Integration of Volleyball Practice and Competition in Diverse Atmospheric Settings Using Computer Simulations of Passing Jump Serves

Michael Roth, Iradge Ahrabi-Fard, University of Northern Iowa, Cedar Falls, Iowa, USA

Computer simulations model the differences in the flight of a volleyball as a result of differing environmental conditions. The FORTRAN program used in this investigation calculates a reference trajectory for a volleyball given either the altitude and air temperature at a team's location, or given the barometric pressure, temperature and relative humidity where they are. Conditions are varied and another trajectory is calculated with the ball speed and spin, the height of the server's jump reach and the net height being the same as before. It is possible to recommend corrective measures to approximate the competition environment at the practice location.

Key Words: atmospheric conditions, volleyball, computer simulations, passing jump serves

INTRODUCTION

Most scientific inquiries related to volleyball have focused on the technical aspects of the player's performance and conditioning. Atmospheric variables related to indoor game play have been believed to be inconsequential. Changes in air density, with varying altitudes and barometric pressures, however, are inescapable.

The main purpose of this investigation was to provide information to assist athletes who train and compete in different locations. If the flight of the ball appreciably changes in different air densities while all other aspects of the serve (height of the server's reach, speed and rotation rate of the ball and the height of the net) are held constant, effects on passing the serve can be devastating. Most athlete training involves reading the flight of the ball, moving to the area of passing, extending the arms early, and developing a kinesthetic feeling of predicting the area of contact before ball contact. A player who trains in a certain air density with a predicted ball trajectory develops certain expectations of the serve flight pattern. If this flight trajectory is different from the training condition, it may adversely affect the passer's ability to pass accurately.

The USA National Men's and Women's Teams have been training in Colorado Springs, CO, for the last five years. During the last Olympic Games, the Men's National Team performed well below its potential in Sydney, Australia. One of the skills performed below the expectation was the passing of the jump serve. Considering the speed of the topspin serve during men's international competition, it seemed unlikely that any considerable effect could be detected.

LITERATURE REVIEW

Factors Affecting Air Density

In general, air density depends upon altitude, temperature, barometric pressure and relative humidity. Some of the previously mentioned variables, however, are interdependent. For example, barometric pressure depends on altitude. Two cases have been considered in this investigation: indoor and outdoor.

Indoor conditions (varying altitude and temperature)

USA Today (http://www.usatoday.com/weather/whumdef.htm) provides an excellent treatment of the various factors that affect air density. The indoor conditions scenario is applicable to practice areas and competition areas that are indoors. In such cases, relative humidity plays a rather small role compared to other variables, so temperature and altitude must be specified. Air density (in kilograms per cubic meter) then takes on the form,

$$\rho(h,t) = \frac{1013e^{-h/7km}}{287T}, \quad \textbf{Equation 1}$$

where h is the altitude of the location in meters above sea level and T is the temperature in degrees Kelvin (originally entered into the program in Fahrenheit and then converted). Equation 1 describes quantitatively how the air density decreases with increasing altitude and also with increasing temperature, because air not in a container is less densely packed at lower pressures experienced at higher altitudes and it also expands when it is heated.

The outdoor condition (varying pressure, humidity and temperature)

The second case takes into account barometric pressure, relative humidity and temperature, and is accurate either indoors or outdoors. This method is calibrated so that the air density is 1.22556 kg/m^3 at a temperature of 59°F, 0% relative humidity and 29.2 in of mercury (Hg) of barometric pressure. Initially, the saturation pressure is calculated:

$$P_{sat} = 611 \cdot 10^{[7.5*(T-273)/(T-35.3)]}. \quad \textbf{Equation 2}$$

Saturation pressure is defined as the maximum partial pressure that only the water vapor component of the air would exert if the air were saturated with vapor at a given temperature. T is the temperature in degrees Kelvin (originally entered in Fahrenheit) and P_{sat} is in units of Pascal (1 atmosphere of pressure = $1.01x10^5$ Pa). Vapor pressure in Pa is then calculated,

$$P_{vap} = H * P_{sat} / 100, \quad \textbf{Equation 3}$$

where H is the relative humidity in percent. Subsequently, a quantity known as the virtual temperature is found:

$$T_v = \frac{T}{\left[1-\left(\frac{P_{vap}}{P}\right)(1-0.622)\right]}. \quad \textbf{Equation 4}$$