The International Journal of Engineering and Science (IJES)
|| Volume || 8 || Issue || 2 Series I|| Pages || PP 11-16 || 2019 ||
ISSN (e): 2319 – 1813 ISSN (p): 23-19 – 1805

Ground Reaction Force At Athletic and Paralympic Runners – 3d_Grfs during Barefoot Running

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ABSTRACT
The subjects were classified into three groups: 10 male athletics runner, 4 female athletics runner, and 3 male paralympic runner (T45-47 (Upper limb/s affected by limb deficiency, impaired muscle power or impaired passive range of movement)). Data were captured using a Basler- scout motion analysis system (Innovision Systems, Columbiaville, MI, USA) and AMTI force platform (BP600900, AMTI Inc., Watertown, USA). Variability in groups was most marked during initial contact (IC). The mean peak of Vertical GRF components was (372.920N), (357.717N) and (271.343N) in male athletics runner, male Paralympic runner and female athletics runner respectively. At the toe-off (TO), a male Paralympic runner was the highest. The mean peak vertical and anterior-posterior ground reaction forces of the male Paralympic subjects at push off were lower.
Keywords: *Barefoot running, Amti, Paralympic runner, Motion capture, Innovision system*

Date of Submission: 24-01-2019 Date of acceptance: 08-02-2019

I. INTRODUCTION

An essential part during athlete locomotion analysis in any activity (stand, run, jump, skip, balance and landing….) is the accurate and efficient assessment of motion events, initial contact (IC) and toe-off (TO) for example. Three-dimensional estimation of ground reaction forces (3D-GRF) is an important point in the biomechanical analysis procedure, especially at Biomechanical Engineering (Sports activities).

Many scientific studies investigated the ground reaction forces, and kinematic variables were found to vary with shoe geometry and shoe hardness[1]. The relationship between kinematic and kinetic variables was also studied using dynamic simulation models[2]. Other studies investigated spatiotemporal variables, ground reaction forces during barefoot and shod running [3].

Some aspects concerning the 3DGRFS are still not well understood. Variations came from differences between genders and classification of athletes (Athletics, Paralympic) during barefoot running. This insight could be enhanced by studying the maximum values of vertical, propulsive, braking, medial and lateral ground reaction forces. These values were measured for different groups (male athletics, female athletics, and male Paralympic). By using a force platform (BP600900-AMTI) for the 2-Point Run Analysis, the values of vertical GRF, times of initial contact (IC) and toe-off (TO) during running cycle can be seen for every group.

The purpose of the current study is to provide a comprehensive description of barefoot running using a statistical analysis results and to compare the results between athletics and Paralympic. Therefore, ground reaction forces are measured from the sagittal and frontal plane.

II. RESEARCH ELABORATIONS

2.1 Subject

During experiments, fourteen healthy athletic runners (ten males and four females from the strongest local sports teams in Iraq) and three male Paralympic subjects from the Iraqi national Paralympic team were recruited. All of them were free of injuries at the time of the trial. Subject characteristics are shown in (Table 1).

Table 1 Subject parameters

Group type / Parameters	Athletics-male mean ±(SD)	Athletics-female mean ±(SD)	Paralympic mean ±(SD)
Age (year)	24.9 ± (4.748)	24.5±(5.196)	23 ± (6.082)
Height (m)	1.764 ± (0.075)	1.637 ±(0.036)	1.703± (0.0416)
Weight (N)	687.87± (102.118)	597.25±(162.861)	592.7 ± (26.265

2.2 Experimental

Basler-scout (scA640) three- dimensional motion analysis system (Innovision system, inc., USA) and AMTI force platform (Advanced Mechanical Technology Inc.) were used to collect spatiotemporal variables data for running cycle.

The infrared light emitting diodes (LED) of the 8-Basler_scout cameras had a flash rate of 120Hz. The cameras were synchronized with the rigid force platforms, which were set up as in (Figure 1).

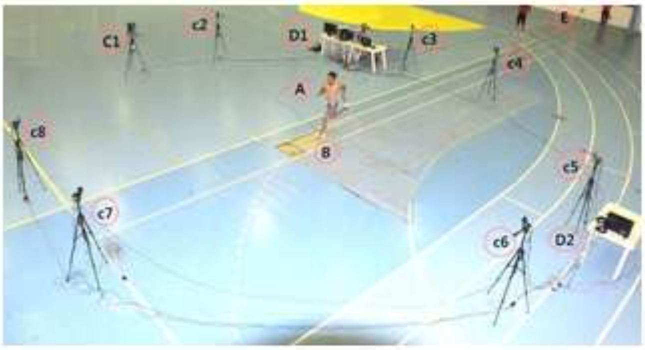

Figure 1 Experimental work (3D-Motion Capture). **A:** Athletic runner, **B:** Force platform, **C (1-8):** Cameras &Infrared light, **D (1-2):** Computer system analysis, **E:** Sync laser system

Also, the analytical system was connected with the laser circuit to synchronize the starting point for all trials, (Figure 2).

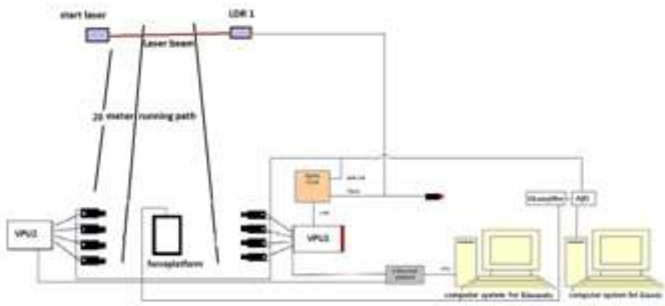

Figure 2 Experimental work (system connections)

Body heights (in meter) and weights (in Newton) of the subjects were measured. All subjects were requested to wear shorts (for males), and a tight-fitting T-shirt with track pants (for females). Subjects did a body muscles warm up with Swedish exercises for at least 5 to 10 minutes before trials.

The surface-mounted markers approach was adopted to track the activities [4]. The selected approach improves the problem of skin movement relative to underlying tissue [5]. Trial recording begins when the runner passes across the laser beam by his or her head. The synchronized system starts recording for a specified 8 seconds.

MAXPRO (version 1.6.1) three-dimensional motion analysis system and AMTINetforce (version 2.4.0) force platforms were used to record data for the running cycle.

2.3 Data Analysis

For clinical analysis purposes, the ground reaction forces were calculated for all 17 trials, by AMTI Biosoft (version 2.3.0). The ground reaction force is resolved into three constituents orthogonal to each other along the three-dimensional system (Figure 3). The constituents are labeled as follows: Fz, the vertical constituent, Fy, the anterior-posterior constituent and Fx, medial-lateral constituent.

First, maximum values 3DGRF were calculated on a force platform. Times of initial contact (IC) and toe-off (TO) be known from statistical analysis results and values of vertical force are calculated. Step times were calculated By MAXTRAQ (version 2.3.3). Mean and standard deviations were used to describe the individual and general results.

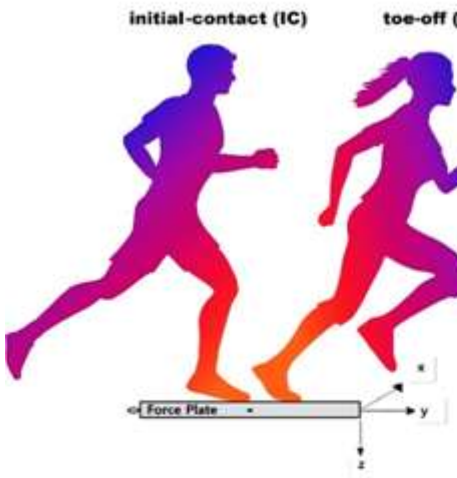

Figure 3 Initial-Toe foot strike on Force Platform

III. RESULTS AND DISCUSSION

In order to gain more insight into the adaptation of athletes to changes in the mechanical characteristics of the interface between foot and ground, differences in ground reaction forces were studied (in general or with specific points such as (IC) and (TO) during barefoot running between male (Athletic and Paralympic) with female Athletic).

The characteristics of the vertical GRF during the initial –toe strike depend upon the initial conditions at land and, subsequently, upon the way the segments of the body are decelerated during the impact phase [6]. The results will be discussed in this order.

3.1 Spatiotemporal Variable in IC and TO

The results are presented in (Table 2). Mean peak vertical GRF associated with each athletics runner type group (male athletics, female athletics, and male paralympic) are presented in (Figure 4).

Male athletics in (IC) point are characterized by larger mean peak vertical GRF than in male paralympic and female athletics. While male athletics in (TO) point are characterized by smaller mean peak vertical GRF than in male Paralympic and female athletics.

Initial-Toe foot strike point time (ms) is the time between initial strike and toe off (i.e., time when foot is in contact with ground) [7].

Strike time (ms) of running female athletics is 137 ms, and ± 14 standard deviation for all subjects in group. For male Paralympic the time is 130 ± 23 ms and for male athletics is 109 ± 37 ms.

Table 2 Mean (±SD) peak vertical GRF at 2-points and Time during running- cycle (IC &TO

	Initial Contact (IC)			**Toe-off (TO)**		
Group Type	Athletics-male Mean ±(SD)	Athletics-female Mean ±(SD)	Paralympic Mean ±(SD)	Athletics male Mean ±(SD)	Athletics-female Mean ±(SD)	Paralympic Mean ±(SD)
Time (ms)	3354 ±(0177)	3954 ±(0223)	3458 ±(0058)	3455 ±(0213)	4091 ±(0237)	3580 ±(0211)
Vertical GRF (N)	372.920 ±(204.495)	271.343 ±(45.045)	357.717 ±(39.216)	15.130 ±(3.985)	17.387 ±(3.839)	21.828 ±(4.357)

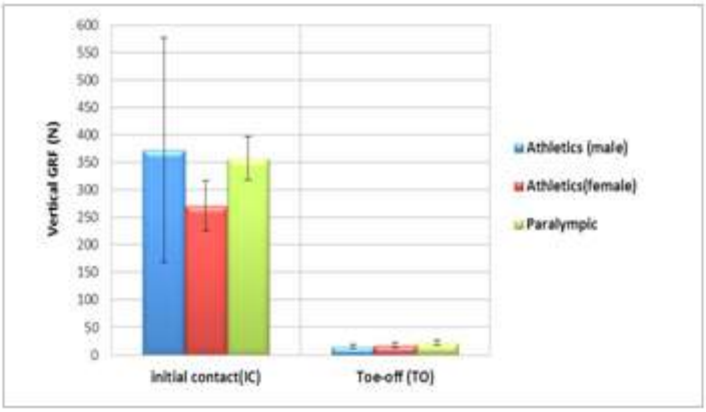

Figure 4 Mean (±SD) peak vertical GRF at 2-points during running- cycle (IC &TO)

3.2 Ground Reaction Forces

The three-dimensional of ground reaction forces (3D-GRF) were normalized to body weight (BW) for comparison.

(Figure 5a) shows the resultant maximum mean vertical ground reaction in male Paralympic athletics group 229.739 ± 106.737 BW, BW was significantly lower 335.576 ± 25.462 BW than male athletics group while female athletics group was 289.171 ± 13.1327 BW.

Antero-posterior mean propulsive force of the male Paralympic athletics group was 21.455 ± 2.281 BW, BW was also significantly smaller than the female athletics group 49.528 ± 7.9222 BW. (Figure 5b).

On the other side, the mean medial force of the male paralympic athletics group 19.511 ± 5.340 BW was larger than the female athletics group 12.417 ± 7.9222 BW (Figure 5c). This increase maintains balance, controls the medial-lateral balance in order to perform a smooth forward motion and the forces changed systematically with walking speed during the early single and stance foot.

The maximum mean force-time curves for the foot - strike relative to the time of trial (8 s) shown in (Figure 5d, e, f) and (Table 3).

A marked difference in the mean anteroposterior force component of the ground reaction forces (A-P GRF) was found between the male Paralympic athletics and male athletics groups during the braking phase of the ground contact. The male athletics group exhibited a maximum mean curve rising gradually from the male paralympic athletics group (Figure 5e).

In (Figure 5d), the maximum mean vertical component of the ground reaction force for male athletics group shows a curve rising to approximately 1.7 times from ground reaction force of male paralympic athletics group. These forces are caused by an increase in the ability of Human muscle system in controlling the vertical displacement of male athletes.

In addition, the maximum mean of mediolateral (M_L GRF) force component in male paralympic athletics group show speak amplitude smaller than the female athletics group but less time (Figure 5f), Which caused a directional change in and reduced the length of the step in females.

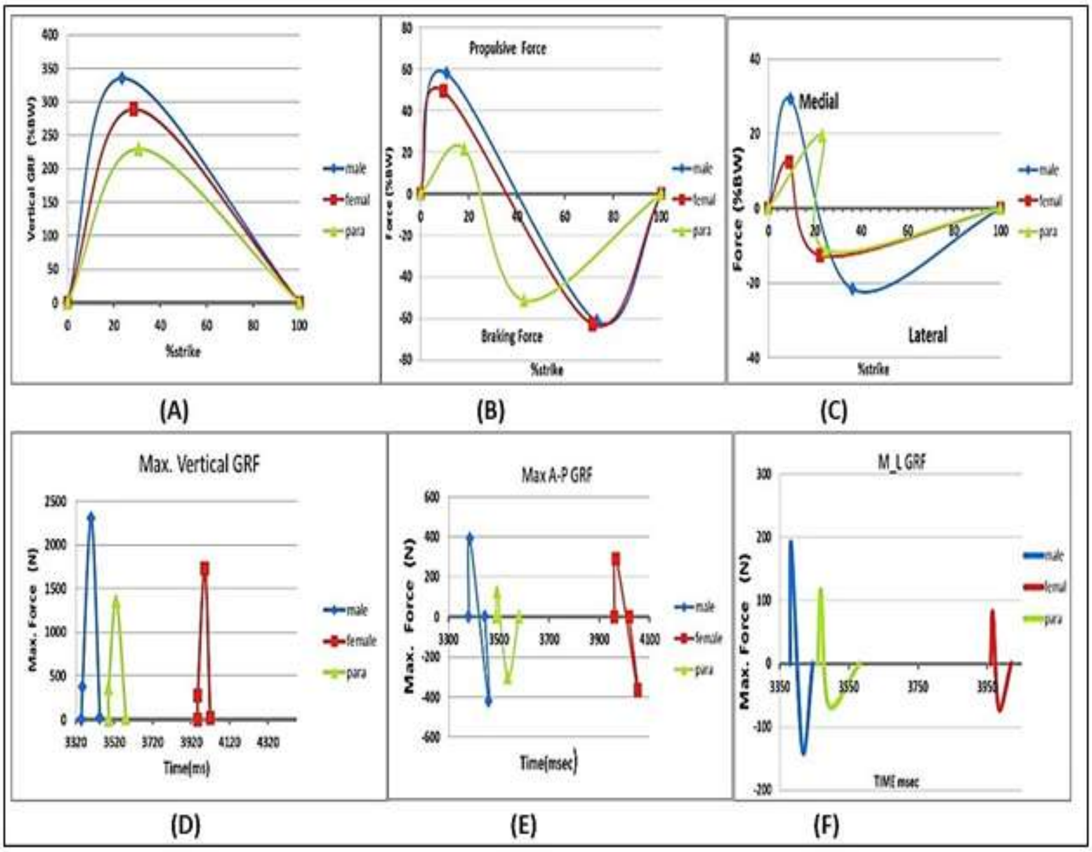

Figure 4 Mean peak 3D-GRF during running- cycle, **(A)** Vertical Force (%BW), **(B)** Anterior–posterior Force (%BW), **(C)** Medial–lateral Force (%BW), **(D)** Max. Vertical Force (N), **(E)** Max Anterior–posterior Force (N), **(F)** Max. Medial–lateral Force (N)

Table 2 Variables of the 3D Ground Reaction Forces (Means and Standard Deviations of seventeen persons at same conditions)

Group Type / Parameters	Athletics (mean ±SD)	Athletics (mean ±SD)	Paralympic (mean ±SD)
Max. Vertical GRF (N)	2300.553±310.051	1734.016±312.93	1355.851 ±309.805
Time(ms)	3400 ±0129	3991±0204	3530±0126
Propulsive Force (N)	388.770 ±91.485	290.614±62.198	126.320±24.696
Time(ms)	3385 ±0139	3966±0220	3494±00126
Braking Force (N)	-421.517±85.987	-364.354±59.467	-301.59±100.378
Time(ms)	3460.8±0143	4052.25±0230	3536±0020
Medial Force (N)	189.783±110.757	80.28425±56.591	115.4237±46.523
Time(ms)	3383±0136	3966±0228	3469.3±0066
Lateral Force (N)	-136.415±127.066	-70.995±13.441	-65.714±44.615
Time(ms)	3415±0128	3983.2±0209	3491±0087

IV. CONCLUSION

This study revealed the three-dimensional running activity characteristics between different types of runner group subjects at their barefoot running (male athletics, female athletics, and male Paralympic). The male athletics subjects run faster and with significant differences in some of the temporal-spatial parameters. The mean peak vertical and anteroposterior ground reaction forces of the male Paralympic subjects at push off were lower.

Future research should include a three-dimensional analysis, to study step running cycle by two-force platform or mobile shoe-transducers. Both methodological changes will permit better understanding of the inter-subject variability regarding kinetic parameters in the running cycle for all runner groups (athletics, paralympic).

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Yasir F. Jabber" Ground Reaction Force At Athletic and Paralympic Runners – 3d_Grfs during Barefoot Running" The International Journal of Engineering and Science (IJES), 8.2 (2019): 11-16