GROUND REACTION FORCE EXAMINATION IN DIFFERENT BODY TYPES OF BASKETBALL ATHLETES

Author 1: Nikos Persidis, NTUA, School of Rural & Surveying Engineering, Postgraduate Student nikospersidis@yahoo.gr

Author 2: Marinos Kattis NTUA, School of Rural & Surveying Engineering, Associate Professor mkattis@central.ntua.gr

1. Introduction

This research aims to offer useful conclusions about the kinetic and kinematic characteristics of basketball athletes depending on their different body type. For the fulfilling of this research 5 basketball athletes followed a number of crucial basketball movements and got recorded by SiMi software, using force plates. This publication deals with the biomechanics of 3 dimensions and for the analyzes the GRF is utilized.

Biomechanics is defined as the application of the laws of engineering to biological systems and in particular to the kinetic system of the human body. Essentially, biomechanics examines the movement of body parts individually or even the whole body according to the laws of physics. The forces / loads that stabilize or destabilize a body, can deform it and in the case of athletes can injure it. The forces exerted on the human body are tensile, compressive, shear and bending, while it exerts torques and axial.

In addition, healthy tissues have been found to have the ability to partially resist changing structure and shape through endogenous stress. On the contrary, an unhealthy tissue (injured, chronically damaged, accustomed to chronic immobility, etc.) can not offer resistance to the forces applied to it. It is distinguished in general biomechanics, which examines special laws under which the movements are carried out, and from other general branches, which examine particular characteristics of the movements based on their purpose.

2. BACKGROUND

2.1. Useful Equipment

In recent years, the development of the technological environment around the world it has also contributed to the development of the science of biomechanics. Specifically, a lot of auxiliary material has been created, which is able to offer a varied analysis of the movements of the human body, with primary application to the body of the athlete.

2.1.1. SiMi

The systems manufactured by SiMi concern the reception and analysis of motion and are based on high quality images, based on which a satisfactory profile of the behavior of the examined person can be created. These systems are based on a high-speed camera and use industrial image processing technology. Their purpose is to develop motion analysis technology, based on high quality images with a clear focus on user friendliness.

2.1.2. Force Plates

Permanently installed three-dimensional plates for measuring vertical force in combination with motion detection systems are used in many cases in research laboratories to record complex motion patterns. Power plates are considered a very useful training aid for the assessment of kinematics and dynamics of motion and are commonly used in biomechanics laboratories to measure the ground forces involved in human movement.

For basic biomechanics and sports, three-dimensional force plates are used to measure the reaction forces of the ground, moments, center of gravity and pressure, which occur when a person is in the correct position (stationary, moving, pressing or jump). They also help to measure the reactive activation time of the muscles and other parameters and forces produced during the specific movements of a sports activity.

2.2. Ground Reaction Force (GRF)

According to the usual definition, in biomechanics the ground reaction force (GRF) is the force exerted by the ground on any body that comes in contact with it. Essentially when a person (or a body in the general sense of physics) stands motionless on the ground, it exerts on it a force equal to its weight and therefore the ground exerts on the man an equal force and opposite direction.

The method used in most cases, as it is the simplest and at the same time the one that seems to have a better application, is the one based on Newton's second law. By way of illustration, total force is related to the resulting acceleration of the vectors of the center of gravity, to the mass of the human body, and to the acceleration of gravity. The function relation of the above quantities is:

$$GRF_z = M \cdot a_z + M \cdot g = M \cdot (a_z + g)$$

Where:

GRFz: The vertical component of the ground reaction force

M: Mass of the human body

a_z: Acceleration of the center of gravity

g: Acceleration of gravity.

2.1. Application

In general, GRF has frequent application in the evaluation of the force produced by the athlete and in his resistance to the force he receives as a reaction. In the field of basketball, it is very common to use it through plyometric jumps, to assess the strength and power produced by the athlete, but also his endurance. As will be done in this research, in cases of testing the reaction force of the soil, the following take place:

• Hoop with the dominant / strongest foot

• Hoop with the weakest leg

• Normal hoop (with both feet)

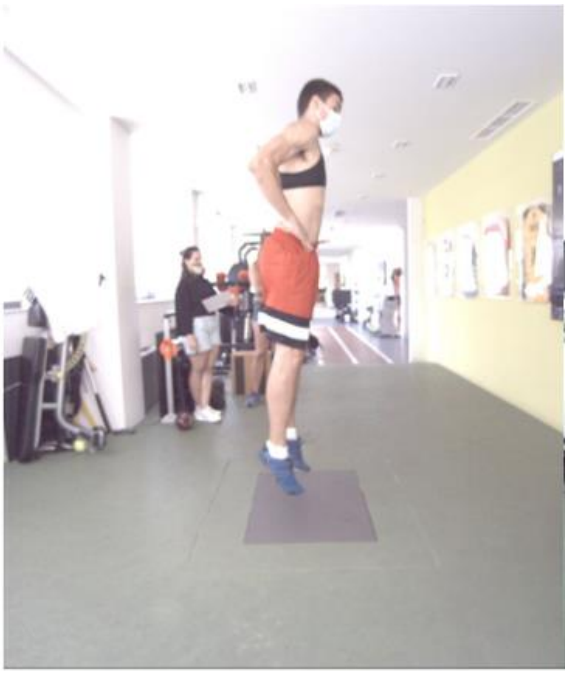

Image 1: Two legs hoop (during athlete 1 effort)

Image 2: Left leg hoop (during athlete 1 effort)

Image 3: Right leg hoop (during athlete 1 effort)

3. Experiment Preparation

In this research, the GRF is examined for a total of five athletes, who will perform all three of the aforementioned types of jumps. Each athlete made two attempts for each movement examined (and 6 in total), so the results presented below are the average of the recorded efforts. The important thing that is required from the research is to draw conclusions regarding the following:

• dominant foot

• weaker leg

• both feet at the same time

• effect of the athlete's jump height on the GRF

• effect of athlete's weight on GRF

• effect of the athlete's body center of gravity on the GRF

• comparison of GRF between different body types.

A key element of the research concerned the selection of athletes. The most important thing, in essence, was to select athletes with different body types, so that the effect of each body structure can be seen in the results. For this reason, two or three athletes with approximately the same height were selected (athletes 1,2 and 4), one athlete of low center of gravity and lower body weight compared to the others (athlete 5) and an athlete who was in the middle of the above two categories (athlete 4). Table 1 presents the somatometric data of each athlete.

Table 1: Body elements of each athlete

Element \ Athlete	1	2	3	4	5
Height (m)	1.98	1.96	1.90	1.99	1.70
Weight (kg)	98	100	85	83	72

4. Results

The SiMi system offers the ability to record the GRF that the ground receives (via the Force Plate) from the athlete and practically the force that the ground returns to the athlete. This recording is made as a function of time. The GRF starts to increase when the athlete starts the jump process. This movement includes the first bend of the waist and knees, the jump in the air and the process of landing.

The peak of the GRF is obviously recorded at the time of the athlete landing on the ground. However, the specific peak of the landing does not concern this research. Instead, the focus is on the GRF peak at the moment before take-off, ie where the athlete has subjected his knees to their maximum flexion in order to perform the jump. The explanation of the results can be given through the following figure.

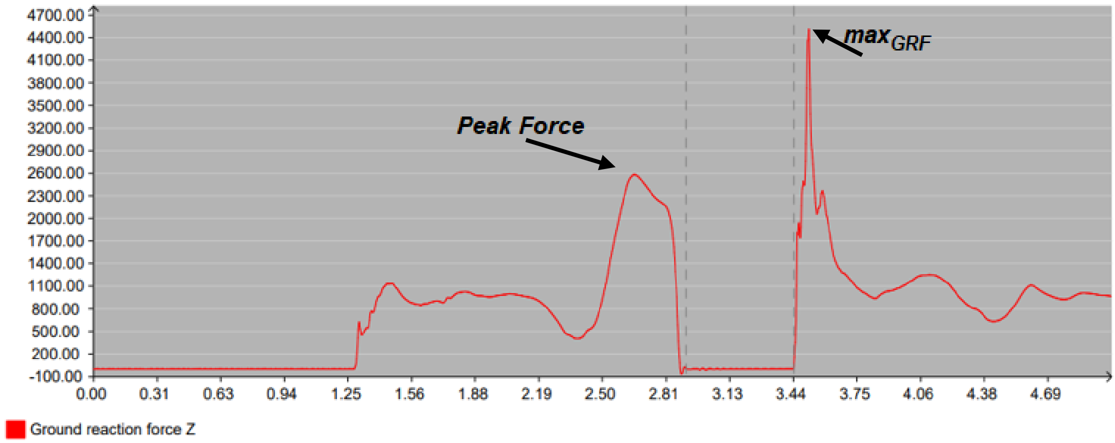

Figure 1: Ground Reaction Force (Axis Y) depending on time (Axis x)

4.1 Two leg hoop

The following is an overview of the average athletes efforts to jump with both feet.

Table 2: Athletes results for the two legs hoop

Element \ Athlete	1	2	3	4	5
Ground Reaction Time (s)	2.20	2.75	3.31	3.9	2.62
Jump Height (m)	0.34	0.28	0.31	0.35	0.35
Flight Time (s)	0.53	0.48	0.50	0.53	0.54
Peak Force (N)	2546.05	1994.90	2116.56	1848.37	1929.39

The data in Table 2 show that the best performances in the height of the jump with both feet and in the time spent in the air, are noted by athletes 5, 4 and 1, followed by 3 and 2. Regarding the GRF at the moment of the start of the jump the results are different compared to the above. Specifically for athlete 1, the highest GRF is recorded, which is significantly higher than its corresponding values for other athletes. Then follows 3 and then 2, followed by 5 and 4.

The interesting thing about the above is that for the heaviest athlete (athlete 1 weighing 100kg) the third highest GRF value is recorded, while for the most important lighter in relation to the rest (athlete 5, weighing 72kg) not only the lowest GRF is not recorded, but its price is close to the prices of the heaviest athlete. The above can be better explained through a ratio of the GRF value per kilogram of body weight (GRF / BW) for each athlete.

The data in the table above can provide the safest and clearest results. Based on these, it is observed that athlete 5 achieves the highest GRF / BW ratio, followed by 1 and 3. On the fourth and fifth in a row better ratio are recorded by 4 and 2.

If the first equation is applied to the above data, the acceleration of the center of gravity of each athlete's body can be calculated. Essentially its calculation is obtained through the relation:

$$GRFz / BW = az + g$$

So the following emerges:

Table 3: Comparison of a_z indicators for each athlete during the jump with both feet

Magnitude \ Athlete	1	2	3	4	5
a_z (m/s^2)	16.17	10.14	15.09	12.46	16.99

As expected, it seems that athlete 4 has the highest acceleration of his center of gravity compared to other athletes, while the sequence for the acceleration of athletes is similar to the one mentioned above for their GRF. A first conclusion that can be drawn is that the lower center of gravity is a very important influential factor, as it affects the increase of its acceleration. In cases where the center of gravity of the body is higher, it seems that its lower acceleration is recorded and therefore a lower GRF value results.

However, acceleration values are obtained in proportion to the GRF / BW ratio. Since the athlete can not significantly differentiate his center of gravity (the only small difference concerns a change in his physique), then by reducing his body weight he can achieve an increase in the acceleration of his center of gravity and thus an increase in GRF.

The above results and individual conclusions concerned the jump with both feet. Therefore, the focus is on jumping with one foot. Initially comparisons will be made between the same support leg for each athlete and then a comparison will be made between the GRF, GRF / BW and a_z values for the leg that exerts the most force at the start of the jump. Starting with the left foot, the following analyzes are presented.

4.2. Left leg hoop

The next one process concerns the left leg hoop, for which the results are presented in Table 4.

Table 4: Comparison of the average results of the two jumping attempts with the left foot for each athlete

Element \ Athlete	1	2	3	4	5
Ground Reaction Time (s)	1.87	2.30	2.87	2.98	2.05
Jump Height (m)	0.20	0.14	0.11	0.18	0.25
Flight Time (s)	0.40	0.33	0.29	0.38	0.45
Peak Force (N)	2158.21	1669.32	1525.56	1498.09	1516.10

Table 5: Comparison of GRF / BW indicators for each athlete when jumping with the left foot

Index \ Athlete	1	2	3	4	5
GRF/BW	22.02	16.69	17.95	18.05	21.05

Table 6: Comparison of a_z indicators for each athlete during the jump with the left foot

Magnitude \ Athlete	1	2	3	4	5
a_z (m/s^2)	12.21	6.88	8.14	8.24	11.24

From the above data it is obvious that the best performance in the height of the jump and in the time spent in the air is recorded by athlete 5, followed by the performance of athletes 1 and 4. Then follows the performance of athletes 2 and 3. In addition, it is observed that maximum GRF is exercised by (or exercised on) athlete 1, with the difference from that of other athletes being significantly large. The second largest corresponds to athlete 2, followed by athlete 3, followed by athletes 5 and 4.

Regarding the GRF / BW ratio and a_z, the highest value is achieved by athlete 1, followed by related values, athlete 5. Next are athletes 4, 3 and 2. During this treatment, the fact that Athlete 4, although he achieves his best performance in the GRF with his right foot, managed to exercise the third largest to make the jump. This movement includes the first bend of the waist and knees, the jump in the air and the process of landing.

Then three new tables are created, which concern the performance and data for athletes when jumping with the right foot.

Table 7: Comparison of the average results of the two jumping attempts with the right foot for each athlete

Element \ Athlete	1	2	3	4	5
Ground Reaction Time (s)	1.93	2.71	2.64	2.99	2.59
Jump Height (m)	0.18	0.16	0.12	0.19	0.18
Flight Time (s)	0.38	0.36	0.31	0.39	0.38
Peak Force (N)	1947.46	1657.47	1463.99	1510.42	1317.10

Table 8: Comparison of GRF / BW indicators for each athlete during the jump with the right foot

Index \ Athlete	1	2	3	4	5
GRF/BW	19.87	16.57	17.22	18.20	18.29

Table 9: Comparison of a_z indicators for each athlete during the jump with the right foot

Magnitude \ Athlete	1	2	3	4	5
a_z (m/s^2)	10.06	6.76	7.41	8.39	8.48

From the above results it can be concluded that the best performance, in terms of the height of the jump and the time spent in the air, has been achieved marginally by athlete 4 (for whom the right foot is the strongest), while athletes with very relevant values follow and 1. Athlete 3 is fourth in order of performance, followed by athlete 3. Furthermore, the GRF at the start of the jump is higher for athlete 1, followed by athletes 2, 4, 3 and 5.

The results for the GRF / BW ratio and a_z are related, in terms of their distribution to athletes, to those obtained for the left foot. In short, the highest values of the above two elements are recorded for athlete 1 and are followed by similar values for athletes 5 and 4. However, it is emphasized that in the case of jumping with the right foot the discrepancies between the specific values for the three athletes are smaller, compared to those for the left foot jump. Finally, athletes 3 and 2 follow.

The last part of the analysis of this chapter concerns the comparison of recorded and resulting performance between the strongest legs of athletes. By way of illustration, the data concerning the left foot for athletes 1,2,3 and 5 and the data concerning the right foot of athlete 4 will be presented.

Table10: Comparison of average results of the two jumping attempts with the strongest leg for each athlete

Element \ Athlete	1	2	3	4	5
Peak Force (N)	2158.21	1669.32	1525.56	1510.42	1516.10
GRF/BW	22.02	1,69	17.95	18.20	21.05
a_z (m/s^2)	12.21	6.88	8.14	8.39	11.24

In conclusion, it follows from the above that the largest GRF, at the beginning of the jump with the strongest leg, is exercised by (or is exercised on) athlete 1 and then on athlete 2. Athletes 3,5 and 4 follow with very close prices. In addition, the maximum values of the GRF / BW ratio and therefore of a_z, are recorded by athlete 1 and then by athlete 5, while athletes 4,3 and 2 follow.

5. CONCLUSIONS

1) From the 3D analyzes it was observed that the highest value of the ground reaction force was recorded for jumping with both feet. Contrarily in case of one leg hoop, the values of this force were significantly reduced.

2) Compared to the values of Ground Reaction Force, for comparison between the hoops with the one foot, it was observed that four of the five athletes exercised (or were exercised) more force with the left foot compared to the right. From this it is concluded that 80% of the participants had the left leg as their strongest.

3) The values of the height of the hoop and the time spent in the air, depending on GRF are related to the position of the center of gravity of each body. It was observed that the change in posture may have increased the value of GRF, but there was no corresponding increase in the above data. The corresponding ending was also observed with the reduction of GRF, which did not bring about a corresponding (or not at all) reduction in the jump height and the time spent in the air.

4) In general, the center of gravity of each athlete's body was a factor of supreme importance for this research. Specifically, its differentiation also led to a differentiation in its acceleration, with the result that there is a direct impact on the values of the soil reaction force.

5) In addition to the acceleration of the center of gravity, which is a very important factor for every athlete's body type, another parameter that must be taken seriously is the GRF / BW index (i.e.: Ground Reaction Force / Body Weight). The GRF Force, as it is, is not able to compare practical results between athletes, especially in cases where athletes have different centers of mass and body weight.

For example, during the two legs hoop, it was observed that the lightest and at the same time lighter (in absolute value of body mass) athlete recorded the highest values of the above index and acceleration, while the heaviest recorded the corresponding smaller ones.

6) During the overall jump, in the three-dimensional analysis, it appeared that athlete 1 had the best performance for the GRF. He may have had the second largest with both feet, but he had the best with each foot separately. Also the strength values had the smallest deviation from the average in each type of jump. Very close overall was athlete 5, who had the highest value of the reaction force of the ground for jumping with both feet and in addition the best performance in the height of the jump and the time spent in the air.

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