KINEMATIC AND KINETIC COMPARISON OF LEAN AND OBESE INDIVIDUALS DURING WALKING

A. Abdulrahman and C. Zebas

University of Kansas
Lawrence, Kansas, USA

INTRODUCTION

The basic prescription for overweight individuals is diet and exercise. One form of exercise frequently prescribed is walking. For the majority of individuals, walking poses few problems. However, for the obese individuals, there may be some inherent complications which can result in discomfort and ultimately in a reason to discontinue the exercise. Very few studies have addressed the special problems that obese people may have in the simple act of walking. Adrian and Cooper (1989) said that obese people will tend to twist as they walk. To reduce the amount of the turning, they stiffen and take shorter steps. They also lean backward slightly because of the large abdominal region. Cavanagh (1985) stated that obese individuals tend to be less efficient when walking requiring more energy than non-obese individuals. In a kinetic analysis, Messier et al. (1990) found greater rearfoot movement in obese female subjects than in normal weight subjects. Although the average observer seems to recognize that the gait of obese individuals is different from that of normal weight individuals, no systematic study has examined the gait characteristics of obese individuals. The purpose of this study was, therefore, to kinematically and kinetically compare the walking gait of obese and non-obese male subjects.

METHODOLOGY

Twenty subjects, ages 18 to 40, were chosen for the study. Ten of the subjects were classified as obese (percent body fat >25%) while the other ten were classified as lean (percent body fat <10%). Percent body fat was determined by skinfold measurement. All subjects signed a consent form and filled out a health questionnaire. The subjects were asked to wear tight-fitting clothing during data collection. Small markers were placed on joint centers of the right side of the body. On a raised walkway, the subjects walked freely six times over a force plate while three trials were filmed by a LOCAM camera operating at 60 frames per second. A Numonics instrument was used to digitize the film. Force plate information was collected with Labview II. The kinematic variables that were measured are listed in Table 1. The kinetic variables that were measured are listed in Table 2. Statistical analysis was accomplished by performing t-tests between the two groups on each variable with a level of significance of $p<0.05$.

RESULTS

The results presented are the average of three trials for the kinematic variables and six trials for the kinetic variables. The kinematic results are presented in Table 1 and the kinetic results in Table 2.

The t-test comparisons on the kinematic parameters did not result in any significant differences between the two groups with the exception of the stance and swing variables. In the stance phase, obese subjects averaged $63.2 \pm 2.0\%$ and lean subjects averaged 60.1 ± 1.0% of the walking cycle. The swing phase results showed that obese subjects spent less time (36.5 ± 2.0%) than lean (39 ± 1.0%) during the walking cycle.

Table 1. Mean values for kinematic parameters for obese and non-obese subjects.

Variables	Obese		Lean		T-value
Stride Length (cm)	122.1	(15.0)	132.8	(13.0)	-0.17
Stride Time (s)	1.13	(0.05)	1.09	(0.09)	0.97
Right Step(cm)	61.6	(7.0)	67.7	(6.6)	-0.20
Left Step (cm)	60.5	(8.0)	60.0	(6.8)	-1.30
Speed (m/s)	1.06	(0.18)	1.19	(0.10)	-2.00
Stance Phase (%)	63.5	(2.9)	60.1	(1.1)	5.40 **
Swing Phase (%)	36.5	(2.5)	39.9	(1.1)	3.41 **
Knee displacement (°)	55.8	(5.4)	59.9	(5.0)	-1.69
Ankle displacement(°)	24.7	(8.0)	31.4	(7.0)	-1.90
Thigh displacement(°)	36.0	(6.0)	36.0	(5.0)	-0.10
Body COG (cm)	5.0	(0.1)	6.0	(0.2)	-1.20
Trunk displacement(°)	12.0	(2.0)	10.6	(2.0)	-1.90

** $p < 0.01$; * $p < 0.05$

Table 2. Mean values for kinetic parameters of obese and non-obese subjects.

Variables	Obese		Lean		T- value
First Peak	10.7	(1.0)	10.7	(0.9)	0.00
Time (%)	22.9	(3.0)	22.3	(3.4)	0.45
Minimum	8.0	(1.1)	7.5	(0.6)	1.25
Time (%)	44.8	(5.1)	46.5	(5.4)	-0.67
Second Peak	10.6	(0.9)	10.6	(0.6)	-0.03
Time (%)	73.3	(5.2)	74.4	(4.17)	-0.72
Medial Peak	0.2	(0.01)	0.4	(0.01)	-2.10 *
Time (%)	4.06	(0.9)	4.1	(0.9)	-0.17
Lateral Peak	0.7	(0.02)	0.6	(0.01)	1.40
Time (%)	68.0	(18.5)	69.6	(14.0)	5.13 **
Fore force	1.4	(0.05)	1.6	(0.05)	-0.70
Time (%)	14.0	(3.0)	14.0	(3.6)	0.01
Aft force	1.9	(0.04)	2.2	(0.02)	-0.10
Time (%)	85.0	(1.8)	86.0	(1.4)	-1.20

* $p < 0.05$; ** $p < 0.01$

The mediolateral forces resulted in significant differences between the two groups. The medial force was 0.2 ± 0.01 N/kg for the obese subjects and 0.4 ± 0.01 N/kg for the lean subjects. The time of the lateral force also resulted in a significant difference between the groups. Lean subjects averaged 29.6 ± 14.0% stance and obese subjects averaged 68.0 ± 18.5% stance.

DISCUSSION

The results of this study in terms of most variables analyzed did not indicate significant differences between the groups. Kinematic variables resulted in two significant differences, namely in stance and swing phases. Lean subjects had a shorter time in stance phase and a longer time in swing phase than obese subjects. It has been said that stance phase percentage of the walking cycle is about 60% and the swing phase about 40% (Adrian and Cooper, 1989; Mann and Hagy, 1980). Lean subjects averaged 60% for the stance phase and 40% for the swing phase while obese subjects averaged 63.5% stance phase and 36.5% swing phase. This may have occurred because of the slower pace of the obese subjects. Also, obese subjects tended to spend more time in stance phase or on the ground by the supporting foot to distribute the pressure resulting from the ground reaction force when the heel strikes over longer time. This is due to the large forces produced by the obese subjects as a result of having a greater mass.

Obese individuals tend to be less efficient when walking requiring more energy than the average individual (Cavanagh, 1985). The stance phase requires more energy than the swing phase (Adrian and Cooper, 1989) thus, theoretically, obese people should spend less time in stance to reduce the energy cost of walking and increase efficiency. It is believed that obese individuals sacrifice reducing energy for stability and distribution of pressure resulting from the ground reaction forces. Radin et al. (1972) stated that obese people tended to have many problems with their knees because of the large girth of their thighs. Radin and associates added that it is natural to attempt to get the feet under the center of gravity, but because of the large girth of thighs, they walk slightly bow-legged. This type of gait transfers the load bearing area of the knee joint medially. This can lead to arthritic involvement in the medial side of the knee joint. The knee joint is very important in helping absorb the shock when the heel strikes and obese people tend to put less stress on the knee joint. As a result, they spend more time in stance phase to reduce that stress as much as possible.

Kinetic values of this study did not result in significant differences between the two groups except in the minimum medial force and the time of the maximum medial force. The minimum medial force (X_{min}) was significantly different between the groups. Unlike obese subjects, lean subjects yielded the same results for X_{min} as Chao et al. (1983).

Pronation allows free motion at the transfer tarsal joint, so the foot remains flexible (Rodgers, 1988) thus aiding shock absorption at heel strike. The results of Xmi_n parameter indicated that obese subjects may not pronate as much as lean subjects during support. Obese subjects may pronate less, as indicated by the X_{min} value, meaning that more stress may be placed on the ankle joint because the joint is not in a flexible position (MacPoil and Knecht, 1985).

The results of lateral force (X_{max}) resulted in similar values for both groups. Obese subjects had an average greater X_{max} than the lean subjects. The occurrence of X_{max} resulted in a significant difference with X_{max} occurring earlier in stance for lean than obese subjects. Time of occurence X_{max} was 68.0 ± 18.5% stance phase for obese subjects and 29.6 ± 14.0% of stance phase for lean subjects. The results for the lean subjects are in agreement with Chao et al. (1983) and Kinoshita and Bates (1981). Obese subjects showed the greatest supination in late stance as evidenced by this parameter. This may occur because obese people tend to be flat-footed as a result of the heavy mass they carry that puts considerable stress on the arches of the feet.

CONCLUSIONS

It was concluded, within the limitations of the study, that obese subjects: 1) in their desire to conserve energy, walk slower and reduce the range of motion of the lower extremity joints; 2) pronate less than lean subjects suggesting that the subtalar joint is not in a flexible position to absorb the shock at heel strike.

REFERENCES

Adrian, M. and Cooper, J. M. (1989). Biomechanics of Human Movement. pp. 277-291. Indianapolis, Indiana: Benchmark Press, Inc.

Cavanagh, P. R. (1985). The efficiency of human movement: A statement of the problem. Med Sci Sports Exer 17:304-308.

Chao, E. Y, Laughman, R. K, Schneider E. (1983). Normative data of knee motion and ground reaction forces in adult level walking. J Biomech 16(3):219-233.

Kinoshita, H. and Bates, B. T. (1981). Effects of two different load carrying systems on ground reaction forces during walking. In Biomechanics VIII-A. H. Matsui and K. Kobayashi (eds.). pp. 574-581. Champaign, IL: Human Kinetics.

Mann, R. A. and Hagy, J. (1980). Running, jogging, and walking: a comperative electromyographic and biomechanical study. Foot and Ankle 12:167-175.

Mann, R. A. and Hagy, John. (1980). Biomechanics of walking, running, and sprinting. Am J Sports Med 8(5):345-350.

McPoil, T. G. and Knecht, G. H. (1985). Biomechanics of the foot in walking: A functional approach. J Orth Sports Phys Ther 7(2):71-78.

Radin, E. L., Paul, I., Rose, L., Robert, M. (1972). Role of mechanical factors in pathogenesis of primary osteoarthritis. The Lancet 4:519-521.

Rodgers, M. M. (1988). Dynamic biomechancs of the normal foot and ankle during walking and running. Phys Ther 68 (12):1822-1829.