BIOKINEMATIC MODEL OF IMPACT IN THE SPORTS

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In my abstract I indicated the reasons which have led me to build a biokinematic model of impact that can be used in the study of the **sports** movements in order to give the coach a valid help for the research of the most efficient **technique,** and to give to orthopedic more opportunities to identify the trauma causes.

Now we have to verify how the concepts of impact can be transferred, practically. into the movements in sports.

Therefore I would like to present the general **biokinematic** model of impact and I start by considering and athlete who clashes against the ground by his lower limbs and whose motion occurs along the axes Z, before and after the impact. The system is formed in the following manner:

1)**by** the athlete's mass m1 which is placed above the concerned joint;

2)by the shock absorber **K1** rapresented by the mass of the anatomic segment, standing under the concerned joint;

3)by the ground mass **m2** that we suppose to be concentraded;

4)by the shock absorber K2 represented by the ground elasticity and then it depends on its nature (athletic ground, **tennis** court, boxinggloves and others);

5)by the fictions shock absorber which acts in connection with the athlete's **g.c.** and indicates the moment of return and balance of the athlete, who rolls off an angle q3 compared to his initial position of impact with the ground. In a few words, K3 takes in to account the action of removal, exerted by the weight of the mass m1 (the athlete).

The system is showed in fig. 1.

I' m going to provide an example to apply to the biokinematic model of impact. According to my intention, I consider an athlete who performs some jumps downwards from a determinated height with following rebounds upwards (pliometrical performance).

For the use of the **biokinematic** model of impact, I focus my attention on the impact which occurs between the athlete and the ground at the end of the descending way.

As coordinates of Lagrange, 1 choose the displacements q1 and q2 in the plane XZ related m1 and **m2** during the time Dt, and the rotation q3 of the athlete round the Y axe, normal to the plane XZ, and be 0 the point of intersection between the Y axe and the plane XZ.

I also specify that the concerned joint is the coxo-femoral and the axes X, Y, **Z,** represent respectively the transversal, sagittal and longitudinal axe.

The motion is defined by **the knowledge** of the **three** above-stated parameters, provided we eccept the case stated, for the execution of the model, so that:

1) the system is defined as plane, that's supposing that the movement takes place without considering the motion along the Y axe.

2) It's supposed that the point 0 is bound to move along the axe Z going through the two springs **K1** and K2 that have been stated, and the equations of the motion of the two masses **m1** and **m2** are the following:

[1] a) q1 **m1+Sm** q3 cos q3-Sm q32 sen q3 = **-(q1-** q2) **K1-(q1+ Rcosq3 tgq3)** K3;
b) q1 cos q3 Sm + q3 Im **= - (q1+ R cos q3 tg q3) K R cos q3;**
c) q2 **m2** = (ql- q3) **K1- q2** K2;

with R which represents the **g.c.** distance of m1 from the sagittal axe going through **0,** **r** which represents the distance of dm from the sagittal axe, so it's stated:

[2] $Sm = \int m1 \, r \, dm$ $\qquad$ $Im = \int m1 \, r2 \, dm$

In **a) the** term Sm q3 sen q3 represents the centripetal force that must be considered unimportant compared to the other terms, and besides **it can be stated** that cos q3 ≅ 1 and tg **q3 ≅ q3,** since the angles q3 assume low values.
Thus the equations a), b), c), can be rewritten as follows:

[3]
$$q1\, m1 + q3\, Sm + q1\,(K1 + K3) - q2\, K1 + q3\, R\, K3 = 0$$
$$q1\, Sm + q3\, Im + q1\, R\, K3 + q3\, R2\, K3 = 0$$
$$q2\, m2 - q1\, K1 + q2\,(K1 + K2) = 0$$

supposing that:

[4]
$$a = \frac{Im}{m1\, Im - S2m} \qquad b = \frac{-Sm\, Sm}{m1\, Im - S2m} \qquad c = \frac{m1}{m1\, Im - S2m}$$

$$A1 = -a(K1 + K3) + b\, R\, K3; \qquad A2 = a\, K1; \qquad A3 = a\, R\, K3 + b\, R2\, K3;$$

$$B1 = \frac{K1}{m2} \qquad B2 = -\frac{(K1 + K2)}{m2}$$

$$C1 = b\,(K1 + K3) + c\, R\, K3; \qquad C2 = b\, K1; \qquad C3 = b\, R\, K3 + c\, R2\, K3$$

the [3] become:

[5]
$$q1 = A1\, q1 + A2\, q2 + A3\, q3$$
$$q2 = B1\, q1 + B2\, q2$$
$$q3 = C1\, q1 + C2\, q2 + C3\, q3$$

if we use a class of particular solutions like for the integrations:

[6] $qj = H(j)\, e^{ht}$

we obtain:

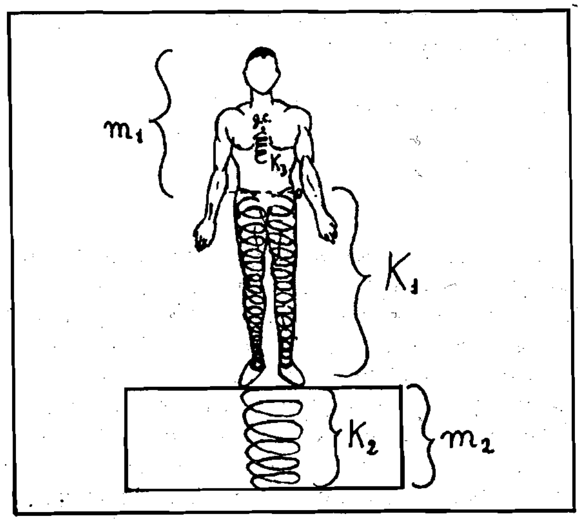
[7]
$$q1 = H1(1)\, e^{h1t} + H2(1)\, e^{\lambda 2t} + \dots H6(1)\, e^{\lambda 6t}$$
$$q2 = H1(2)\, e^{h1t} + H2(2)\, e^{\lambda 2t} + \dots H6(2)\, e^{\lambda 6t}$$
$$q3 = H1(3)\, e^{h1t} + H2(3)\, e^{\lambda 2t} + \dots H6(3)\, e^{\lambda 6t}$$

with h1 **...**h6 roots of the equation belonging to the system **[5].**
By replacing [6] with [5] forh = hi the following relations are found among the Hi

[8]
$$Hi(2) = -\frac{B1}{B2 - \lambda i2} Hi(1)$$

$$Hi(3) = \frac{Hi(1)}{A3}\left[\frac{A2\, B1}{B2 - hi2} \cdot (A1 - \lambda i2)\right]$$

so the constants H which must be defined with the beginning conditions in the system **[7]** are six.



Biokinematic model of impact in the sport

For t = 0 it has to be: $q1 = 0; q2 = 0; q3 = 0$

$q1 = V; q2 = 0; q3 = 0$

represents the athlete's speed at the moment of the impact.

If we wanted to examine the impact effect between the athlete and the ground on the knee of a triple jumper, we'd make some preliminary considerations.

The impact can provoke some traumas along the sagittal, transversal and longitudinal axe.

Therefore, for the examination of the impact on the **knee,** it is convenient to consider separately the motion along every axe with the opportune variants on the biomechanic model.

The studies made by Harmut **Krahl** and **KarlPeter** Knebel. Heiderlberg. West Germany published by Track Technique, emphasize the problem of the impact for high jumpers using the flop technique, being filmed at 300 photograms per second.

In fact, during the impact we can notice:

1)a remarkable rotation of the foot round the longitudinal axis when the heel touches the ground.

2)While resting the foot on the ground there is a great compression and a pronation of the heel as well as the bending of the plantar arch in the highest point of the tibiatarsal joint.

3)A position of complete pronation when all the foot plant is in contact with the ground.

From everything stated so far, it seem clear that the development of the most efficient technique for an athlete must take into account **his/her** anthropometric features as well as the shockabsorbing capabilities of the sporting facilities. Besides, the shoes must consider the approaching and removing speeds during,the clash, and also the relative positions taken

by the single anatomic segments during the movement, and finally the freedom degree or degrees of the articulations concerned.