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EFFECTS OF OBESITY ON BALANCE AND GAIT ALTERATIONS IN YOUNG ADULTS

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Abstract : The effects of obesity on the balance and gait parameters like step width and foot angle (degree of toe out) in young adults were studied. 60 subjects of both the genders were taken. 30 were taken as a control group (non-obese, BMI < 25) and 30 were taken as experimental group (obese, BMI 30 >). Functional Reach Test (FRT) was used for Balance Testing and the Footprint method was used for Gait parameters measurements. The value of functional reach test in females was 11.90±0.12 inches in control group and 7.01±1.80 inches in experimental group (t=5.31, P<0.001) and in males, it was 16.45±0.72 inches in control and 11.66±0.53 inches in experimental group (t=6.47, P<0.001). The degree of toe out in females was 6.66±0.08 degrees for control and 8.13±0.21 degrees for experimental group (t=4.08, P<0.01) and in males, it was 6.59±0.04 for control and 9.79±0.51 for experimental group (t=6.53, P<0.001). The step width was found to be 4.41±0.15 inches (control group) and 6.27±0.35 inches (experimental) in males (t=4.53, P<0.01) and it was 3.95±0.03 inches (control) and 3.42±1.05 inches (experimental) in females (t=0.77, P>0.05). We concluded that obesity has a negative impact on balance of an individual. The degree of toe out was more in obese group as compared to normal BMI group in both genders. The Step Width measurement was more in males of obese group than that in males of normal BMI group but it showed statistically insignificant when compared in females of both groups.

Key words : obesity functional reach test gait balance degree of toe out step width

INTRODUCTION

A high body mass index (BMI) does not have a negative influence on the locomotor system in general but obesity is associated with an increased risk of falls and subsequent injury (1). Previous studies have shown that weight loss and muscle strength training exercises were beneficial to maintain balance, but which one is more beneficial to maintain body balance and to reduce the risk of falls allow the researchers to extend

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the study (2). Fjeldstad et al (3) have reported that obese subjects have a higher prevalence of falls and ambulatory stumbling or a loss of balance than their non-obese counterparts. Excess weight increases the stress within the bones, joints, and soft tissues, resulting in impaired musculoskeletal function such as abnormal mechanics of the body (4). These impairments, such as impaired balance, gait, strength, sensory function, and neuromuscular function have been identified as strong risk factors for falls.

Reduced walking speed, cadence, and step length as well as increased stance duration have also been identified as strong risk factors for falls (5). Obesity causes alterations in gait that are associated with an increased risk of falls. Several studies have found that walking speed, step length, and step frequency to be significantly lower in the obese compared to the non-obese. Additionally, the obese have a longer stance phase and greater period of double support (6). De Vita et al (6) have found that obese adults tend to have a more erect posture while walking at a standard speed, compared to non obese adults, as a result of reduced knee and hip flexion. This posture provides stability in the obese by counteracting an anterior displacement of the center of mass (COM) from the longitudinal axis of the body associated with obesity, reducing the amount of corrective torque needed to maintain balance (6).

Spyropoulos et al (7) have suggested that obesity requires an individual to walk slowly, take smaller strides, and remain in double support longer in order to maintain balance. Deviations from the obese gait pattern would result in instability and loss of balance. Authors also have found that the obese have a larger step width during walking which provides a wider base of support for balance (7). The dynamic aspects of gait like speed, cadence, stride, and support base and foot angle were significantly lower in the obese subjects, except for support base which was more. These were consistent with poor skeletal muscle performance, high metabolic expenditure and constant physical exhaustion (8). Previous studies have shown that males show reduced peak torque in planter flexion strength and females show decreased knee extension strength leading to increased tendencies to fall in obese elderly subjects (9).

The objectives of the present study was to elucidate the effect of obesity on gait and balance impairment.

MATERIALS AND METHODS

Sixty subjects of both genders at the age group of 20–30 years were recruited randomly and put into two groups. 30 were in non-obese and 30 in obese group. Non-obese group (n=30) was used as a control group and obese group as experimental group. Out of thirty in each group, fifteen each were males and females respectively in each control and experimental group. Subjects who were able to stand and walk unsupported and had full joint range of motion at shoulder joint were included in the study. Subjects having any neuromuscular and neurological diseases and any contracture in lower limbs and any visual loss were excluded from the study. Basic anthropometric parameters such as body weight, body height, BMI were measured.

BMI was calculated by dividing the subject's weight by the square of his/her height, expressed in metric units: Metric: BMI = kg/m^2, where *kg* is the subject's weight in kilograms and *m* is the subject's height in meters. According to WHO (10), BMI between 18.5-24.9 is considered as normal, BMI between 25-29.9 is considered as overweight and BMI 30 and above is considered as obese.

Procedure: All subjects attended a single testing session and were instructed concerning the ongoing tests before data acquisition.

Balance testing

Functional Reach Test (FRT) was used for balance testing. In this test, a level yardstick was mounted on the wall and positioned at the height of the subject's acromion. Then, the subject stood sideward next to the wall (without touching), feet normal stance width and weight equally distributed on both feet. The shoulder was flexed to 90 degrees and elbow extended with the hand fisted. An initial measurement was made of the position of the 3rd metacarpal along the yardstick. For forward reach, the subject was instructed to lean as far as possible without losing balance or taking a step. A second measurement was taken also using the 3rd metacarpal for reference. This measurement was then subtracted from the initial measurement. This was repeated three times for each subject and average of the three values was taken and compared to the normative values of the test.

Gait parameters test

The Footprint method was used. The subjects were made to wear stockings/socks and the bottom of the stockings on the plantar surface of the foot was painted. Then, the subjects were made to walk in their comfortable walking speed on a 3 meter paper walkway each and the footprints of the subjects during gait were recorded (11). The walking speed was self-spaced. Then, the step width (i.e. the width of walking base which was the linear distance between one foot and the opposite foot) and foot angle (i.e. degree of toe out which was the angle of foot placement with respect to the line of progression) were measured. Step Width was measured by measuring linear distance between the midpoint of the heel of one foot and the same point on the other foot. Foot Angle was measured by measuring the angle formed by each foot's line of progression and a line intersecting the center of the heel and the second toe. This was repeated three times for each subject and average of the three values was taken.

Statistical analysis

Unpaired t–test was applied to find out the level of significance of balance test and gait parameters between non-obese and obese males and females separately and non-obese males and females and obese males and females. The level of significance was set at $P<0.05$. BMI was correlated with functional reach test, step width and degree of toe out for both the genders. Pearson's correlation coefficient values were calculated to find out whether correlation was existing between

BMI and balance and BMI and gait alterations.

RESULTS

Subject's characteristics are presented in Table I. The balance (measured by FRT) of obese males was poorer than that of males with normal BMI of same age group (t=6. 47, P<0.001), the step width was more in obese males as compared to those with normal BMI (t=4.53, P<0.01) and also the degree of toe out was high in obese males than in males with normal BMI (t=6.53, P<0.001). The balance (measured by FRT) of obese females was poorer than females with normal BMI of same age group (t=5.31, P<0.001), the step width showed statistically insignificant change in obese females than females with normal BMI (t=0.77, P>0.05) and also the degree of toe out was more in obese females than in females with normal BMI (t=4.08, P<0.01).

Fig. 1 showed balance was poorer in obese males as well as obese females as compared to those males and females with normal BMI respectively. The FRT was decreased by 29.1% in obese males and 41.09% in obese females. There was also a difference in balance of males and females with normal BMI when FRT was compared between them. Males are having more balance than females of non-obese group which was significant at P<0.001 when un-paired t-test was applied between non-obese males and females. It was found by applying un-paired t-test, that the degree of toe out and step width between males and females of non-obese group were insignificant (P>0.05).

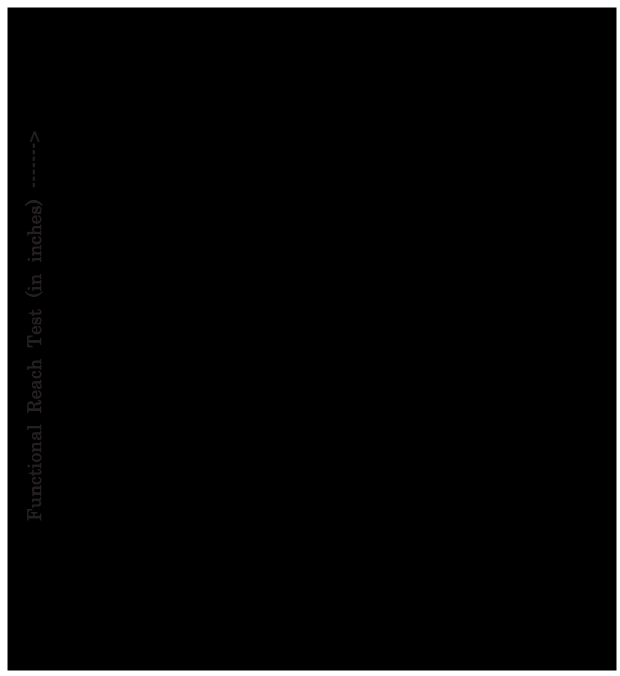

Fig. 1 : Comparison of FRT values (for balance) in males and females of both non-obese and obese group (P<0.001).

TABLE I : Demographics of the participants.

Subjects	*n*	*BMI (kg/m²)*	*Age (year)*	*Foot length (mm)*	*Foot width (mm)*
Female(N)	15	21.92±1.43	27.6±0.3	238.2±0.6	91.2±1.4
Female(O)	15	35.54±0.23**	26.0±1.2	240.9±2.1	94.9±1.7*
Male(N)	15	21.97±0.51	26.3±0.8	266.6±1.6	101.4±0.5
Male(O)	15	35.21±0.18 **	26.1±0.6	266.5±2.1	106.2±1.1**

Values are means±standard deviation. *P<0.05; **P<0.01.

Fig. 2 showed that step width was more in obese males than non-obese males ($P<0.01$) and it also showed that the difference of step width between females of both groups were insignificant ($P>0.05$). The step width in obese males was increased by 42.17% whereas in obese females, it was decreased by 13.4% and the difference was not significant. The degree of toe out was more in obese males when compared with non-obese group (significant, $P<0.001$) and same in female groups (significant, $P<0.01$) also as shown in Fig. 3. The degree of toe out was raised by 48.55% in obese males and 22.97% in obese females. When FRT was compared between obese males and females by applying un-paired t-test, it was found significant ($P<0.01$). The degree of toe out and step width between obese males and females were highly significant at $P<0.02$ and $P<0.01$ respectively when un-paired t-test was applied to verify the difference between these group.

The Pearson's correlation coefficient (r) values were calculated between BMI and FRT of obese males and females separately, which

Fig. 2 : Comparison of step width in males of both non-obese and obese group ($P<0.01$) and in females of both groups ($P>0.05$).

Fig. 3 : Comparison of degree of toe out in males of both non-obese and obese group ($P<0.001$) and females of both groups ($P<0.01$).

were found to be –0.33 and +0.16 respectively. The r-values for BMI and step width of both males and females of obese group were found to be –0.86 and +0.96 respectively and BMI and degree of toe out of both obese males and females were –0.076 and +0.91 respectively. The positive correlation were existing between BMI and balance, BMI and gait parameters of obese females but negative correlation were found for these variables among obese males.

DISCUSSION

Obesity is highly associated with numerous health conditions. Obesity is highly associated with hypertension, type 2 diabetes mellitus, cardiovascular disease, osteoarthritis (OA), and respiratory disease (11–16). In addition, the obese tend to have higher levels of functional limitation than the non-obese (17). It was found from our study that the balance in the obese individuals of both the genders was poorer than that of non- obese of same age group ($P<0.001$) which was shown in Fig. 1. Goulding et al. (8) found that the balance of obese individuals was poorer and the score of the test was lesser in obese individuals than in non-obese individuals.

In our study, step width of the obese individuals especially males found out to be increased than the non-obese individuals ($P<0.01$) which was also evidenced by the studies of Spyropoulous et al (7) and Hills and Parker (18) who also found that obese had larger step width during walking, which provides a wider base of support for maintaining balance while walking. In our study, it was found that in females, step width of obese subjects was found to be insignificant when compared with non-obese ($P>0.05$). This may occur due to difference in android type obesity pattern of males and gynoid type in females (19). In females with normal BMI, the distribution and accumulation of fat is at the region of pelvis and thighs and when a female becomes obese then also the site of accumulation of fat is the same which is unlike to that in males as in males the site of accumulation of fat is around the abdomen (19). Hence, it may cause increase in step width of obese males than that of non-obese males and no significant change in step width of obese females than that of non-obese females was found. Fabris de Souza et al (2) observed that the increased step width of obese individual was due to their poor skeletal muscle performance and high metabolic expenditure.

Degree of toe out was also found to be more in obese individuals (males > females) than in non-obese. Hills and Parker (18) and Cynthia Norkins (20) observed that the walking speed of obese individuals was found to be decreased than that of non-obese individuals. As the speed was lowering in obese, so the degree of toe out was found to be more in obese as compared to that in non –obese individuals. Increased obesity has shown to be positively correlated with impaired postural balance even in younger individuals. Postural balance was improved in these individuals following a weight reduction program combined with balance training (21). It was found in our study that FRT score in obese females was decreased by 41.09% whereas in obese males, it was reduced by 29.11% when compared to non-obese groups. It indicates that balance in obese females is impaired more than obese males. So obese females are more prone to the risk of falls. The greatest effect of body weight on higher peak pressures in the obese was found under the longitudinal arch of the foot and under the metatarsal heads. The higher pressures for obese women compared to obese men during static weight bearing (standing) may be the result of reduced strength of the ligaments of the foot (7).

The increase in body mass is associated with changes in many of the components of normal gait. Gait speed has been shown to be slower in obese individuals. Even overweight children may require more balance control and lower extremity muscle strength than non-overweight children in order to accommodate for the increased body mass (22). Hills and Parker found that obese subjects displayed a consistently higher double stance period at normal, fast, and slow walking speeds (18). Obesity modifies the body geometry by adding mass to different regions and influences the biomechanics of activities of daily living (23). The increased body mass seems to produce postural instability in both genders as evidenced from our study, but it has more impact on females of same age group.

REFERENCES

1. Kiess W, Marcus C, Wabitsch M. Obesity in Childhood and Adolescence. *Pediatr Adolesc Med Basel* 2004; 9: 137–147.

2. Fabrice de Souza SA. Gait cinematic analysis in morbidly obese patients. *Obes Surg* 2005; 15: 1238–1242.

3. Fjeldstad C. The influence of obesity on falls and quality of life. *Dyn Med* 2008; 7: 4 (Abstract).

4. Wearing SC. The biomechanics of restricted movement in adult obesity. *Obes Rev* 2006; 7: 13–24.

5. Kanis JA, Johnell O, Oden, A. What is the role of falls ? *Best Pract Res Clin Rheumatol* 2005; 19: 913–935.

6. De Vita P, Hortobagyi T. Obesity is not associated with increased knee joint torque and power during level walking. *J Biomech* 2003; 36: 1355–1362.

7. Spyropoulos P, Pisciotta JC, Pavlou KN. Biomechanical gait analysis in obese men. *Arch Phys Med Rehabil* 1991; 72: 1065–1070.

8. Goulding A, Jones IE, Taylor RW. Dynamic and static tests of balance and postural sway in boys: effects of previous wrist bone fractures and high adiposity. *Gait & Posture* 2003; 17: 136–141.

9. Stephen RL. Falls in older people : risk factors and strategies for prevention. *J Am Podiatrics Med Assoc* 2002; 92: 371–377.

10. WHO. Obesity: Preventing and Managing the Global Epidemic: Report of the WHO Consultation of Obesity. Geneva: World Health Organisation, 1998.

11. Van Loo MA, Moseley AM, Bosman JM, de Bie RA, Hassett L. Inter-rater reliability and concurrent validity of walking speed measurement after traumatic brain injury. *Clin Rehabil* 2003; 17: 775–779.

12. Puska P, Nishida C, Porter D. Global Strategy on Diet, Physical Activity and Health. *Journal of Pediatric Psychology* 2007; 32: 250–259.

13. Flegal KM, Harris MI, Cowie CC. Prevalence and trends in obesity among US adults, 1999–2000. *Jama,* 2002; 288: 1723–1727.

14. Wannamethee SG, Shaper AG, Whincup PH. Overweight and obesity and the burden of disease and disability in elderly men. *Int J Obes Relat Metab Disord* 2004; 28: 1374–1382.

15. Ogden CL, Guo SS. Prevalence of overweight and obesity in the United States, 1999- 2004. *Jama* 2006; 295: 1549–1555.

16. Bray GA. Medical consequences of obesity. *J Clin Endocrinol Metab* 2004; 89: 2583–2589.

17. Wearing SC, Hennig EM, Byrne NM, et al. Musculoskeletal disorders associated with obesity: a biomechanical perspective. *Obes Rev* 2006; 7: 239–250.

18. Hills AP, Parker AW. Gait characteristics of obese children. *Arch Phys Med Rehabil* 1991; 72: 403–407.

19. Ohtake Patricia J. Impact of obesity on Walking: Implications for Fitness Assessment an Exercise Prescription, *Cardiopulmonary Physical Therapy Journal* 2008; 19: 52–53.

20. Cynthia C Norkin, Pamela K Levangie. Joint structure and function-a comprehensive analysis; 3rd edition; Ch-14. F.A. Davis Publications: 2001.

21. Maffiuletti NA, Agosti F, Proietti M, Riva D, Resnik M, Lafortuna CL, Sartorio A, Posturalinstability of extremely obese individuals improves after a body weight reduction program entailing specific balance training. *J Endocrinol Invest* 2005; 28: 2–7.

22. Teasdale N, Hue O, Marcotte J, Berrigan F, Simonau M, Doré J, Marceau P, Marceau S, Tremblay A: Reducing weight increases postural stability in obese and morbid obese men. *Int J Obes (Lond)* 2007; 31: 153–160.

23. Francesco M, Manuela G, Elena T, Luca V, Marco C, Paolo C. Gender-specific Effect of Obesityon Balance. *Obesity* 2009; 17: 1951–1956.