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Original Article

Walking pattern deviation in 10-15 year old obese children at the Lady Ridgeway Hospital, Colombo: A cross sectional comparative study

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Key words: childhood obesity, gait, walking pattern, stride, cadence

Background and objectives
Childhood obesity, a major health concern, could lead to many complications including alterations of the gait. Therefore, the aim of the study was to identify the deviation in walking pattern of 10-15 year old obese children from their non-obese counterparts.

Methods
A cross sectional comparative study was done at the Lady Ridgeway Hospital, Colombo involving 50 obese and 50 non-obese children aged 10-15 years. A simple random sampling method was used, and the participants were asked to walk along a 12m walkway with a 6m center recording zone, at a self-selected walking speed. The step length, stride length and cadence were measured by foot print analysis. A frontal stationary camera and a lateral running camera were used for two-dimensional walking analysis. Single limb and double limb support time was assessed by a Motion view 8.0 video analyzer using captured videos. Data was analyzed using the independent sample t test on SPSS 25. Ethics clearance was obtained from the Ethics Review Committee, Faculty of Medicine, University of Colombo.

Results
Non-obese children had a significantly higher mean step length, right stride length, left stride length and cadence than obese children ($p<0.05$). When each gender was considered separately, non-obese male children had a significantly higher step length and right stride length compared to obese male children. Non-obese female children had a significantly higher cadence than obese female children ($p<0.05$). No significant differences in single and double limb support time were seen between the two groups ($p>0.05$).

Conclusion
There is an association between childhood obesity and alterations in gait characteristics such as step length, stride length and cadence.

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Introduction

Gait is the locomotor activity of the body and it can be described as moving the human body from one place to another [1]. It is a cycle with a sequence of movements occurring between two continuous contacts of the same foot [2]. The gait cycle can be divided into two phases, stance phase and swing phase. Stance phase comprises 60% of the gait cycle and is the period of time where the foot is on the ground. Stance phase can be sub divided in to five sub phases, initial contact, loading response, mid stance, terminal phase and the pre swing phase [2]. Double leg stance is the period of time in which both feet are in contact with the ground [3]. Double leg stance occurs twice during the gait cycle of a healthy person [2]. When only one foot is in contact with the ground it is known as the single leg stance phase and this occurs twice in the normal gait cycle [2] and is said to comprise 40% of the total duration of the gait cycle [3].

When the foot is not bearing weight and moving forward, it is said that the swing phase occurs [2]. This is, again, divided into three sub phases, initial swing, mid swing and terminal swing. The swing phase represents 40% of the gait cycle [3]. Initial swing occurs when the foot is lifted from the ground. Mid swing occurs immediately with the knee flexion. When the swing leg decelerates and prepares for the initial contact with the floor it is known as the terminal swing and a greater amount of control of hip flexion as well as knee extension can be seen in this swing [2].

The WHO has defined obesity as an abnormal or excessive accumulation of fat in the body that has an impact on the health of a person [4]. Apart from conditions such as cardiovascular diseases, sleep apnoea and diabetes, obese individuals are more prone to suffer from an increased number of foot and ankle problems due to the additional mechanical stress of carrying an excess amount of weight. They may suffer from muscular skeletal problems such as plantar fasciitis, arthritis, bursitis, posterior tibial tendon dysfunction and difficult with shoe fit in addition to slipped capital femoral epiphysis (SCFE) and tibia vara. [5].

Childhood obesity is one of the fastest growing global epidemics and requires early attention in order to maintain quality of life [6]. Obesity in children can affect almost any organ in the body with long-term consequences. It is noted that obese individuals have reduced functional ability compared to individuals with normal weight [6]. Obesity is also associated with postural instability, in which an individual may not be able to maintain the centre of mass with respect to the base of support [7]. Furthermore, obese children may be at an increased risk of bone fractures [8].

In addition, gait changes are reported in obese individuals [9]. Obese individuals take significantly shorter steps, walk slower and have increased step widths with a greater ankle dorsiflexion and less plantar flexion [10]. Increased Q angles with increased hip abduction and significantly more abducted foot angles are also reported in these individuals [11]. Gait patterns of Sri Lankan children have not been studied before and this study was designed to observe changes in gait in obese Sri Lankan adolescents.

Methods

A cross sectional comparative study was carried out at the Lady Ridgeway Hospital, Colombo to study deviation in the walking pattern of 10-15year old obese children from their non-obese counterparts. Obesity was determined as a body mass index (BMI) above +2SD for age and non-obese as a BMI in the range of -2SD to +1 SD for age according to WHO growth standards (WHO 2007 standards). Children with congenital deformities affecting the gait, any systemic illness that could affect the gait, any other pathology of the foot, with an injury or with a history of any surgical procedures involving the foot were excluded from the study. According to the available resources and timeframe, a sample size of 50 obese and 50 non-obese children were selected by consecutive sampling from the eligible children attending the nutrition clinic or medical clinic of the Professorial Paediatric Unit at the Lady Ridgeway Hospital for Children. Both obese and non-obese children were recruited sequentially until the required sample size was achieved. A self-administered questionnaire was distributed to the parents after obtaining their consent to gather personal information and past medical status.

Height and weight was measured using standard protocols. A wall mounted stadiometer was used to measure the height of the participants to the closest 0.1cm (Seca® Germany). They were asked to remove their shoes and stand with his/ her back against the height ruler and to look straight (head in Frankfurt plane). Then the head piece of the stadiometer was lowered so that the hair of the participant was pressed flat and the height was recorded. A digital weighing scale (Seca® Germany) was used to measure the weight to the closest 0.1kg. Participants were asked to remove their shoes and stand in the center of the platform, so as the weight distributed evenly to both feet and the weight was recorded. A measuring tape was used to diagnose any discrepancy in leg length of subjects. The leg length measurement was taken from the anterior superior iliac spine to the medial malleolus while the subject was lying supine on the examination couch.

Small pieces of sponge with ink in two different colors spotted onto them were attached to the heels of both legs of the participants and they were asked to walk on a 12m long walking pathway, maintaining their normal walking speed. Light reflective markers were attached to the base of the fifth metatarsal, lateral malleolus and head of the fibula. The walking pattern was recorded by a static video camera located in front of the walking pathway and a dynamic video camera which moved with the participant at the speed they were walking. A fresh paper walkway was used for each of the participants.

Gait parameters related to time, single limb support time (the time that passes during the period when only one foot is on the ground in the gait cycle) and double limb support time (the time that a person spends with both feet on the ground during a single gait cycle) were obtained by the Motion View 8.0 Video analyzing software which is automated. Step length was measured as the length from the heel center of one foot to the heel center of the opposite foot in a gait cycle and stride length, the distance from one heel strike to the next heel strike of the same foot, was measured as one heel contact mark to the next heel contact mark made by the same foot, on the walking pathway. The average for the middle 6m of the walking path was used for analysis. Cadence, the number of steps per unit time was calculated using the video analysing software.

Statistical analysis was done using SPSS version 20 and the level of significance was considered to be at $p<0.05$. Descriptive data was presented as mean values and standard deviations and the independent sample t test was used to find the relationship between gender and gait parameter fluctuation.

Ethics clearance was obtained from the Ethics Review Committee of the Faculty of Medicine, University of Colombo and also from the Ethical Review Committee of LRH prior to the conduct of the study. Informed written consent was obtained from the accompanying parent after explaining the study protocol to both parents and child. Assent was obtained from children above 12 years of age.

Results

The study population consisted of 50 obese and 50 non-obese children between 10 to 15 years. Table 1 shows the demographic and anthropometric characteristics of the study population.

Table 1: Demographic and anthropometric characteristics of the study population.

	Male		Female	
	Non obese	**Obese**	**Non obese**	**Obese**
Number of children	25	25	25	25
Age (years)	12.16 (±1.43)	12.08 (±1.46)	11.84 (±1.37)	12.12 (±1.50)
Weight (kg)	41.04 (±6.59)	57.39 (±5.31)	38.78 (±5.13)	55.57 (±4.10)
Height (m)	150.50 (±8.00)	147.35 (±5.36)	147.36 (±7.13)	147.79 (±4.47)
BMI (kg/m^2)	17.97 (±1.13)	26.44 (±2.20)	17.77 (±0.97)	25.46 (±1.88)

Gait characteristics of the study population

Step length, right stride length, left stride length, cadence, single limb support time and double limb support time were taken as gait characteristics. Table 2 shows the comparison of the gait parameters between obese and non-obese participants.

Table 2: Distribution of gait characteristics of the study sample

	Non obese	**Obese**	**p value**
	Mean / SD	Mean / SD	
Step length (cm)	63.5(±2.4)	62.3(±2.7)	0.024*
Right stride length (cm)	128.9(±5.0)	126.4(±5.2)	0.015*
Left stride length (cm)	125.0(±4.9)	122.8(±5.6)	0.042*
Cadence (steps/min)	118.8(±4.2)	116.8(±4.1)	0.019*
Single limb support time (% of GC)	15.4(±1.3)	16.0(±2.5)	0.102
Double limb support time (% of GC)	23.0(±2.0)	24.0(±3.7)	0.102

cm: centimetres; SD: Standard deviation; GC: Gait cycle

Mean step length of the non-obese group (63.5±2.4 cm) was higher than that of the obese group (62.3±2.7 cm) and this was statistically significant (t= -2.292; df= 98; p= 0.024) (Table 2). Mean right stride length of the non-obese group (128.9±5.0 cm) was higher than that of the obese group (126.4±5.2 cm) and was statistically significant (t =-2.471; df= 98; p= 0.015).

The two groups differed significantly in terms of mean left stride length which was 125.0±4.9 cm in the non-obese and 122.9±5.6 cm in the obese (t= -2.063; df = 98; p = 0.042). Mean cadence of the non-obese group (118.8±4.2 steps/min) was higher than that of the obese group (116.8±4.1 steps/min) and this was statistically significant (t = -2.384; df = 98; p = 0.019). There was no significant difference in single limb support time (t= 1.653; df=98; p= 0.102) or double limb support time (t= 1.653; df= 98; p= 0.102) between the two groups.

Gait characteristics in male participants (Table 3)

Non-obese males had higher step lengths (63.8±2.4 cm) compared to obese males (62.3±2.5 cm) and this was statistically significant (t= -2.186; df= 48; p= 0.034). But only the right stride length of the non-obese males was higher (129.7±5.0 cm) when compared to the obese males (126.3±5.0 cm), (t= -2.378; df=48; p= 0.021). Other gait parameters, left stride length, cadence, single limb support time and double limb support time were not significantly different between the male participants in two groups.

Gait characteristics in female participants (Table 3)

When comparing the female participants in the two groups, mean cadence of the non-obese females (119.5±3.4 steps/min) was higher than that of the obese females (116.3±3.7 steps/min). A significant difference (t= -3.190; df= 48; p= 0.003) on cadence was seen between the two groups. Other gait parameters were not significantly different between the female participants of the two groups.

Table 3: Comparison of gait characteristics in male and female participants

	Males			Females		
	Non obese male	Obese male	p value	Non obese female	Obese female	p value
	Mean / SD	Mean / SD		Mean / SD	Mean / SD	
Step length (cm)	63.8(±2.4)	62.3(±2.5)	0.034*	63.1(±2.5)	62.3(±2.8)	0.283
Right stride length (cm)	129.7(±5.0)	126.3(±5.0)	0.021*	128.1(±5.0)	126.4(±5.4)	0.265
Left stride length (cm)	125.7(±4.6)	123.0(±5.3)	0.059	124.3(±5.1)	122.7(±5.9)	0.311
Cadence (steps/min)	118.0(±4.7)	117.2(±4.6)	0.568	119.5(±3.4)	116.3(±3.7)	0.003
Single limb support time (% of GC)	15.2(±1.1)	15.8(±3.2)	0.419	15.5(±1.5)	16.3(±1.4)	0.073
Double limb support time (% of GC)	22.9(±1.7)	23.6(±4.8)	0.419	23.3(±2.3)	24.4(±2.1)	0.073

cm: centimetres; SD: Standard deviation; GC: Gait cycle

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Discussion

Gait characteristics of non-obese children

According to the results of the study, the mean step length in both males and females was 63.5cm (SD=2.4) which is higher than that recorded in the study done by Gill *et al.* (56.1cm (SD=10.7) on a group of healthy 2 to 17 year old (n=254) American children [12]. A study done by Tesio *et al.* on 9-13 year old Italian children (n=20), reported a mean step length of 58.0cm (SD=0.05) [13]. The present study showed a higher step length in the male population compared to the female population. This finding is similar to the findings of the study conducted by Zakaria *et al.* where step length in boys was 59.0cm while in girls it was 58.0cm [14]. The reasons for the gender difference in leg length could be the pelvic rotation, pelvic width and short leg length seen in females. The study showed a mean right stride length of 128.9cm (SD=5.0), whereas the left stride length was 125.0cm (SD=4.9). In the study by Zakaria *et al.* the stride length was calculated as a single variable rather than for right limb and left limb separately [14]. The study stated that boys showed a higher mean stride length (119cm) compared to girls (116cm), which is consistent with the findings of our study.

Compared to the mean cadence (118.8) demonstrated by the non-obese participants in the present study, the study done by Beck *et al*, showed similar values for each age subgroups, 115.0 steps/min for 10-11 year age group, 112.0 steps/min for 11-13 year age group and 100 steps/min for 13-15 year age group [15]. This could be the result of the differences in physical activity in different ethnic groups.

The present study calculated a mean of 15.3(SD=1.3) for the single limb support time and this contrasts with the data (17.4, SD=1.6) from the study done by Stansfield *et al.*[16] with 16 subjects. However, that study was done using children with a mean age of 8.18 years while the children in the present study had a mean age of 12.0 (SD=1.4) years.

Gait characteristics of obese children

The gait characteristics of obese children identified a mean step length of 62.3cm (SD=2.7). These findings are on par with the study conducted by Hills and Parker on Australian Caucasian children, where it was 60.0cm for the left leg and 63.0cm for the right leg at normal walking speed [17]. Hills & Parker described a mean stride length of obese children walking at normal speed of 124.0cm (SD=0.16) [17]. These findings are in line with the present study.

The mean cadence of obese children in our study was 116.8 (SD=4.2) steps/min and is comparable to the data (110.9) from a study done by Nantel, [18]. In a study done by Boys *et al.* [19] the mean cadence was 130.0 steps/min while the study done by Hills and Parker observed a mean cadence of 125.0 steps/min [17]. The slight discordance in the findings could be due to the age difference in the children participating in the studies.

Although the single limb support time in our study differed from the results in the study by Nantel [18], the double limb support time of our study is consistent with his findings. It is possible that this may have been influenced by the physical activity level of the two different ethnic groups, where Nantel stated that most of the participants were engaged in two supervised moderate physical activities per week [18] whereas the physical activity level of the population in the present study has not been accounted for. According to Nantel, regular physical activity improves the walking speed and kinematic parameters of the gait pattern in a symptomatic population [18].

Comparison of the gait characteristics of obese and non-obese children

Similar to Hills and Parker [17], the present study shows an increased mean step length in the non-obese population compared to the obese population. This could be due to the effect of the increased body mass of obese children on velocity which will ultimately lead to a shorter step length. The study done by Nantel [18] also found that non-obese children showed a higher stride length compared to the obese children. But interestingly, Hills & Parker reported that the stride length was higher in the obese population [17]. This apparent lack of correlation could be attributed to the three different walking speeds used in the study done by Hills & Parker.

The mean value of cadence was higher in the non-obese population (although this was not significant)and this has been shown previously [18,19] Hills and Parker [17], who studied three different walking speeds in obese and normal-weight subjects found that the cadence was increased in normal-weight subjects in all three different walking speed compared to the cadence of the obese subjects.

The obese population spent a significantly greater percentage of time in double limb support than the non-obese population, which has been shown by other studies [17,19]. Previous studies have suggested that a greater support time could be an indication of a safer and more tentative ambulation which will reduce the nonsupport period and, hence, the possibility of instability. The increased double limb support could be due to adaptation to maintain the stability in the gait cycle where the center of mass is inside the base of support and bounded by the two feet [19]. The same study discussed that the increased step length and stride length of the non-obese population could be due to decreased body weight allowing them to move rapidly and with a wider base of support compared to the obese population where the increased body weight may limit the movement pattern [20].

Limitations

The main limitation of our study is the relatively small sample size of 50 in each arm. An automatic running camera which adjusts its speed according to the subject's speed would have been a more accurate method for motion capture. Other limitation was that children were asked to walk at their usual speed but the study did not account for the impact of different walking speeds on gait characteristics. Also, we did not study the effect of age, height and leg lengths and level of physical activity on the step length, stride length and cadence of these children.

Conclusion

The present study identified an association between childhood obesity and alterations in gait pattern. A larger study to confirm this association is recommended.

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