

Mathematical principles in tennis

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Tennis is a technically challenging sport. To achieve high results, a trainer can develop a method of targeted training, which makes it possible to acquire the necessary theoretical, technical, tactical, physical and mental conditions (fig. 1).

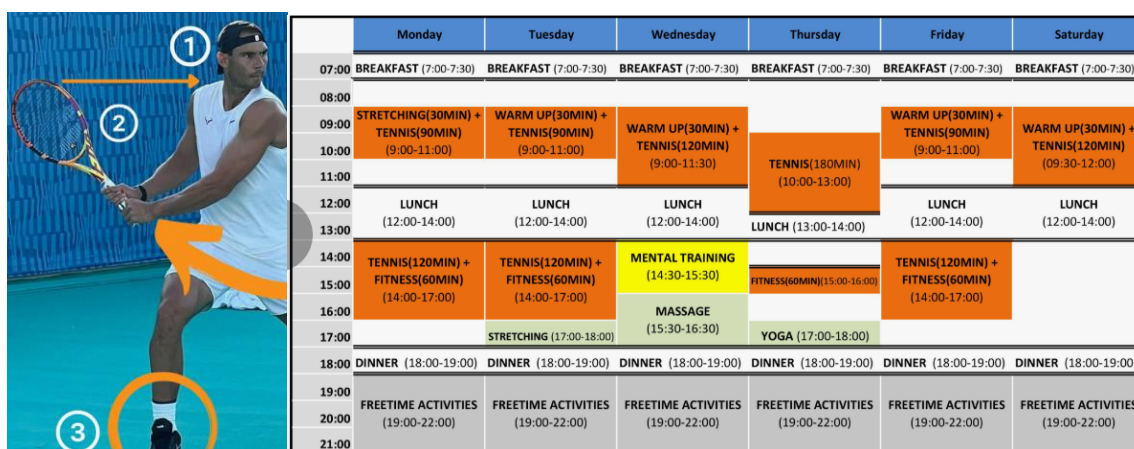


Figure 1 – Analysis of position of spotters. Training week for program [1]

A wide range of studies on tennis were conducted in the past. In motion analysis of tennis stroke, Akutagawa & Kojima once explored the effect on the contact speed caused by torsional moment, which was formed by the player's trunk and hip joints [2]. Tanabe & Ito used to analyze the ball contact during tennis serving with 3-D camera [3]. Mathematical models use the strict language of mathematics and computer experiment to describe physiological phenomena, which makes it possible to quantify various phenomena arising from model representations.

Modeling is an effective tool for identifying non-obvious consequences. The ability to manipulate model parameters in wide ranges makes it possible to find different modes of system functioning, which, due to the complexity and high degree of nonlinearity of biological systems, are often impossible to predict using verbal schemes. In this sense, a model, if it is complex enough to be realistic, can be a source of new knowledge, sometimes even counterintuitive.

The system of equations obtained on the basis of the equation of motion of the center of mass of the ball:

$$\begin{aligned}
m U'(t) &= -R(t) U(t)/V(t) - Q(t) v(t)/V(t), \\
x'(t) &= U(t), \\
mv'(t) &= -mg - R(t) v(t)/V(t) + Q(t) U(t)/V(t), \\
y'(t) &= v(t), \\
R(t) &= 0,5\rho C_d S V(t)^2, \\
Q(t) &= 0,5\rho C_l S V(t)^2, \\
V(t) &= (U(t)^2 + v(t)^2)^{0,5},
\end{aligned}$$

where x , y are the coordinates of the center of mass of the ball, the upper sign in the lifting term refers to clipping, the lower sign refers to rolling. Set task parameters: $\rho = 1,23 \text{ kg/m}^3$. $m = 0,0023 \text{ kg}$, $S = \pi d^2/4$, $d = 0,038 \text{ m}$. $C_d = 0,45$. $C_l = 0$, when rolling and trimming $C_d = 0,6$. $C_l = 0,35$ The Cauchy problem is solved with initial conditions for the functions $x(t)$, $y(t)$, $u(t)$, $v(t)$ [4].

In Wolfram Mathematica we used function NDSolve for solution of system. Plot of function $U(t)$ is on fig. 2.

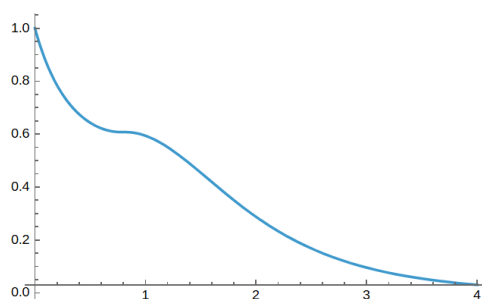


Figure 2 – Plot of $U(t)$

Differential equations of motion of the center of mass of a tennis ball were compiled, which were solved numerically in a computer system. Based on them, trajectories can be investigated. movement of the ball after receiving it in the near and far zones with a direct central impact on the ball, as well as rolling reception (top rotation).

Literature:

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