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Kinetic Evaluation of Some Daily Activities

C. Bozer, B. S. Cigali, E. Ulucam

Faculty of Medicine, Department of Anatomy, Trakya University, Edirne, Turkey

The reaction force from the ground is called the ground reaction force (GRF). The GRF is important external force acting upon the human body in motion and we use this force as propulsion to initiate and to control our movements.

We have measured the GRF on the foot by using an insole system and evaluated the net forces acting on the foot during unobstructed level walking and stepping over obstacles with the opinion that rarely is the path of walking perfectly level and clear.

As a result, unobstructed level walking and stepping over obstacles data showed statistically significant differences particularly for Fmax1 and Tmax1 variables.

Key words: kinetics, ground reaction force, level walking, obstacle.

Introduction

Walking is one of the most basic forms of human motion. The basic unit of walking is the gait cycle, which is typically recorded from the time one foot strikes the ground until that episode recurs and starts the next, repeating cycle [14].

Biomechanics is the study of normal mechanics (kinetics and kinematics) in the musculoskeletal system by analyzing forces and their effects on anatomical structures. And kinetics studies the relationship between the forces acting on a body and the changes they produce in the motion of the body. Kinetics concentrates on the study of forces associated with motion using force plates, pressure platforms and/or inshoe sensors providing a direct description/orientation of foot posture. The basic principles of kinetics are Newton's three laws of motion. Newton's third law, the law of action and reaction (to every action there is an equal and opposite reaction), is very important for the study of gait and other aspects of biomechanics. This law relates the forces interacting between the foot and the floor as always being equal and opposite. In other words, the action to the ground is always accompanied by a reaction from it. The unit of force is Newton (N) that is defined as the force necessary to accelerate a mass of 1 kg by 1 ms^{-2}. Forces in walking can be internal (such as muscle activity, ligamentous constraint or friction in muscles and joints) or external (such as ground reaction forces created from external loads) [1, 3, 9, 10, 12, 15].

The reaction force from the ground is called the ground reaction force (GRF). The GRF is important external force acting upon the human body in motion. We use this force as propulsion to initiate and to control our movements. The GRF is represented by three perpendicular directions: forward, lateral and vertical. The GRF is counteracted and controlled by the function of the lower limb muscles which, in conjunction with the bones, joints and tendons of the foot, controls the kinetic progression of foot with the ground [1, 14].

Rarely is the path of walking perfectly level and clear. Commonly, during walking a person is confronted with a course consisting of obstacles of various heights, widths, depths and compositions like water, mud, drainage, sidewalks, stairs, doorsteps etc.

We have measured the forces of ground reaction on the foot by using an insole system and evaluated the net forces acting on the foot during unobstructed level walking and stepping over obstacles.

Materials and Methods

Ten able-bodied young adult subjects (5 males — 5 females) aged between 19 and 24 were taken place in this study. The Medical Ethical Committee of Trakya University Faculty of Medicine Hospital approved the study and the subjects signed an informed consent.

Subjects wore boot-like designed flat shoes of Zebris© with insole-mats inserted in them. Subjects were asked first to walk at their natural rhythm and then cross the obstacles which is 0 cm height from the ground (sticky tape) and 2 cm height (doorstep), across the 8 m long gait laboratory walkway. They were not asked to restrict their movement, including arm swing. After a few trials of familiarization, the ground reaction forces were recorded from both sides by Zebris 3D Motion Analysis System©. For each subject at least three individual trials were collected. This system has insole mats connected to an analog to digital converter by a cable adapter. Vertical GRF is sampled continuously at 60 Hz. Data converter was connected to a computer to enable the time versus force graphics to be seen while the subject was walking. Data from hind foot, middle foot, forefoot lateral side and forefoot medial side were recorded separately in the same steps. The hind foot is from 0% to 30%, midfoot is from 30% to 60% and forefoot is from 60% to 100% of the foot length. The forefoot divides equally into forefoot lateral and forefoot medial sides. Each of these foot areas are represented with a time versus force graphic in the report paper and it is possible to convert the data as a text file to process in a worksheet program. The maximum value of each kinetic curve was extracted for each subject's leading limb (limb crossing the obstacle first) of selected step (Fig. 1).

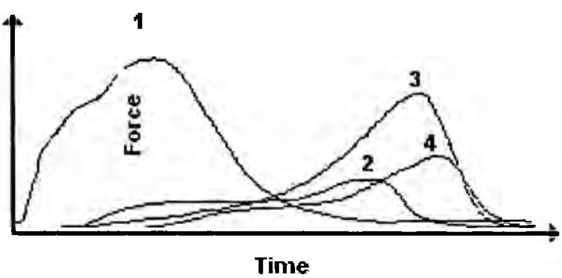

Fig. 1

The force-time data were normalized to body weight in order to compare force magnitudes across subjects independent of body mass. Fmax1 - Tmax1, Fmax2 — Tmax2, Fmax3 — Tmax3 and Fmax4 — Tmax4 variables are for the hind foot, midfoot, forefoot lateral side and forefoot medial side respectively (Fig. 2).

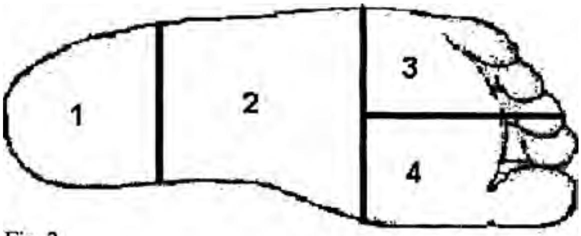

Fig. 2

Descriptive statistics were calculated for accordance to normal distribution. It is tested with a One-Sample Kolmogorov — Smirnov test. The statistics were compared with the use of a one-way analysis of variance (ANOVA) and a post-hoc Bonferroni t test. ANOVA was used to see if there are differences between level walking, stepping over 0 cm and stepping over a doorstep. Bonferroni t test was used for evaluation of differences between the walks. Significance level was set at $p < 0.05$.

Results

All subjects adapted their gait easily and naturally to the obstacles. None of them showed any difficulties in performing the task. Unobstructed level walking, stepping over 0 cm and stepping over a doorstep data showed statistically significant differences particularly for Fmax1 and Tmax1 variables (Table 1).

Fmax1 and Tmax1 values were significantly different between unobstructed level walking and crossing over the doorstep (p=0.030 for Fmax 1 values and p=0.000 for Tmax1 values). Also, Tmax1 values between unobstructed level walking and crossing over 0 cm obstacle was significantly different (p=0.035<0.05). There was no significant difference in other force and time values between the tests.

Discussion and Conclusion

In this basic study about human gait analysis, we see that different conditions affect gait. According to the results; in crossing over the doorstep, the GRF on the hind foot region increases and the time needed to reach maximum GRF shortens accord-

T a b l e 1. Differences of time and force values between unobstructed level walking, crossing over 0 cm and crossing over the doorstep. The units are "N/kg" for force and "ms" for time.
(Statistically significant differences are marked in bold, p<0.05)

Test	Fmax1±SD	Tmax1±SD	Fmax2±SD	Tmax2±SD	Fmax3±SD	Tmax3±SD	Fmax4±SD	Tmax4±SD
Level Walking	**5.05±0.71**	**0.20±0.04**	1.06±0.33	0.43±0.13	2.82±0.94	0.62±0.60	2.69±0.81	0.65±0.49
0 cm	5.47±0.93	**0.16±0.05**	1.13±0.44	0.35±0.14	3.07±1.27	0.62±0.89	2.49±1.17	0.64±0.08
Doorstep	**5.79±0.84**	**0.14±0.04**	1.11±0.04	0.36±0.14	2.91±1.06	0.62±0.05	2.72±1.01	0.63±0.06

ing to unobstructed level walking. Also, in crossing over the doorstep maximum GRF time shortens according to crossing over a 0 cm obstacle. In normal human gait, foot's first contact surface with the ground is the heel which is named as "initial contact" in gait terminology. So we can say, the heel of the leading foot exerted greater force during the initial contact phase, and the time to reach the maximum point of this force shortens in obstacle crossing. These findings are consistent with earlier literature [2, 4-8, 11, 13, 16].

The foot is critical to an understanding of the mechanics of gait, as the foot often affects the normal motion pattern of the entire lower extremity. Alterations of normal foot mechanics can adversely influence the normal functions of the ankle, knee, hip and even the back. Measurement of GRF can be used to assess the loads to which the human body is subjected in normal activities like walking, stepping over obstacles, stair ascent and descent, running, sports etc. Measurement of GRF with insole systems is useful and advantageous because there is no constraint on foot placement and it is possible to measure several consecutive strides during gait and it provides detailed information specific to each region of the foot sole.

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