The Effect of Gender and Carried Loads on Normalized Maximum and Minimum Vertical Force Components in Walking

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SUMMARY

To inverstigate the effect of gender and carried loads on maximum and minimum floor reaction force components in verical direction during walking, 10 male and 10 female subjects were used. The weight of the carried loads were 0, 50, 100, 150, 200, and 250 N held in front of the walking subjects at about their centre of mass. Only the male subjects used all of the loads but the females performed the tests with only the loads 0, 50, 100, and 150 N. A gait study test rig was also used to measure the floor reaction force components during walking. The maximum and munimum reaction force components obtained from the subjects were then normalized by the total weights. The results indicated that only gender affected the normalized maximum and minimum force components significantly. The loads carried did not affect the two variables. There was no interaction effect of these two factors on the normalized maximum and minimum vertical force components. The results also suggested that the men presented greater normalized maximum vertical force component than the women. In contrast, the women produced bigger normalized minimum vertical force component than the males.

1. Introduction

At present, carrying heavey objects is quite common in performing various tasks in this country. Therefore it would be very useful to study the effect of the carried loads on maximum and minimum floor reaction force components in vertical direction during walking. The information obtained from this study may be applied in the areas of safety science. rehabilitation engineering,and medicine. Some studies related to load carrying have already been done including physiological and biomechanical assessments of the effect of carried loads (Males and Saunders 1979, Pierrynowski et al. 1981, Martin and Nelson 1985 and 1986, and Nigg et al. 1987). In the second approach, floor reaction force components were studied. Demoya (1982) compared the floor reaction force components in three directions : vertical, mediolateral, and antero-posterior, beneath militay boots and running shoes using 12 male and 9 female subjects running at 200 m/min. The conclusions were that the differences in peak amplitudes and time to the peaks were significant and marked variability was noted in the mediolateral component. Mean peak amplitudes were greater in boots for all of the three force components. Martin and Nelson (1985) studied the effect of carried loads on the combative movement performance of 16 male and 14 female subjects under 5 load conditions ranging from no load to about 37 kg. They reported that performance levels decrease in a nearly linear fashion as load was increased and the comparison of male and female-performances indicated significantly better performances for the males than the females for all tests. Martin and Nelson (1986) investigated the effect of carried loads on the walking patterns of 11 men and 11 women walking at 1.78 m/s with no load and the loads of 9, 17, 29, and 36 kg. They concluded that males and females displayed significantly different gait pattens under all load conditions and these patterns were affected by the increases in carried loads.

1.1 Objective

The aim of this work was to learn the effect of gender (male and female) and carried loads (0, 50, 100, 150, 200 and 250 N) on maximum and minimum vertical force components.

2. Methodology

2.1 Subject

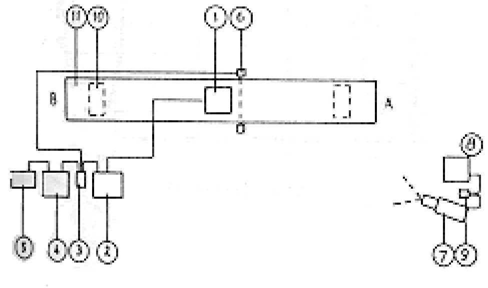
Ten male and 10 female subjects who had no known disorders which could affect their walking patterns were used for this investigation. The mean values and standard deviations for age, height, leg length and body mass were 29.1 (+8.0) years, 170.1 (+5.7) cm, 85.9 (+3.8) cm, and 65.6 (+6.2) kg for men and 30.3 (+7.4) years, 159.7 (+3.9) cm, 80.9 (+3.0) cm, and 52.1 (+5.7) kg for women respectively, The leg length was defined as the vertical distance between the floor surface and the subject's greater trochanter. The measurements of the height and leg length were done when the subjects were wearing shoes.

2.2 Materials used

The only materials used in this study were shoes and the weights to be carried. For the shoes, all subjects wore their own casual shoes with soft heel materials. The average values and standard deviations of the heel height were 2.3 (+0.7) cm for men and 1.9 (+1.0) cm for women. The weights used were 50, 100, and 200 N metal discs which were easy to be handled. These three discs were used to make up the weights of 50, 100, 150, 200, and 250 N to be carried by the subjects. Since this work was done in New South Wales (NSW), Australia, it had to comply with the state's regulations, According to the NSW state legislation on maximum loads for manual lifting for women and young persons, the female subjects were allowed to carry only the weight up to 150 N (ACTU/VTHC 1983).

2.3 Instrumentation

The gait study test rig developed at the Centre for Safety Science, the University of New South Wales, was used to carry out the tests. This test rig has been built up by the Centre. Its main components consist of a six-components loas platform (Kistler 9281B11) placed in the middle of a 0.8 m wide X 6.0 m long walking platform, a charge amplifier unit (kistler Type 9807),and a microcomputer (IBM Compatible). The sensitivities of the load platform in vertical direction is less than 10 mN. This system was used to measure the floor reaction force components of the stance foot in walking. The motion recording system included a video camera (Sony, V.- 8), a video recorder (National AG 6200), and a video time (VTG-22). Two pieces of aluminium foil taped to the walking platform were used to obtain the sujects' footprints. These foolprints had fire steps between them. Then the walking patterns for each walk : step length, cadence, and walking speed could be estmated through these footprints and the time displayed on the TV monitor. The instrumentation arrangement for this test rig is illustrated in figure 1. In doing the tests, the subjects usually started to walk from end A of the walking platform to end B. According to the arrangement of the starting point of the walk for each subject, the foot which hit the load platform would interrupt the electronic light switch (Item 6 in Figure 1) before striking the load platform. This interrupiton would trip the computer to start taking the data. In collecting the kinetic data from the walking subjects, a software package called ASYST was used.



1. Load Platform
2. Electronic unit for 1
3. Interface box
4. Personal computer
5. Printer
6. Electronic light switch
7. Video camera
8. Video recorder
9. Video timer
10. Aluminium foil
11. Walking platform

Figure 1 Instrumentation arrangement

2.4 Experimental procedure

There were two major parts of measurement in this work : the measuring of kinetic and kinematic data. For kinetic data, the floor reaction force component in vertical direction was measured using the load platform. Then the maximum and minimum vertical force components for each walk could be determined. For kinematic data, the walking time in five walking steps was recorded by means of the video system. These five steps were in the middle of the walks. The distance between the five steps was determined through the two footprints on the aluminium foil immediately after each walk.

Before doing the tests, all subjects practised walking on the walking platform until they became familiarised with the system. The sequence of all of the loads carried were statistically randomized to minimize training effects. The loads used in this study were 0 (no extra load), 50, 100, 150, 200, and 250 N and named load conditions 1, 2, 3, 4, 5, and 6 respectively. For the male sujbects, all of the load conditions were used. Only the load condition 1, 2, 3, and 4,were used with the female subjects. In the load condition 1, the subjects walked without any extra load but their own body weight, clothes, and shoes. In the load condition 2-6, the subjects held each of the loads in front and at about the centre of mass of their bodies using their two hands. This carrying method was considered as a normal method of carrying heavy objects for a short distance. Figure 2 illustrates a walking subject carrying the 200 N weight.

Each subject performed 5 walks for each load condition and struck the load platform with the right foot. To make sure of obtaining natural gait, the walking patterns were not controlled. Instead the subjects were asked to walk as normally as possible. All subjects completed all of the tests in a single test session.

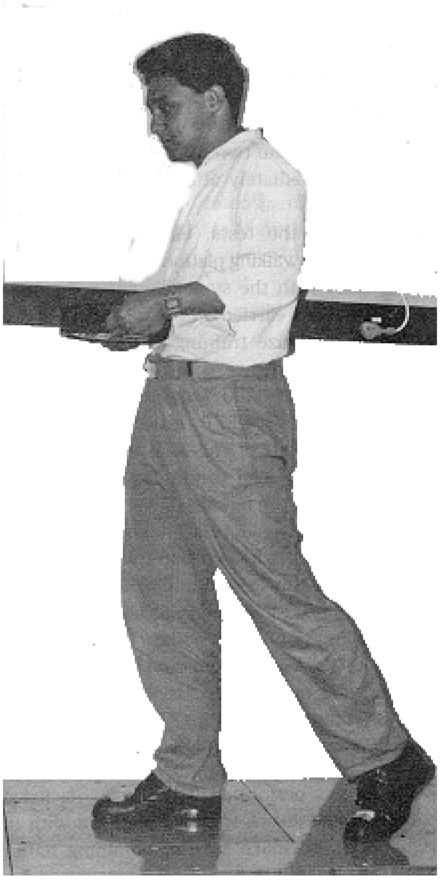
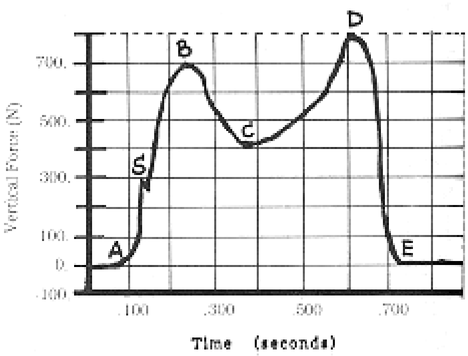


Figure 2 A Walking subject carrying the 200 N weight.

2.5 The floor reaction force component in vertical direction

In normal walking, the stance foot inserts force to the groud in various directions. The load platform used in this study can detect the ground reaction force components in three direction : vertical (Fz), horizontal in the walking direction (antero-posterior or Fy), and horizontal normal to the walking direction (medio-lateral or Fx). But only the vetical force component (Fz) is presented in this work. Figure 3 illustrates the vertical force component in normal walking.



Time (seconds)

Figure 3 Typical floor reaction force component in vertical direction

As presented in Figure 3, the vertical force component starts to rise when the swing foot strikes the floor (A). Then more force is applied to the ground when the body is moving forward.

The force reaches the first peak (B) and comes down to the bottom (C) then goes up to the second peak (D) and then comes down to the point that the stance foot leaves the floor. In most cases, there were small spikes (S) between the points A and B.

The data recorded in this study were the maximum vertical force component (either at B or D the greater one was selected) and the minimum vertical force component (C).

3. Recorded data

The data obtained from the tests are presented in Table 1 and Table 2. Table 1 shows the average values and standard deviations of the normalized maximum vertical force components in various load condition. Each value in this table was averaged from 10 walking subjects and each subject performed 5 walks for each load condition. Table2 illustrates the average values and standard deviations of the normalized minimum vertical force component

Table-1 Means and Standard Deviations of the Normalized Maximum Vertical force Component in Varous Load Conditions for Male and Female Subjects

Gender \ Load Cond	1	2	3	4	5	6
Male	1.2 (0.1)	1.3 (0.1)	1.3 (0.1)	1.3 (0.1)	1.3 (0.1)	1.3 (0.1)
Female	1.2 (0.1)	1.2 (0.1)	1.2 (0.1)	1.2 (0.1)		

Table-2 Means and Standard Deviations of the Normalized Minimum Vertical force Component in Various Load Conditions for Male and Female Subjects

Gender \ Load Cond.	1	2	3	4	5	6
Male	.7 (0.1)	.7 (0.1)	.7 (0.1)	.7 (0.0)	.7 (0.0)	.7 (0.1)
Female	.8 (0.1)	.7 (0.0)	.7 (0.1)	.8 (0.0)		

3.1 Handling of the recorded data

The data taken from the tests were handled using the statistical software calledSPSS/PC+to analyse the variance. To obtain the effect of gender and carried loads on the observed variables, the subprogram called analysis of variance (ANOVA) was selected. In using the sub-program, only the load conditions 1,2, 3,and 4 were used for the male subjects. The reason for using only the 4 load conditions was because there were only 4 load conditions for the female subjects.

4. Results

For the effect of gender and carried loads on the normalized maximum vertical force component, the ANOVA results are presented in Table 3. The results indicated that only gender affected this variable significantly ($p = .001$). The carried loads used in the tests did not affect this variable. The data presented in Table 1 suggested that the men had greater maximum vertical force components than the women. The average values of this variable regardles of the load conditions were 1.3 and 1.2 times the total weight for the male and female subjects respectively. There was no interaction effect of gender and carried loads on the normalized maximum vertical force component. The relationships between this variable and the carried loads for male and female subjects are presented in Figure 3.

Table-3 The Effect of Gender and Carried Loads

on the Normalized Maximum Vertical
Force Components

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F.
Main Effects	.067	4	.017	3.084	.021
Gender	.060	1	.060	11.056	.001
Carried Load	.007	3	.002	.426	.735
2- way Interactions	.007	3	.002	.396	.756
Gender X Carried Loads	.007	3	.002	.396	.756
Explained	.074	7	.011	1.932	.077
Residual	.394	72	.005		
Total	.468	79	.006		

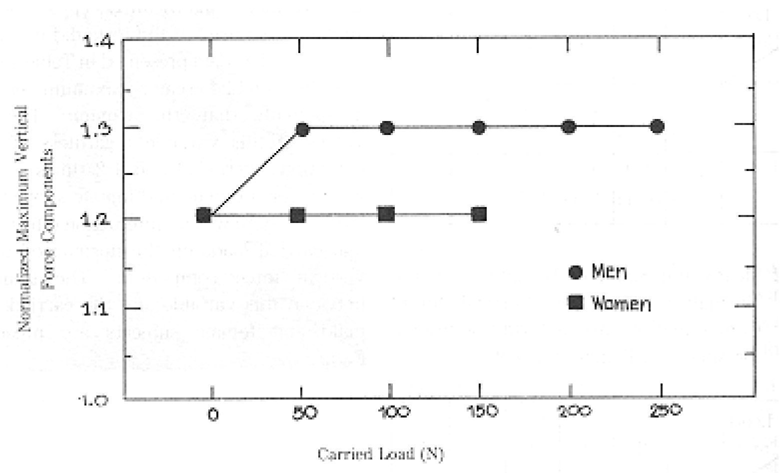


Figure 3 Normalized maximum vertical force components as a function of carried loads.

For the effect of gender and carried load on normalized minimum vertical force component, the ANOVA results are illustrated in Table 4. These results indicated that only gender affected this variable significantly (P < .001). The data shown in Table 2 indicated that the average values for this variable were 0.7 and 0.75 times the total weight for male and female subjects respectivel. The women presented greater normalized minimum vertical force components than the men. The relatationships between the normalized minimum vertical force components and the carried loads for male and female subjects are illustrated in Figure 4.,

Table-4 The Effect of Gender and Carried Loads
on the Normalized Minimum Vertical Force Components

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif. of F.
Main Effects	.081	4	.020	4.826	.002
Gender	.072	1	.072	17.053	.000
Carried Load	.010	3	.003	.750	.526
2- way Interactions	.002	3	.001	.158	.942
Gender X Carried Loads	.002	3	.001	.158	.942
Explained	.084	7	.012	2.825	.012
Residual	.304	72	.004		
Total	.388	79	.005		

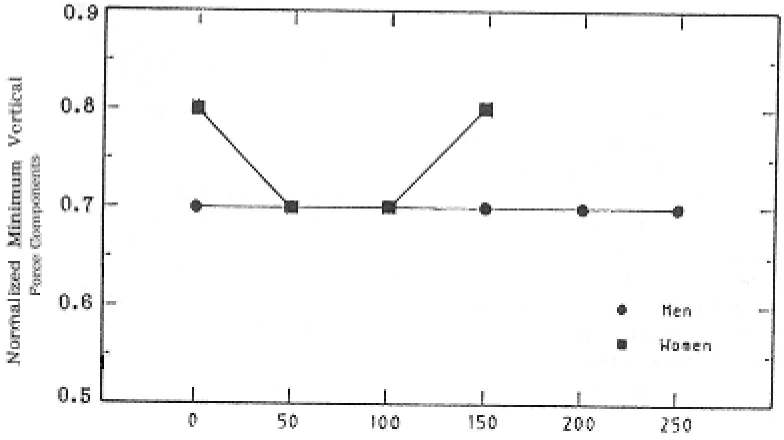


Figure 4 Normalized minimum vertical force components as a function of carried loads.

According to Figure 3, the maximum vertical force component can be either at the Peaks B or D. The data observed from the tests (500 walks) indicated that almost all of the maximum vertical force components were at the Peak B (approximately 82.4%).

Walking speeds in the tests were also varied when the subjects walked with various load conditions. The variations of the walking speeds according to the carried loads are presented in Figure 5.

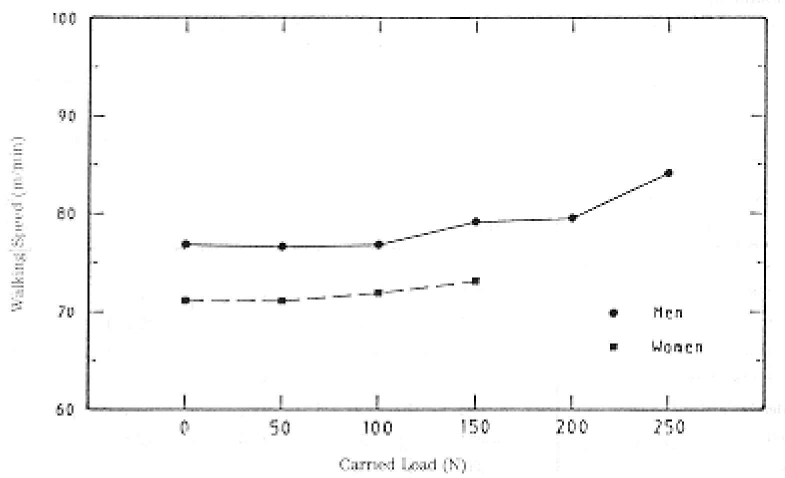


Figure 5 Walking speeds as a function of carried loads.

5. Discussion

Eke-Okoro, and Sandlund (1984) reported that the load was the factor that significantly reduced the velocity of travel, and this was due both to significant reduction in stride length and stride frequency. This report was from the study of street pedestrians on a level sidewalk of a busy street, at about 100 m from a major shopping centre. The load mentioned in the report could be the bags bought from the shopping centre. As illustrated in Figure 5, the more the carried loads, the faster the walking speeds presented. The main reason for the difference in the walking speeds could be the conditions used in the both investigations. It should be mentioned here about the effect of the hands in the tests. In walking without any extra load (Load Condition 1), the hands were swinging during walking. In walking with the loads, the hands did not swing at all. Therefore, the hands may or may not affect the vertical force components. To clearify this point, the investigation on the effect of hands on the vertical force components may useful.

The values of the maximum vertical force component for the men in most cases were 1.3 times the total weigh. Normally, 1.3 times body weight is not so big. If the body weight is 686.7 N (70 kg), the maximum vertical force of about 892.7 N will pass through various joints and bones of the lower extremities. If the load of about 300 N is being carried in walking, the maximum vertical force component of about 1282.7 can be expected. Therefore, speical care must be taken into consideration in order to avoid injuries that might occur carring loads.

6. Conclusions

This study investigated the effect of gender and the magnitude of carried loads on normalized maximum and minimum vertical force components in walking. The results suggested that only the gender influenced the two variables (normalized maximum and minimum vertical force components) significantly. The carried loads in the tests did not affect the two variables. There was no interaction effect between gender and carried loads on these variables. The results also indicated that in walking, the maximum vertical force component was nearly unchanged at about 1.3 times the total weight for the men and about 1.2 times the total weight for the women. These results suggested that the maximum vertical force components in times of total weight are essentially the same whether the weight is of body or the load.

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