# INITIAL BALL SPEED AND FORCE ESTIMATION AT IMPACT IN VOLLEYBALL AND FOOTBALL

**M.M, Shahbazi[1], H.R, Sanders[2], S.G.S, Coleman[2].**
**[1]Physics Department of Teheran University, [2]Department of Physical Education, Sport and Leisure Studies of Edinburgh University.**

This study was undertaken to show how with a simple electronic design we could estimate the initial speed of a ball at impact as well as the force exerted on it. The system has been used for top elite, top university and beginners volleyball and football players. The electronic system can provide the time of flight of ball and also the time of impact. From the time of flight, the initial ball speed can be obtained while from the time of impact the force exerted to ball can be estimated. The results showed that highly skilled players apply larger forces and produce higher ball speeds than lower-level athletes. The values of initial speeds and forces achieved by this simple arrangement are very comparable to those obtained by other researchers.

**KEY WORDS:** electronic design, initial speed, average force, volleyball, football.

**INTRODUCTION:** Electronic devices are widely used in sports training and applied research, to measure running, walking, jumping and skiing velocities. In recent years, measurements of human body movement by motion analysis systems have been used increasingly for a wide range of applications. Computer simulations have also greatly contributed to the understanding of the kinematics and dynamics of human motion. In sports, these measurements and simulations are used to optimise performance , to develop equipment for injury prevention and to speed and enhance recovery from injury. Although there have been several reports showing the biomechanical nature of spiking, serving in volleyball or kicking in football using two or three dimensional motion analysis and electromyography techniques, the indirect biomechanical assessments to determine the speed and force exerted on the ball seldom have been reported. Few papers in the literature have dealt with the force applied to the ball in serving or spiking (Kao,Sellens & Stevenson,1994). In kinematic analysis, the ball's post-impact linear velocity can be estimated from the first three fields after ball contact, and has been found to be 19.85±1.89 $m.s^{-1}$ in volleyball spiking (Kao et al., 1994). Other researchers (Coleman, Benham & Northcott, 1993; Li 1983; Maxwell, 1980) have reported the range of linear velocity of a hard spiked volleyball to be 15-35 $m.s^{-1}$ when hit by highly skilled players. Fewer studies have investigated serving. McElroy (1980) gave values of 14.4±1.3 $m.s^{-1}$ for overhead 'float' serves and Coleman (1997) reported figures of 23.7±2.1 $m.s^{-1}$, for 'jump' serving by international players. In the present paper, an attempt was made to offer a simple electronic model to assess the mechanical parameters. The model has been justified by APAS system at 120Hz in the Biomechanics Laboratory of Faculty of Education, Edinburgh University. Nevertheless, the proposed system is not complicated, easy to use and is not expensive.

**METHODS:** In order to estimate ball speed in serving, spiking and shooting, a simple elaborated electronic circuit has been designed and constructed, Fig. 1. Two pad switches are used, via a R-S Flip-Flop, to measure the time of flight of ball. One of these pads is fastened in hand (in plantar), in case of volleyball and/or on shoe, in case of a soccer ball, and the other is fastened on the wall. The former can also be used for the measurement of the impact time in both cases via a simple AND gate. A 1MHz crystal based oscillator is made for precise time measurements and is used, after three steps decade dividing, to provide $10^{3}$ Hz. This frequency yields a precision of $10^{3}$ Sec.. In case of volleyball, a ball is hung at appropriate height, depending on the height of players and in front of wall and 50cm away from it.

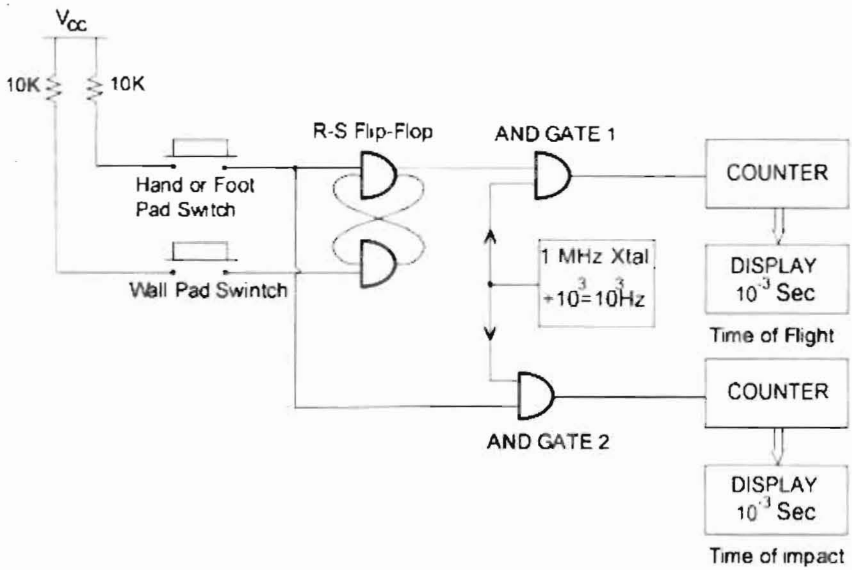


Figure 1 - Electronic schematic for determination of initial ball velocity and the impact force.

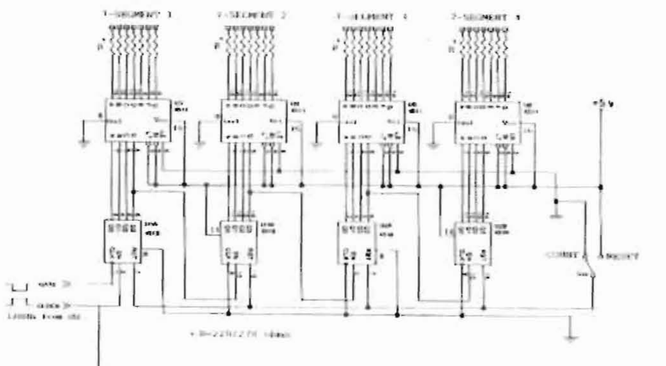

**Figure 2** . The detailed schematic of an oscillator unit, divider and counter-timer used.

Once a player hits the ball, the corresponding switch pad provides a signal to FF to toggle and letting $10^3$ Hz pass through the AND gate1. The corresponding counter begins to count until the ball hits wall. At this moment, the pad switch on the wall, toggles the FF in order to stop the same counter. The ball was hung 7 meters from ceiling , therefore a simple calculation showed that the deviation angle of the ball relative to its normal position was smaller than 6°and the ball actual displacement is 74cm. This displacement is also short enough to neglect the air resistance and to consider the ball velocity as uniform. The speed of ball can directly obtained by division of displacement over the measured time. Pad switch 1, is also used to measure the time of impact. In fact, this pad not only makes the R-S Flip-Flop toggle but also makes the AND gate 2 pass the clock pulse to second counter for determining the touch-down time. In Figure 2 the detailed schematic of crystal based oscillator, divider, and counter-timer to seven segments are presented. In case of football, the same procedure has been applied except, the ball was placed on the ground and, two meters away from wall. In order to determine the ball displacement, for speed calculations, chalk powder was used on the wall in order to trace the impact area allowing measurements of the centre of the ball print relative to the point which is as high as the radius of the ball over the kicking point. This measurement allowed to determine the ball displacement, ball velocity and also the angle of release relative to the ground, which is normally important for estimating the range of ball. This angle can readily be found in a triangle which we know at least two sides of three sides e.g. the opposite and the adjacent.

**RESULTS AND DISCUSSION:** The values of time of flight, impact time, and the force applied to the ball which is exactly the same as exerted to hand or foot of the players, due to Third Newton's Law, are presented in Tables 1 and 2. The ball velocities obtained from this simple method agree well with those obtained by the other researchers. The values of ball velocities in volleyball, compare well with those given in previous studies on overhead serves, although those for jump serves are lower than those obtained by Coleman (1997).

**Table 1.** Mean ± SD of Mechanical Parameters in Volleyball .

| Level | Serve Type | **T- F** (ms) | tB (ms) | Vi (ms $^{1}$) | **Fh** (N) |
|---|---|---|---|---|---|
| Top-Elite | Overhead | 29.1 ± 1.3 | 12.5 ± 1.5 | 17.2 ± 0.8 | 364.6±23.9 |
| | Jump | 26.5 ± 1.5 | 11.5 ± 1.5 | 18.9 ± 1.0 | 435.5±29.9 |
| University Players | Overhead | 33.6 ± 2.3 | 13.3 ± 1.7 | 14.9 ± 1.1 | 269.9±12.8 |
| | Jump | 31.1 ± 1.7 | 11.5 ± 1.6 | 16.1 ± 0.9 | 371.0±27.1 |
| Beginners | Overhead | 38.8 ± 3.1 | 14.7 ± 1.7 | 12.9 ± 1.1 | 232.6±6.4 |
| | Jump | 35.2 ± 1.9 | 13.7 ± 1.4 | 14.2 ± 0.8 | 274.7±11.5 |

**Table 2.** Mean ± SD of Mechanical Parameters in Football.

| Level | Ball Position | **T- F** (ms) | tB (ms) | Vi (ms $^{1}$) | **Ff** (N) |
|---|---|---|---|---|---|
| Top-Elite | Ground-Position | 71.4 ± 5.5 | 10.3 ± 1.4 | 28.8 ± 2.1 | 1258.3±47 |
| University Players | Ground-Position | 82.1 ± 10.2 | 11.6 ± 1.9 | 25.3 ± 3.2 | 983.6±51 |
| Beginners | Ground-Position | 87.5 ± 14.8 | 13.1 ± 2.2 | 23.5 ± 3.8 | 815.2±45 |

This may be because the players were of a slightly lower elite level (national vs. international player) or that the players were slightly restricted by using a suspended ball instead of tossing it themselves, in volleyball case. In football case, the players were also restricted to shoot against a wall, about two meters away from them, instead of shooting in open space. Elite players showed higher ball velocities than university players or beginners, as would be expected. Forces on the ball (and thus on the hand or on the foot) were also higher for elite players compared to the university players or, the beginners.

**CONCLUSIONS:** The proposed electronic system is inexpensive and very simple to use. Mechanical parameters such as initial ball velocities and forces exerted on hand or on foot are quickly and easily obtained. The precision of measurements of this method would get improved if we could make a curtain of photo-cells which would certainly reduce the above restrictions and provides the direction of future biomechanical studies on determination of ball speeds and forces exerted on it.

## REFERENCES:

Coleman, S.G.S., Benham, A.S. & Northcott, S.R. (1993). A three-dimensional cinematographical analysis of the volleyball spike. *Journal of Sport Sciences*, **11**(4), 295-302.

Coleman, S.G.S. (1997). A three-dimensional analysis of the volleyball jump serve. In. Biomechanics in Sports XV (Eds., J. Wilkerson, K. Ludwig, W. Zimmermann), *Texas Women's University Press*, Denton, Texas, 83-87

Kao, S., Sellens, R.W. & Stevenson J. M. (1994), A Mathematical Model for the Trajectory of a spiked volleyball and its Coaching Application, *Journal of Applied Biomechanics*, **10**, 95-109

Li, Z. (1983). Improving the ability of power attack is one of the most important weapons for Chinese men's volleyball team in the way to world champion. *The Symposium of Research Defending papers for National Volleyball Coach* (in Chinese), 7-8

Maxwell, T. (1980). A cinematographic analysis of the volleyball spike of selected top calibre female athletes. *Volleyball Technical Journal* **VII** (1), 43-54

McElroy, G.K. (1980). Understanding the volleyball float serve. *Sports Coach*, 35-37

**Acknowledgement**: The first author is grateful to Professor Dave Collins in Edinburgh University for the possibilities and kind hospitality he provided. The financial support of the Tehran University is also kindly acknowledged.