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Some Aspects Regarding the Kinematics Parameters in the Football Game

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Introduction

Football, one of the most spreaded games, "imported" from its origin country, England, more than two centuries ago and nowaday present in the farthest sides of the world, is characterized by dynamism, spectaculozity, impredictibility. Becoming a social phenomenon, widely accesible, with many watchers, football is a very industry.

From physiologically point of view, during the game, the effort characterizing the motion capacity of the football player has an alternating regime, that is, the physical actions, spontaneous and unpredicted as length and intensity, are followed by uneven and incomplete recovery pauses. To physical solicitations occuring during the game are added undetermined technical and tactical solicitations, related to attack and defense actions, as well to psyhic solicitations.

The present paper aims some biomechanical aspects of the sportman and his action on the ball during the game, namely, the position and relative angular speed of the shank related to thigh during the free hit and the initial kinematic parameters of the ball as effect of the hit.

The direct or indirect free hits are characterized by the following aspects:

- bigger time to analyse the situation in the respective area of that one executing the hit: the location of the wall, the opposite and own team, the goalkeeper;
- narrow corridors (high density of players);
- low visibility of the gateway;
- high execution technique;
- big final angle but partially closed by the wall.

The distances to the gateway with the biggest succes chances are: 18 – 20 [m], from central area; 20 – 25 [m], from central area; 20 – 25 [m], laterally left/right to the gateway.

A very important relation is that between the position of body when the ball is hit – the biomechanics of execution – and the place where the ball is hit. In this situation, the succes owns totally to the player executing the hit. The biomechanics of execution aims especially:

- setting the support leg close to the ball, with the foot approximately parallel to the ball;

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- swinging the leg which is hitting the ball – backward and forward motion;
- the flexibility of the knee joint and especially of the ankle joint and positioning of the foot in function of the way the ball is hit – inside, outside shoelace or full hit;
- position of the arms – slightly relaxed along the body;
- position of the trunk and head – slightly bended forward.

The results of this scientific paper may be used both by sportmen and trainers, thus:

a. the players – probationists of football for at least two-three years – they may improve from this point of view:

- technical training level when executing direct or indirect free hits;
- capacitaty to accumulate data from the ground (during a playing sequence – phase), to analyse it and to solve it in a very short time;
- capacity to see narrow corridors (paths),angle occuring during a play phase or *corridors, angles* that may form through displacements of the players;

b. the trainers – they may complete the technical training level by describing, presentation and demonstration of technical procedures and actions (play sequences) from ***biomechanical*** point of view.

Description of used method

The trajectory of the ball is that may ensure the succes of a free hit. From this point of view, there exist certain conditions or geometrical or kinematical constraints that must be taken into account when the trajectory of the ball is analysed.

At first, we are starting with the following observations:

- the trajectory of the ball is considered to be along a plane denoted in figure 1, with (x'Oy);
- the ball is placed at a known distance, denoted with „l", with respect to the center of the gateway;
- there is considered that the ball has a uniform motion (without acceleration) with respect to Ox' axis and a uniformly varied motion (with acceleration) with respect to Oy axis;
- the plane (x'Oy) is inclined with respect to reference plane (xOy) with a given angle, α;
- at a given distance, between the ball and the gateway there may form a wall of opposite players attempting to obstruct the motion of the ball toward the gateway.

With the specified conditions, the acceleration of the ball is:

$$\bar{a} = \bar{a}_{tr} = \ddot{\bar{r}} = a_{x'} \cdot \bar{i}' + a_y \cdot \bar{j} = \ddot{x}' \cdot \bar{i}' + \ddot{y} \cdot \bar{j}, \tag{1}$$

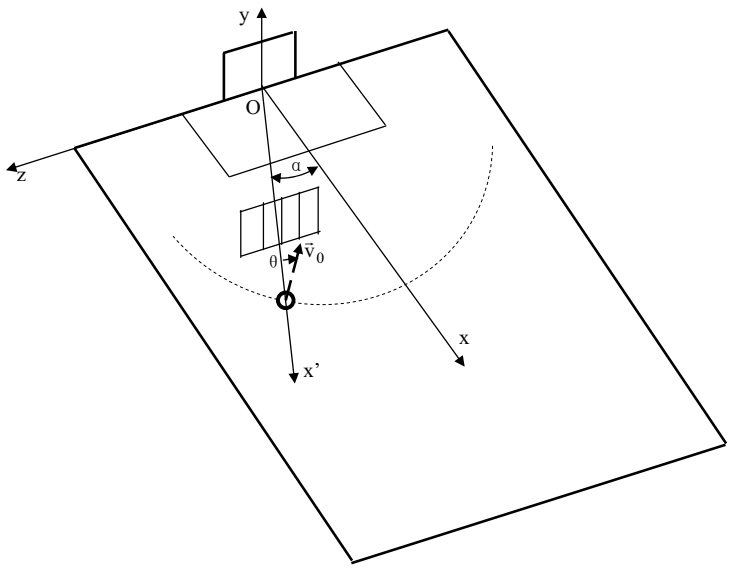

Figure 1: The initial position of the ball for the direct hit

with the specified constraints:

$$a_x = \ddot{x}' = 0 \;\Rightarrow\; \dot{x}' = \text{constant} = C \;\Rightarrow\; x' = \int_t C \cdot dt + C_1 = C \cdot t + C_1 \qquad (2)$$

$$a_y = \ddot{y} = -g \;\Rightarrow\; \begin{cases} \dot{y} = \int_t (-g) \cdot dt + K = -g \cdot t + K \\ y = \int_t (-g \cdot t + K) \cdot dt + K_1 = -\frac{1}{2} \cdot g \cdot t^2 + K \cdot t + K_1 \end{cases}, \qquad (3)$$

where g is gravity acceleration, with known value, and C, C_1, K, K_1 are integration constants.

The integration constants are determined from the inital conditions:

$$\text{at } t = 0 \;\Rightarrow\; \begin{cases} x' = l \\ v_x = \dot{x}' = v_{x'o} = v_o \cdot cos\theta_o \\ y = 0 \\ v_y = \dot{y} = v_{yo} = v_o \cdot sin\theta_o \end{cases}, \qquad (4)$$

and after calculus there results:

$$C = -v_0 \cdot cos\theta_0, \quad C_1 = l, \quad K = v_0 \cdot \sin\theta_0, \quad K_1 = 0. \qquad (5)$$

The initial kinematic parameters of the ball, v_0 and θ_0, are determined by the angular speed of the sportman's shank during the hit, by the position of contact

surface between the foot and the ball and by the biomechanical angular position of the football player body.

In order to determine these kinematic parameters, the videographical method was used, using a camera with normal recording. Then, using specialized programs of decomposition into separate frames (frame by frame) and of measurement of the angular or linear values, there were determined the kinematic parameters by the ratio between the angular or linear variation and the time variation between two successive video frames. Thus, in figure 2 there are represented a few successive frames used to angular measurements between thgih and shank for a junior football player during a direct free hit.

Figure 2: Successive video frames used for geometrical measurements

During the experiment, performed onto a lot of junior sportmen, aged over 10 years and onto a football field of small dimensions, there was considered a single distance „l" between the point of hit and gateway, but three angular positions „α" of this point.

Results

The direct free hits have had the initial point at a distance of 11 [m] from the center of the gateway, and the three angular positions α were equal to 0° and $\pm\, 21^{\circ}$. The results of measurements are given in table 1, for each sportman being specified also, the height and the weight.

The results in the tabel are presented only for four sportmen considered to be the best carrying out of the free hit for the analysed team. At the same time, the relative angular speed of the shank with respect to thigh was calculated as the average of the angular speeds obtained as a sequel of angular variation from a frame to another. Thus, depending on the number of frames recorded between the position of maximum amplitude of the flexion of the leg used for hit and the position of the

Table 1: Results (partial) of measurements

Height [m] / weight [kg] sportman	Angle value α [°]	Average relative angular speed of the shank with respect to thigh [rad/s]	The inital angle of the ball θ_0 [°]	Initial linear speed of the ball, v_0 [m/s]
1.37/31	0	9.82	30	33.88
1.40/38	0	13.71	26	35,43
1.40/30	0	23.44	26	37,24
1.25/30	0	10.15	32	21,36
1.37/31	-21	11.56	34	23,55
1.40/38	-21	21.37	25	29.02
1.40/30	-21	28.72	29	39.02
1.25/30	-21	9.58	34	23.24
1.37/31	+21	10.36	38	19.77
1.40/38	+21	18.63	29	24.51
1.40/30	+21	35.78	31	45.67
1.25/30	+21	8.59	35	18.92

leg in contact with the ball, denoted with „n", the number of calculated angular speeds is, n – 1". In general, for the used normal camera, there were recorded 4 or 5 video frames necessary to calculate the relative angular speed.

Discussion

Analysing the results, the following observations were done:

- the initial angle of the ball, θ_0, depends on the position of the sportman on the field, with the sense that lateral positions, left or right, with respect to the center of the gateway have significant variations for the same sportman;
- between the angular relative speed of the shank and the initial speed of the ball there is a positive dependence, but the angular speed of shank does not depend directly by the flexion amplitude of the leg;
- the height of the sportman is influencing directly the initial angle of the ball, which determines the length of the ball trajectory.

Determination of optimum initial kinematic parameters of the ball

In order to determine the best values for the initial kinmatic parameters of the ball, v_0 and θ_0, so that the direct free hit to be successful, there was conceived a graphic model for simulation of the hit, using a specialised software. Using these simulations, there can be individualized the initial kinematic paramters of the ball, no matter the position on the ground of the point of hit, and there can be determined the proper intervals that ensure, theoretically, the succes of the hit.

In figure 3 there is presented a sequence of the realized simulation model.

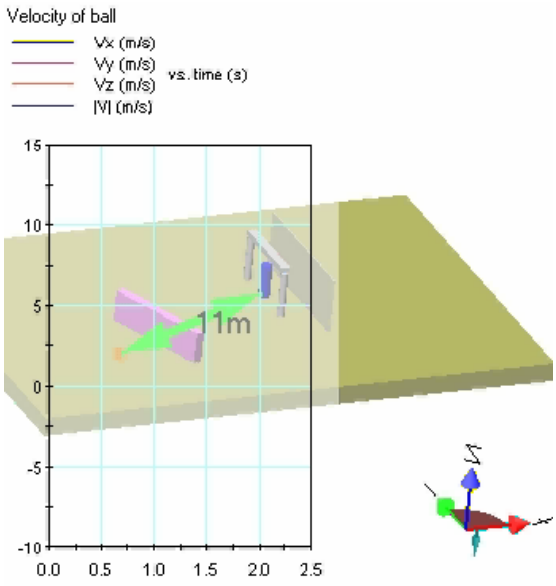

Figure 3: Sequence of software module for numerical simulation

After the real values of kinematic parameters are obtained, v_0, θ_0 and the angular spped of the shank, for a given player there can be determined, using the proposed software module, the optimum values of these parameters, with the help of which there are improved, from biomechanical point of view, the position of the body of the player, the intensity of leg motion and the position of contact point between foot and ball, so that the direct hit have the biggest chance of success.

Conclusions

The use of such analyses for the children wishing to become great sportsman is helpful to improve various biomechanical parameters, being aware of possible mistakes and explaining the technique of direct hit. Computer simulation of such a hit, that may be done by the sportsman or trainer, is more suggestive for improving the execution of a football phase for a given player.

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