2009) [25]who suggested that the net metabolic cost of walking normalized by body mass is greater in obese and overweight subjects than in normal weight subjects. He hypothesized that in obese and overweight subjects, greater mediolateral center of mass (COM) displacement and lower recovery of mechanical energy could induce an increase in the external mechanical work required to lift and accelerate the (COM) and thus the net metabolic cost of walking.

This finding comes in agreement with Browning and Kram (2007) [26]who reported that net metabolic rate was positively related to percent body fat, in addition to the extra load, biomechanical changes in walking pattern could be responsible for a greater net metabolic rate. For instance, greater step width has been reported in obese and overweight subjects due to an excessive amounts of adipose tissue in the lower limbs, hence a larger thigh circumference, greater step width is associated with other differences in walking kinematics such as greater leg swing circumduction and has been shown to increase net metabolic cost.

Overweight and obese children have increase in oxygen consumption and energy expenditure as a result of greater body mass which lead to decrease distance of walking. This is supported by the finding of Hills and Parker (1993) [27] who mentioned that it requires more energy to move a larger body mass, energy expended in physical activity during weight bearing increased with increasing body mass, oxygen consumption increases more rapidly in obese than lean children. RowLand (2004) [28] suggested that obese children require higher oxygen up take to perform submaximal tasks such as walking or running, the high cost of locomotion may reflect a wasteful walking style.

In addition Kang (2008) [29] reported that energy cost during walking can also be affected by factors such as body mass, body mass distribution and load carriage as walking. Walking and running are activities in which the body mass is supported by the lower extremities it follows that the greater body mass of the person the greater the energy cost incurred. As the mass of the limbs can be considered inertia that muscles must overcome, the greater the inertia the greater the muscle effort necessary to move limbs.

This comes in agreement with the finding of Spyropouloes *et al.,* (1991) [12] who tested the biomechanics of gait for obese and overweight subjects compared to normal weight subjects and found that obese and overweight subject walked shorter distance than normal weight subjects.

There was a decrease in the total distance that underweight children walked when comparing with total distance that normal children walked and this may lead to the presence of a significant difference between normal and underweight children as the mean difference value was (58.26) and *P* value was (0.0001).this is may attributed to decreased energy expenditure during walking, low level of physical activity, exhaustion and muscle weakness.

This is supported by the opinion of Fugate *et al.,* (2005) [31] who suggested that underweight subjects have a reduction in muscle and body tissue mass as a result of decrease energy storage which leads to decrease energy expenditure related to activity, altered metabolic and physiologic functions which have adverse effect on health lead to muscle wasting, weakness and decrease mobility.

This comes in agreement with the finding of Sonila (2010) [39] who tested the effect of BMI in gait biomechanics in children and found that underweight children walked shorter distance than do normal weight children.

There was a decrease in total distance that obese children walked when compared with total distance that overweight and underweight children walked. This may lead to the presence of a significant difference between obese and overweight children as the mean difference value was (108.36) and p value was (0.0001) and also lead to the presence of a significant difference between obese and underweight and the mean difference value was (129.36) and *P* value was(0.0001).also there was a decrease in total distance that overweight children walked when compared with total distance that underweight children walked which lead to the presence of a significant difference between them as mean difference was(21.0) and *P* value was (0.0001).

This is may be due to the difference amount of body fat between all groups which affecting their physical performance that obese children have the large amount of body fat so they walked shorter distance than overweight and underweight children. Overweight children have more fat than underweight children so they walked shorter distance than them.

This come in agreement with the finding of Hills and Parker (1991) [22] who reported that the greater the body fat the decreased ability to move total body weight. The shorter the distance that body travel.

Average walking speed

There was a decrease in average walking speed for obese and overweight children when comparing with average walking speed of normal weight children and this may lead to the presence of a significant difference between normal and obese children as the mean difference value was (0.65) and P value was (0.0001) and the presence of a significant difference between normal and overweight children as the mean difference value was (0.37) and *P* value was (0.0001). This decrease in speed may attributed to the greater ground reaction force (GRF) for obese and overweight children as a result of increased loads on the lower extremity and the child attempt to overcome it by decreasing walking speed.

This is supported by the idea of Leveau and Bernhardt (1984) [33] who suggested that during normal walking the major joints of the lower extremity are exposed to considerable loads with joint reaction forces of approximately three to five times body weight, when participating in movement tasks such as walking or running, it involves joint reaction forces at the higher end of this range and beyond. Based on Newton's Laws of Motion it would appear reasonable to hypothesize that obese and overweight children will experience greater loads on their lower extremities than normal weight children and these loads increase with walking speeds.

In addition Browning and Kram (2007) [26] reported that at each walking speed, peak vertical ground reaction force values were approximately 60% greater for obese and overweight subjects versus normal weight subjects. Greater sagittal-plane knee joint moments in the obese and overweight subjects also suggest that they walked with greater knee joint loads than normal weight subjects. Walking slower reduced GRF and net muscle moments.

The slow speed of walking for obese and overweight children may be also related to reduce confidence of movement, increase need for safer, steady walking and increase need for stabilization. This is supported by the idea of De Souza *et al.,* (2005) [34] who suggested that the increased need for stabilization is the result of a wider contact angle of the heel with the floor as a consequence of obesity overloading the lower limbs, as the body fights to keep upright by separating the knees and ankles, in order to achieve a lower center of gravity and more anterior-posterior and lateral stability. This pattern is consistent with slow body movements, poor fitness and easy fatigability of overweight and obese individuals along with a large and unstable body mass requiring a wider base of support.

This is supported by the opinion of Hogan (1998) [35] who suggested that flatfoot and subtalar pronation contribute to a considerable degree of out-toeing, particularly during the swing phase of walking. Greater motion at joints of the body generally requires increased muscle activity and decreased walking speed to maintain joint stability, the lower speed of walking may be a means of minimizing any threats of instability.

This comes in agreement with the findings of Browning and Kram (2007) [26] who studied the effect of obesity on the biomechanics of walking. Twenty subjects (10 obese and 10 normal weights) were tested as they walked on a level force measuring treadmill. Results showed that they walked with slow speed than normal weight subjects.

It also comes in agreement the findings of Hills and Parker (1991) [22] where 10 overweight/obese and 4 non obese children were tested and found that a number of temporal characteristics have been found to differ between overweight/obese and non obese children. In this study, the obese showed slower speed of walking as represented by longer cycle duration and lower relative velocity. These results confirm the commonly held subjective view of a slower, safer and more tentative walking gait in obese and overweight children relative to normal weight children.

There was a decrease in average walking speed for underweight children when comparing with average walking speed of normal children. This is may be attributed to that underweight children trying to safe energy by decreasing energy expenditure and energy cost to cope with decreasing energy intake.

This is supported by the idea of Whittle (1999) [36] who reported that an increase in walking speed requires a corresponding increase in energy expenditure. And this is supported also by Muller *et al.,* (2002) [37] who reported that underweight subjects prefer a walking speed that approximately minimizes the energy cost per distance.

The results of this study revealed that there was a significant difference between normal and underweight children as the mean difference value was (0.31) and *P* value was (0.0001) which lead to walking speed decreased in underweight children than normal weight children as a result of increased need for stabilization. This is supported by the idea of Damiano *et al.,* (2000) [38] who reported that balance may be reduced in underweight children due to muscle weakness and low level of physical activity.

This comes in agreement with the finding of Sonila (2010) [39]who tested gait parameters of underweight children in relation to normal weight children and found that underweight children was inferior to normal weight children as they walked with slow speed.

There was a decrease in average walking speed that obese children walked when compared with average walking speed that overweight and underweight children walked. This may lead to the presence of a significant difference between obese and overweight children as the mean difference value was (0.28) and *P* value was (0.0001) and also lead to the presence of a significant difference between obese and underweight children as the mean difference value was (0.33) and *P* value was (0.0001). Also there was a decrease in average walking speed that overweight children walked when compared with average walking speed that underweight children walked. As there was a significant difference between them, mean difference was (0.05) and *P* value was (0.02).

This is may be due to different body weight between groups which affecting loads on their lower extremities and GRF acting on their bodies. That obese children have increasing loads on their lower extremities than overweight and underweight children which leads to increasing GRF acting on their bodies so obese children walked slowly to compensate for that and to make safer walking. The same for overweight children who have more loads on their lower extremities than underweight children making them walking slowly to compensate for increasing GRF resulting from this increase on loads acting on their extremities.

This come in agreement with the opinion of Browning and Kram (2007) [26] who reported walking slowly reducing GRF acting on bodies and produce safer and stable walking.

Average step cycle

There was a decrease in average step cycle for obese and overweight children when comparing with average step cycle of normal weight children which lead to the presence of a significant difference between normal and obese children as the mean difference value was (0.4) and *P* value was (0.0001) and the presence of a significant difference between normal and overweight children as the mean difference value was (0.32) and *P* value was (0.0001). This may attributed to increase metabolic cost during walking for obese and overweight children in order to move their heavy bodies so that they attempt to decrease stride speed to cope with it.

This is supported by the idea of Kang (2008) [29] who reported that it is important to recognize that a major portion of the metabolic demand during walking needed for acceleration and deceleration of the limbs with each stride.

Increased body mass is a major contributing factor in minimizing stride speed in obese and overweight children. This is supported by the opinion of De Souza *et al.,* (2005) [34] who suggested that a factor to consider relative to obesity and gait is that with an increase in BMI there is an accumulation of adipose tissue, which lead to an increase in thigh circumference. The increased thigh circumference requires circumduction of the thigh with each stride which takes longer time and slow speed.

The decreased average step cycle time for obese and overweight children may be attributed to reduce balance due to muscle weakness, limited range of motion and low level of physical activity.

This is supported by the idea of Hue *et al.,* (2004) [40] who suggested that increased body weight is correlated with anterior displacement of the center of mass, which places children closer to their boundaries of stability and at greater risk of falling during walking.

This comes in agreement with the findings of Spyropouloes *et al.,* (1991) [12] who tested the biomechanics of gait for obese and overweight subjects compared to normal weight subjects and found that the obese have been consistently slower with reduction in step cycle.

There was a significant difference between normal and underweight children as the mean difference value was (0.26) and P value was (0.0001) which lead to a decrease in average step cycle of underweight children when comparing with average step cycle of normal weight children. This is may be attributed to muscle weakness especially dorsi flexors which lead to easy fatigue and decrease average step cycle.

This is supported by the idea of Felner (2008) [41] who suggested that weakness of dorsi flexors in underweight children lead to inability to counteract planter flexion moment resulting in excessive planter flexion of ankle so that the limb can be lifted by leg circumduction which increased energy expenditure and lead to fatigue.

Underweight children walked with decreased average step cycle to cope with possible muscle weakness in order to provide support, propulsion and balance to the body during gait. This is supported by the opinion idea of Whittle (1999) [36] who reported that at lower step cycle subjects may feel that they are moving sufficiently and more safe.

This comes in agreement with the findings of Sonila (2010) [32] who reported that the underweight subjects walked with decreased average step cycle when compared to normal weight children.

There was a decrease in average step cycle that obese children walked when compared with average step cycle that overweight and underweight walked. This may lead to the presence of a significant difference between obese and overweight children as the mean difference value was (0.08) and *P* value was (0.002) and also lead to the presence of a significant difference between obese and underweight as the mean difference was (0.14) and *P* value was (0.0001). Also there was a decrease in average step cycle that overweight children walked when compared with average step cycle that underweight children walked which lead to the presence of a significant difference between them as mean difference was (0.05) and *P* value was (0.03).

This is may be due to the amount of body fat differs between groups. That obese children have larger amount of body fat than overweight and underweight children which causing increase thigh circumference lead to making circumduction of thigh when walking resulting in taking more time and decreasing average step cycle. And so overweight children as they have large amount of fat than underweight making them walking with decreased step cycle.

This come in agreement with the opinion of De souza *et al.,* (2005) [34] who suggested that increased amount of adipose tissue lead to walking with decreased step cycle.

Average step length

There was a decrease in average step length of obese and overweight children in relation to normal weight children and this may lead to the presence of a significant difference between normal and obese children as the mean difference values for the right and left leg were (0.14), (0.16) respectively and P value was (0.0001) and the presence of a significant difference between normal and overweight children as the mean difference values the right and left leg were (0.1) and *P* value was (0.0001). This is may be attributed to decreased joint range of motion which result from increased subcutaneous adipose tissue blocking joint excursion, abnormal body torsion or decreased muscle strength. This decrease in R.O.M may lead to subsequent reduction in flexibility and suboptimal postural alignment which make obese and overweight child walked with low step frequency and decreased step length to adapt to that.

This is agreed with Jones *et al.,* (2003) [42] who report children who are physically active have better muscle flexibility while increased body weight has been shown to be inversely associated with lower limb range of motion and impaired hip R.O.M which lead to reduced level of activity.

In addition Sjolie (2004) [43] reported that tight quadriceps and hamstring may increase compression of the pattelofemoral joint causing impaired hamstring length which affects pelvic tilt by drawing pelvic posteriorly affecting posture and causing pain.

Reduced muscle strength in obese and overweight children can predispose them to musculoskeletal fatigue and adding large fat mass for this weak muscle make it difficult for such children to walk with high step length.

This is supported by Riddiford *et al.,* (2006) [44] who suggests that there is a positive relationship, exists between muscle strength and activity and a negative relationship exists between muscle strength and obesity. He thought that in obese and overweight children, the dampening and decelerating capability of lower limb musculature is impaired secondary to muscle weakness and the resistance offered by the body's weight thus increasing rate of joint loading.

This comes in agreement with the findings of Gouws (2010) [45] who reported that step length for the overweight/obese children was significantly shorter than non obese group.

The results of this study revealed that there was a significant difference between normal and underweight children as the mean difference value for the right and left leg was (0.07) and *P* value was (0.0001), which lead to a decrease in average step length in underweight children in relation to normal weight children and this is may be attributed to muscle weakness in underweight children as a result of decreased energy and protein intake.

This is supported by the idea of Mikesky *et al.,* (2000) [46] who suggested that in underweight, the dampening and decelerating capability of lower limb musculature is impaired secondary to muscle weakness which arises from negative nitrogen balance resulting from inadequate protein intake or catabolic stress and lean body mass.

In addition Felner (2008) [41] suggested that weakness of hip extensors increase tendency for excessive hip flexion and anterior pelvic tilt causing the child to lean the trunk backward to shift the GRFV behind the axis of the hip joint and to prevent the trunk from falling forward. The long term effects of this compensation lead to excessive lumbar lordosis and this causes the step length to be very short.

This decrease in average step length in underweight children also may be due to the decrease in average walking speed. This is supported by the idea of Inman *et al.,* (1981) [47] who reported that every feature of walking changes when changes speed. As there a strong positive relationship between speed and step length and stride length.

This comes in agreement with the finding of Sonila (2010) [32] who tested the effect of BMI in gait biomechanics in children. Results showed that they walked with shorter steps than normal weight subjects.

There was a decrease in average step length that obese children walked when compared with average step length that overweight and underweight walked. this may lead to the presence of a significant difference between obese and overweight children as the mean difference value was (0.03) and *P* value was (0.007) and also lead to the presence of a significant difference between obese and underweight as the mean difference was (0.06) and *P* value was (0.0001).also there was a decrease in average step length that overweight children walked when compared with average step length that underweight children walked which lead to the presence of a significant difference between them as mean difference was (0.02) and *P* value was (0.03).

This is may be due to the amount of body fat differs between groups. That obese children have larger amount of body fat than overweight and underweight which lead to decrease R.O.M, decrease flexibility and decrease muscle strength which all lead to obese children take shorter steps when walked than overweight and underweight children. And so for overweight children as they have larger amount of fat than underweight making them walked with shorter step length.

This is supported by the idea of Sjolie (2004) [43] who suggested that there is inverse relationship between body fatness and joint flexibility and muscle strength.

Time of each foot contact

There was no significant difference among the four groups for the right foot and left foot as P values were (0.97), (0. 58) respectively as There is no change in time of each foot contact when comparing between all four groups. This is may be attributed to good neuromuscular control for all groups as time of foot contact provides information about neuromuscular control. This is supported by the idea of Yang and Winter (1994) [48] who reported that in neurological pathologies such as stroke, traumatic brain injury or peripheral neuropathies there is poor neuromuscular control and proprioceptive deficits resulting in improper foot placement.

This comes in agreement with the finding of Hills and Parker (1993) [13]who reported that change in BMI did not result in significantly different patterns of EMG activity than normal weight counterparts and EMG features of gait in children with different weight abnormalities include consistency of neuromuscular patterning across speeds of walking and no incremental rise in EMG amplitude with an increase in speed of walking

There was a significant difference in total distance, average walking speed, average step cycle and average step length when comparing between four groups. The worst results were for obese children while the best results were for underweight children when comparing all groups with normal weight children. This is may be attributed to body mass and the amount of fat deposition which have a negative effect on gait parameters.

This is supported by the idea of Kang (2008) [49] who reported that gait parameters affected by body mass, body mass distribution, load carriage and amount of fat deposition. It follows that greater the body mass the greater the energy cost incurred which resulting in gait abnormalities.

From the results of this study, it could be concluded that. The poorer results were for obese group as they walked less distance with slow average walking speed, short step length and slow average step cycle when compared to results of normal weight subjects. While the results of underweight children were better than the other groups but still less than the results of normal weight group. This study produced results similar to that found in a study by Sonila (2010) [39] who evaluated gait parameters of forty subjects composed four groups based on their BMI, with ten subjects in each of the groups: obese, overweight, underweight and normal weight. The obese subjects walked with significantly slower gait speed by taking shorter steps and strides and longer gait cycle time than other subjects.

Conclusion

From the obtained results of this study, it could be concluded that there were a number of differences in gait parameters when comparing obese, overweight and underweight with normal weight children and when comparing them with each other. The obese children walked little distance with significantly slower gait speed by taking shorter steps with decrease in average step cycle than the other subjects when compared to normal weight children. While the results of the underweight children were better than the other groups but still less than the normal weight group.

Recommendations

In the light of the achieved results of this work, the following recommendations are mandatory:

Further studies are needed to examine whether weight abnormality is a major limiting factor in movement tasks and ADL activities.

Further studies are needed to identify effects of weight abnormalities on the biomechanics of walking at different speeds.

Longitudinal studies, with a larger sample size of children with different weight abnormalities to assist in the development of normative data base for such children.

It is also recommended to examine whether weight abnormality affecting postural control and balance.

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