Biomechanics Analysis on Running

Mohd Yusof Baharuddin[1], Mohd Sayuti Mohd Salim[1], Adilah Hashim[1]
[1] Biomedical Electronics Engineering Program,
Schools of Mechatronics, University Malaysia Perlis, Malaysia

***Abstract*— Running is a complex coordination process that involves the movement of the entire body. Although human runs differently, but certain general features of running motion are common. The phases for running are similar as walking except in running there is no double support phase. Compared to walking, humans actually moves from one leg to the collateral leg while running which expends a tremendous amount of energy opposing gravity and absorbing shock during take-off and landing. This paper will study the current literature regarding walking and applied to the analysis of running gait comparing between shoe wear and bare foot point of view. The characteristics of the gait cycle and its relationship to the potential kinematics and kinetics parameter (including center of pressure measurements, raw force plate data, and joint moments) and the impact of changes in velocity, acceleration and angle. The research also will be hold at Biomechanics and Motion Analysis which equipped with two of Force Plate (Bertec), five of High Frequency Camera, and Qualisys Track Manager QTM as Windows-based data acquisition software with an interface that allows the user to perform 2D and 3D motion capture. At the end of the research we can conclude the interactions among the data and finally can develop an extending methodology to this research to the other variable for example different kind of shoes.**

***Keywords*— Running, Gait, force plate, biomechanics**

I. INTRODUCTION

Human gait is characterized by two main modes of locomotion; walking and running that differ in terms of both biomechanics and coordination. However, the usually considered defining difference is that walking entails a double (i.e., bipedal) support phase, whereas running entails a flight phase. As a result, both gaits differ in the timing of key events in the stride cycle: walking involves an alternating sequence of single and double support phases, while running entails alternating sequences of support phases (during which one foot contacts the ground) and nonsupport phases (during which both feet are off the ground).

The gait cycle is the basic unit of measurement in gait analysis. The gait cycle begins when one foot comes in contact with the ground and ends when the same foot contacts the ground again. These moments in time are referred to as initial contact. Stance ends when the foot is no longer in contact with the ground. Toe off marks the beginning of the swing phase of the gait cycle.

During running, toe off take place before 50% of the gait cycle is accomplished. There are no periods when both feet are in contact with the ground. As an alternative, both feet are above ground twice during the gait cycle, one at the start and one at the last part of swing [1-2], referred to as double float. The timing of toe off depends on speed. Fewer times is spent in stance as the subject moves faster. Faster runners and elite sprinters spend much less time in stance than that. World class sprinters toe off as early as 22% of the gait cycle [3].

II. MATERIAL AND METHODS

Only one subject was assigned for the purpose of this study. The subject needs to run on the walkway platform with shoe and bare foot. The experiment was carried out in the Biomechanics and Motion Analysis Laboratory. A brief explanation of the experiment and its significance was provided by the teaching engineer and lecturer as well as the prior to the initiation and caution of the procedure.

The subject was asked to measure his weight and height and record the file name that to be analyzing by QTM software. Markers were placed bilaterally on hip, knee, ankle and toe of each subject. Subject walked along the platform with self-selected pace and when reaches the force plate, he was asked to step on each force plate with different foot. As we want to acquire normal running, the subject was asked to run several times before data taken.

The Biomechanics and Motion Analysis Laboratory has an instrumented, horizontal walkway. The walkway is an 8m long plywood floor build with 2 set of force plate leveled on the center of the platform. A five-camera motion capture system (ProReflex infrared, Qualisys) was applied to capture the range of motion of hip, knee, ankle and toe joints in sagittal plane during walking. Eight reflecting markers were placed at different joint positions for defining joint motion. The marker protocol was based on the Helen Hayes model. The commercial software, Qualisys Track Manager (QTM), an interface that allows the user to perform 2D and 3D motion capture was used to acquire kinetic and kinematic data during gait.

III. Results and Discussions

According to the *Newton's Law of Gravitation*, any two objects with masses attract each other and the magnitude of this attracting force is proportional to the product of the masses and inversely proportional to the square of the distance. This also holds for the gravitation between the earth and an object on the earth. The gravitational force acted upon an object by the earth is called gravity or weight of the object.

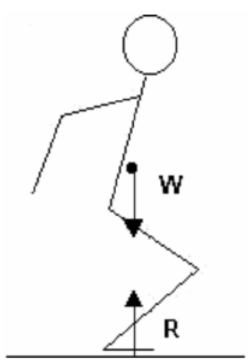


Figure 1: Two external forces acting on the subject's body are weight (W) and the ground reaction force (R).

Since we always have contact with the ground due to this gravity there always is an interaction between our bodies and the ground. According to the *Newton's Law of Reaction*, there is an equal and opposite reaction to every action. In other words, the action to the ground is always accompanied by a reaction from it. This reaction force from the ground is called the *ground reaction force*, R as stated in Figure 1. The ground reaction force is important external force acting upon the human body in motion. We use this force as propulsion to initiate and to control the movement.

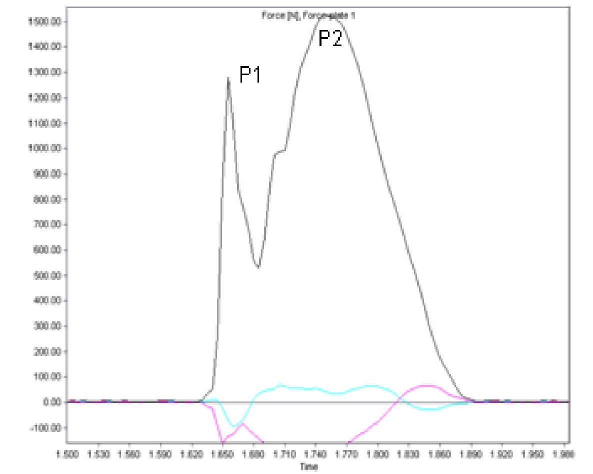


Figure 2: Ground reaction force, Rz during running

There are two peaks in the vertical ground reaction force. The first peak is called the impact peak (P1) while the second is called the propulsion peak (P2). The impact peak is associated with the impact of the foot to the ground during early foot contact phase. The propulsion peak is associated with the propulsion of the body forward.

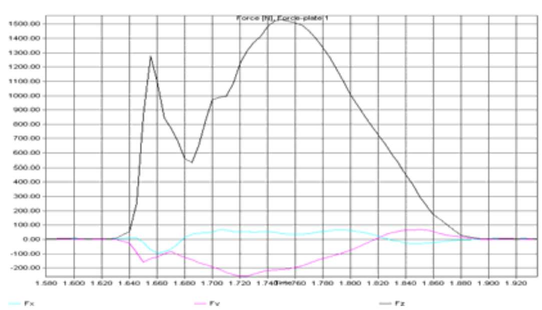
Table 1: Male 1 running with shoe

SUBJECT WITH SHOE: Male 55.8kg 173cm		P1	P2
Kinetics:			
Force [N]	X	-71.87	40.74
	Y	-133.21	-208.28
	Z	1278.40	1528.65
Moment [Nm]	X	278.23	185.40
	Y	-44.86	-96.86
	Z	13.69	-12.41
C.O.P	X	32.84	64.43
	Y	213.47	115.83
	Z	0.00	0.00
Kinematics:			
Angle (Knee – Ankle – Toe) [°]		78.15	74.05
Velocity (Knee) [mm/s]		3089.90	1080.93
Acceleration (Knee) [mm/s²]		29263.90	30738.42

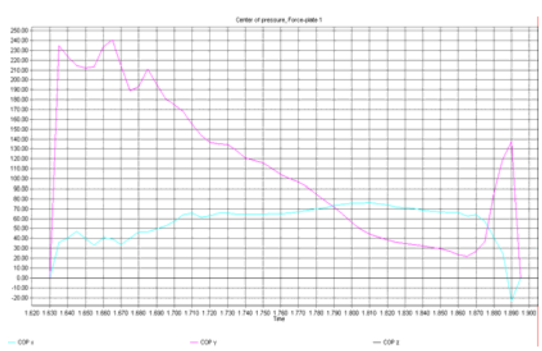
Table 2: Male 1 running barefooted

SUBJECT WITH BARE FOOT: Male 55.8kg 173cm		P1	P2
Kinetics:			
Force [N]	X	-93.84	5.95
	Y	71.26	-75.53
	Z	963.13	1263.42
Moment [Nm]	X	166.35	97.87
	Y	-21.91	-49.01
	Z	13.96	2.34
C.O.P	X	15.79	33.95
	Y	147.11	65.39
	Z	0.00	0.00
Angle (Knee – Ankle – Toe) [°]		89.17	74.47
Velocity (Knee) [mm/s]		2379.60	1025.36
Acceleration (Knee) [mm/s²]		17873.30	19995.08

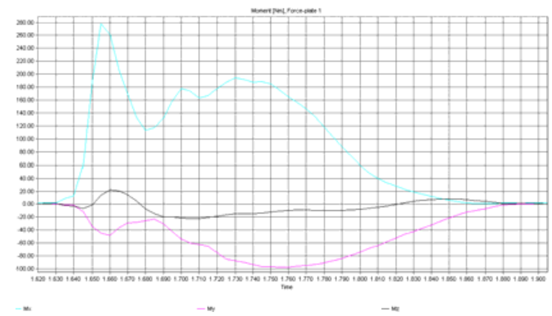
The maximum vertical ground reaction force (P2) reaches 2 to 3 times of the body weight. The factors affecting the magnitude of the ground reaction force are running style (rear foot, midfoot or forefoot strike), running speed, footwear, ground surface and inclination of the ground. T1 in Figure 2 is the impact peak time, the instant when P1 occurs, while T2 is the propulsion peak time. The time periods involved in ground reaction force development are also very important since these determine the rate of impact or force development. From the result, during running force usage on the subject with shoe indicated lesser than the subject bare foot. This might happen due to the force has been absorbed into the shoe.



(A)



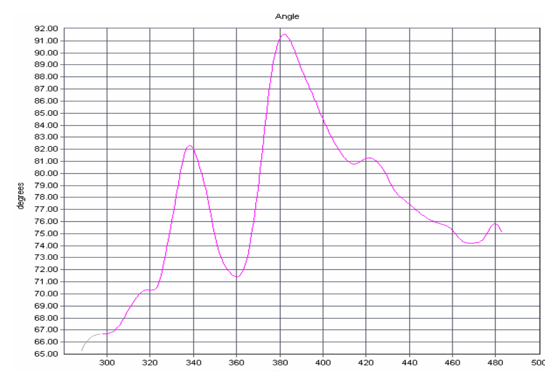
(B)



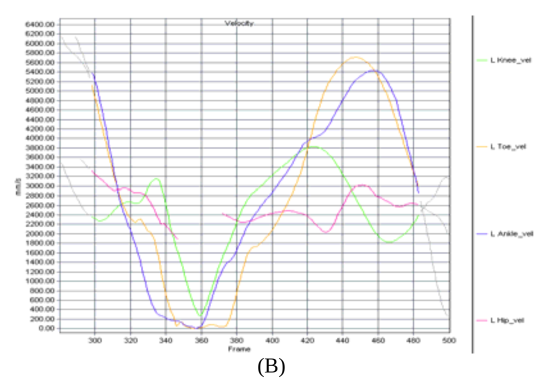
(C)

Figure 3 Kinetic graph of Male 1 during running

Figure 3 shows the kinetic data which comprise force (A), center of pressure (B) and moment (C). As we can see from Table 1 and 2, COP is equivalent to 0 which mean Male 1 is in stable position. However, the value for moment ranged from -12.41 to 13.96 Nm.



(A)



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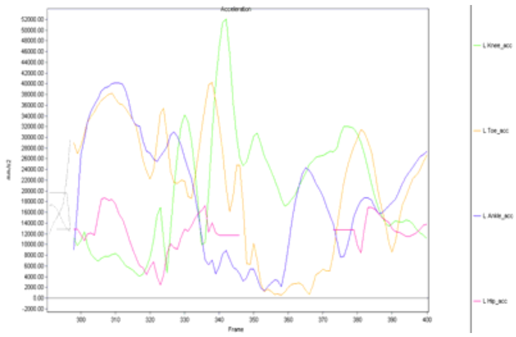

(C)

Figure 4 Kinematic graph of Male 1 during running

Conversely, Figure 4 provides information about kinematics which is the angle (A), velocity (B) and acceleration (C). Different foot strike patterns can greatly influence ankle movement patterns and both dorsiflexed and plantarflexed ankles have been observed at foot strike as shown in Figure 4 (A) which is the angle between knee, ankle and toe. Most runners initially contact the running surface with their rear foot and, for these runners, initial degrees of plantarflexion, followed by 15 - 20˚ of dorsiflexion. In the latter half of the support phase, as the knee extends, the ankle plantarflexes up to 30˚ before toe off.

At the faster speed, the hip angles at heel-strike and during swing and the knee angle during load response, in the normal leg, and the knee angle during swing in the amputated leg, all increased significantly. Speed of gait significantly affected symmetry between knee angles as reflected by the increased differences measured during load response and during toe-off by increasing inter-leg differences in the free and fast speeds respectively. The resulted from increased knee angle under influence of speed on the amputated side only. The inability of the artificial ankle to dorsiflex (and plantarflex) during stance, is expressed also by the inability to lower the heel and straighten the knee. Thus, during toe-off, the knee on the amputated side is being "pushed" into flexion by the rigid ankle, an outcome which increases significantly in faster speed of gait.

IV. CONCLUSIONS

Running is dissimilar than normal walking gaits where there is no double phase support and this added by shorter stance phase. For this preliminary study, we had restricted to have one subject due to limited equipments in Biomechanics and Motion Analysis Laboratory. There are plenty room of improvements especially for analysis purpose using Qualisys Track Manager (QTM) software in the future.

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