

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(7), 2014 [1948-1957]

Table tennis diameter changes to audience influence research based on mechanics and least square method

Zhaopeng Ji

Department of Physical Education, Xi'an Shiyou University, Xi'an 710065, Shaanxi, (CHINA)

ABSTRACT

The paper adopts qualitative and quantitative combinative method researching table tennis diameter changes caused influences. At first, it makes physical analysis and mechanical analysis of athletes experience quality, it gets the conclusion that table tennis diameter enlarge causes flight speed slow down, rotation weakens and rebound angle increase. Then, by analyzing audience applauses times and time relations, the paper establishes linear least square method model. On the premise that meet residue squares sum be minimum, apply MATLAB software; it gets audience appreciation quality and table tennis diameters size mathematical relational graph.

KEYWORDS

Least square method; Physical sports mechanics; Magnus force; Circulation theory; Table tennis.



INTRODUCTION

Table tennis development until now, basic principle of its playing, one is fast speed, another is strong rotation, but human race with an aim regarding audience as God discovers that audience appreciation achieved in this way is not so strong, because ball plays so fast that audience already misses exciting parts without understanding it, it weakens table tennis enthusiasts interests, changing small ball into big ball, the purpose is to reduce ball rotational speed, increase hitting round numbers, and increase competition appreciation. The aim is to further increase ball air movement air resistance, slow down competition ball running speed, so that further achieve purpose of further increasing and enriching table tennis professional players hitting techniques and skills, finally increase table tennis competition overall appreciation.

Athlete experience quality influence factors include two aspects, one is table tennis diameter changes caused flight speed, rotational speed suffered elastic changes; the other is athletes height, self technique and gripping habits. The paper gets a series of relationships by quantitative analyzing of table tennis diameter changes, and then makes comparison of obtained relations and athletes themselves qualities, qualitative gets ball diameter changes to athlete influence. In view of audience appreciation quality, it mainly shows appreciation quality from table tennis competitions audience applauses times, theres information indicates that if two parties round numbers arrive between seven and eight, audience will applaud, if round numbers go beyond ten, audience will burst into thunderous applause, therefore to some extent, increase table tennis competition every time round numbers is the key issue to table competition attracts audience^[1]. To best diameter selection, the paper adopts above calculation result, establishes linear least square method model, by matlab fitting, it draws curve graph analysis result, substitute result back to equation, test is effective.

PHYSICAL MODEL ESTABLISHMENT

Athlete experience quality analysis

(1) Research on table tennis flight speed

Set hitting moment table tennis initial speed and end speed are respectively v_0 , v_t , then it can know their average speed is \bar{v} , flight distance from table one end to another end is s . Set table tennis diameter is d , then:

$$f = kd^2$$

According to theorem of kinetic energy it gets formula as following:

$$-kd^2 * s = \frac{1}{2}mv_t^2 - \frac{1}{2}mv_0^2$$

That:

$$v_0^2 - v_t^2 = 2 \frac{kd^2s}{m}$$

And because: $\bar{v} = \frac{v_0 + v_t}{2}$, that: $v_t = 2\bar{v} - v_0$, therefore: $v_0 - v_t = 2v_0 - 2\bar{v}$

$$v_0^2 - v_t^2 = (v_0 - v_t)(v_0 + v_t)$$

$$= 2(v_0 - \bar{v}) * 2\bar{v} = 2 \frac{kd^2s}{m}$$

It can get from above: $(v_0 - \bar{v}) * \bar{v} \propto d^2$

Then:

$$\frac{(v_0 - \bar{v}_1) \bar{v}_1}{(v_0 - \bar{v}_2) \bar{v}_2} = \frac{d_1^2}{d_2^2} = 0.9025$$

Set: $\bar{v}_1 : \bar{v}_2 = 1 : x$, then: $\bar{v}_2 = x \bar{v}_1$.

According to table tennis association investigation group provided information, when smashing 38mm table tennis, hitting speed is nearly 26.35m/s, ball average flight speed is nearly 17.8m/s.

Due to hitting speed basically will not change with ball diameter changing, therefore 40mm table tennis hitting speed can also approximately thought to be 26.35m/s.

That:

$$v_0 = 26.35m/s, \bar{v}_1 = 17.8m/s, \bar{v}_2 = 17.8xm/s.$$

Therefore:

$$\frac{v_0 - 17.8}{v_0 - 17.8x} * \frac{1}{x} = 0.9025,$$

Among them:

$$v_0 = 26.35m/s$$

Then it has:

$$160645x^2 - 23.7809x + 8.55 = 0$$

It solves:

$$x = 0.8652$$

$$\bar{v}_2 = 16.4006$$

Because: $t_1 \bar{v}_1 = t_2 \bar{v}_2$,

Therefore:

$$\frac{t_2}{t_1} = \frac{v_1}{v_2} = \frac{1}{x} = 1.1558$$

That: $t_2 = 1.1558t_1$

Therefore, 40mm table tennis flight time is $\Delta t = 0.1558t_1$ longer than 38mm table tennis flight time; it can see flight time can increase 15.58% .

(2) Table tennis flight rotational speed research

Magnus force F_L table tennis air movement process can be regarded as even distribution sphere movement process in fluid. Generally speaking, object movement in fluid will suffer lift force, resistance and lateral pressure as well as others effects. Specifically, it is when table tennis rotates, circulation generates in its surrounding boundary layer, front incoming flow and circulation common acting result is same direction of incoming flow and circulation one side flow speed quickens, and in the other side of reverse direction, flow speed slows down. According to Bernoulli principle, flow speed quicken one side pressure reduces, flow speed slowing down’s side pressure rises, two side pressure gap generated lateral acting on table tennis is called Magnus force, the force acting direction is vertical to table tennis instant axis, and it vertical to table tennis movement direction. Because table tennis diameter, rotational angular speed, air density and flow speed relative to ball are respectively D, ω, ρ, v . By Joukowski circulation theory, it can solve Magnus force as:

$$F_L = \frac{8}{3} \pi \rho \omega \left(\frac{D}{2}\right)^3 v = \frac{\pi \omega \rho D^3 v}{3}$$

$$\omega = \frac{3F_L}{\pi \rho D^3 v}$$

$$\omega_1 = \frac{3F_L}{\pi \rho D_1^3 v}, \omega_2 = \frac{3F_L}{\pi \rho D_2^3 v}$$

By consulting relative documents, it is clear: Diameter as 38mm table tennis and diameter as 40mm table tennis Magnus force are approximately equal.

$$\frac{\omega_2}{\omega_1} = \left(\frac{D_1}{D_2}\right)^3 0.857375$$

Therefore 40mm table tennis rotational speed reduces 14.26% by comparing with 38mm table tennis rotational speed.

(3) Table tennis rebound angle research

After table tennis changing from small ball to big ball and athlete swinging to hit ball, ball flight route arc will get small and more stable, while ball drop point gets further, incident angle that ball touches table and rebounds will get big^[5]. In above, it already solves after table tennis changing from small ball to big ball, ball rotational speed will reduce. Due to big ball rotational speed reduces, it causes its friction acting with table reduces, after touching table and rebounding big ball speed reduces relative to small ball speed, and big ball reflection angle will increase, reflection arc will be more higher, so that let receiving players more easily receive the ball. Big and small balls incident angle as well as reflection angle is as following Figure 1, big ball speed is smaller than that of small ball while rebounding arc is higher, angle α is big ball incident angle, angle θ is big ball rebound arc

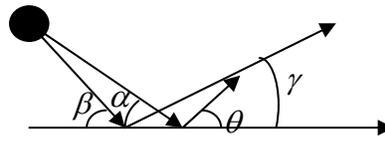


Figure 1 : Diameter different balls rebound angles differences

Athletes influence analysis

By analyzing above factors theoretical data, it is well known that Chinese table tennis players' advantage lies in unpredictable hitting trajectory. However, when competition ball changes from small one to big one, by above model, it is clear that table tennis flight speed and rotational speed has been obviously reduced. It is very bad for Chinese players. Besides, table tennis diameter changes influences to athlete will also be different with athlete playing type differences. Due to ball flight speed and rotational speed suffered influence, athletes major playing with loop suffers larger influences. These athletes take speed rotation, skill as main playing, however, athletes that good at service strength due to hitting motion big range, strong strength, they still can play high qualities speed and rotation, therefore their suffered less influences. Therefore big ball basic law, speed and rotation achievement is mainly up to strength; speed without strength will quickly slow down rotation that is an essential difference between big ball and small ball.

In view of athlete height, due to big ball rebound angle is big, it causes ball arc gets big, which is a big challenge for short athletes. But most of athletes' heights conform to requirements. Arc increasing is beneficial to players' better receiving.

In view of athletes' playing habits, small ball era always relies on speed and rotation confrontation, and speed dominates, to the emergence of big ball, it causes professional athletes perceptibility reduction, meanwhile it constraints speed and rotational power, strength function is obviously higher than speed and rotation, to mainly relying on quick service speed and directly achieving first strokes advantages athletes, no doubt it is a kind of technical weakening, while is a promotion to athletes win mainly by strength, their hitting strength is strong, motion range is big, playing big ball can still give their speed and high quality rotational advantages into play, using big ball also provides more opportunities for driving first service reception and counter-hitting.

In view of athletes gripping habits, by consulting information, it is clear that table tennis diameter changes has larger influences on athletes that accustomed to use forehand hitting.

On a whole, athletes experience qualities mainly influence factor is skill that is playing habit. According to Chinese table tennis association-research staff of the Scientific Committee made "different diameters table tennis to hitting speed and rotation influences experiments"^[6], experiment result was: big diameter ball, speed is slower than that of small diameter ball, rotation is weaker than that of small diameter ball; same diameter balls, large weight and elastic force ball is faster and stronger rotating than that of small weight and elastic force ball. Flight speed and rotational speed reduction, reflection arc increase is beneficial to player receiving the ball, and better improve their skills.

Audience appreciation research

According to above calculation result, it indicates: big ball era incoming, let ball speed reduces, rotation weaken, rebound angle increase, athletes have more time to think and make reaction^[7]. In 90s, international table tennis association experiment in Suzhou, the conclusion is most of athletes feel 40mm ball speed is slow, and adding fighting rounds; in table tennis athletes two parties turn opponents' force against them will play ball further away from table when playing, long table confrontation, opposite pulling is more attractive than drop shots inside table. In table tennis competition, athletes hitting rounds times will improve competition appreciation, there is data showing that if two parties fighting round times get more, audience applauds and loudly shouting will increase,

therefore to some extent, audience applauses times in table tennis competition can show table tennis competition's attraction to audience.

ESTABLISH LINEAR LEAST SQUARE METHOD MODEL

Known a group of two-dimensional data, that plane n pieces of point (x_i, y_i) , $i = 1, 2, \dots, n$, x_i is different from each other, look for a function curve, let it get closest to all data points under one criterion that has best curve fitting. Linear least square method is common method to solve curve fitting, basic thought is, let:

$$f(x) = a_1 r_1(x) + a_2 r_2(x) + \dots + a_m r_m(x)$$

Among them, $r_k(x)$ is beforehand selected a group of linear uncorrelated function, a_k is undetermined coefficient ($k = 1, 2, \dots, m, m < n$) fitting criterion is letting y_i , $i = 1, 2, \dots, n$ and $f(x_i)$ distance δ_i squares sum to be minimum, it is called least square criterion.

Coefficient defining:

$$J(a_1, \dots, a_m) = \sum_{i=1}^n \delta_i^2 = \sum_{i=1}^n [f(x_i) - y_i]^2$$

To solve a_1, a_2, \dots, a_m , let J arrive at minimum, only need to make use of extremum necessary condition

$\frac{\partial J}{\partial a_k} = 0 (k = 1, \dots, m)$, and get linear equations regarding a_1, a_2, \dots, a_m :

$$\sum_{i=1}^n r_j(x_i) \left[\sum_{k=1}^m a_k r_k(x_i) - y_i \right] = 0, \quad (j = 0, 1, \dots, m)$$

That:

$$\sum_{i=1}^m a_k \left[\sum_{i=1}^n r_j(x_i) r_k(x_i) \right] = \sum_{i=1}^n r_j(x_i) y_i, \quad (j = 1, \dots, m)$$

Record:

$$R = \begin{bmatrix} r_1(x_1) & \dots & r_m(x_1) \\ \dots & \dots & \dots \\ r_1(x_n) & \dots & r_m(x_n) \end{bmatrix}, \quad A = [a_1, \dots, a_m]^T, \quad Y = (y_1, \dots, y_n)^T$$

Equation can be represented as $R^T R A = R^T Y$, when $\{r_1(x), \dots, r_m(x)\}$ is linear uncorrelated, R is column full rank, $R^T R$ is reversible, and then equations have unique solution.

$$A = (R^T R)^{-1} R^T Y$$

The paper makes statistics Schrage versus Wang Li-Qin, Bohr versus Ma Lin as well as Ma Lin versus Wang Hao three competitions every section competition time and every section applauses times

by watching 2008 Beijing Olympic Games table tennis competition video. Statistics table is as following TABLE 1, TABLE 2, TABLE 3 show:

TABLE 1 : Bohr versus Ma Lin

Bohr VS Ma Lin		
	Competition time t(s)	Audience applaudes times N(time)
First section	410	16
Second section	316	15
Third section	530	18

TABLE 2: Ma Lin versus Wang Hao

Ma Lin VS Wang Hao		
	Competition time t(s)	Audience applaudes times N(time)
First section	490	16
Second section	500	17
Third section	420	17
Fourth section	540	18
Fifth section	665	16

TABLE 3: Schrage versus Wang Li-Qin

Schrage VS Wang Li-Qin		
	Competition time t(s)	Audience applaudes times N(time)
First section	320	16
Second section	275	14
Third section	390	15
Fourth section	300	13

Successively input above table statistics competition time data into formula:

$$D^2 = \frac{1912113.56}{t} - \frac{554989490.5}{t^2}$$

It can get different competition times corresponding table tennis diameters, as following TABLE 4 show:

TABLE 4: Competition time and table tennis diameters relations

Competition time t(s)	Table tennis diameter D(mm)
410	36.91
316	22.21
530	40.4
490	39.88
500	40.053
420	37.5
540	40.47

665	40.25
320	23.57
275	insignificant
390	35.41
300	14.39

Screen data, it finds that table tennis diameter bottom first, bottom third data have obvious deviation with other data, it is insignificant and eliminate it.

According to above table data, correspond different table tennis diameters with corresponding every section audience applauses times, and get as following TABLE 5.

According to least square method theory, use MATLAB fitting toolbox making n squares ($n = 1,2,3,4,5,6$) fitting of Table 5 data, it can get following Figure 2, Figure 3.

TABLE 5 : Number of applauses and diameters relations

Number of audience applauses N(time)	Table tennis diameter D(time)
16	36.91
15	22.21
18	40.4
16	39.88
17	40.053
17	37.5
18	40.47
16	40.25
16	23.57
15	35.41

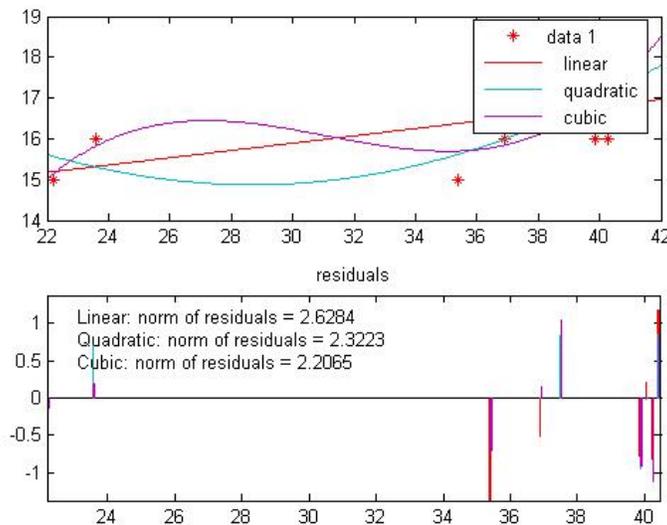


Figure 2 : Simple equation, quadratic equation, cubic equation fitting chart

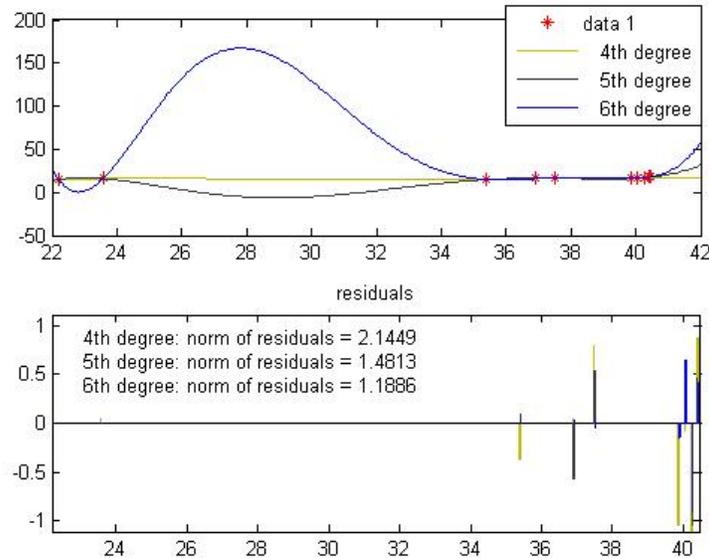


Figure 3 : Quartic, quintic, sextic fitting chart

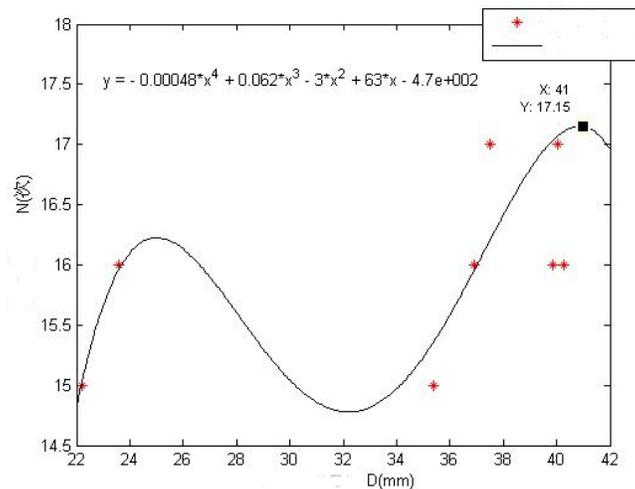


Figure 4 : Table tennis diameter and audience applauds times' relation chart

By Figure 4, it is clear that best diameter can be selected as 41mm. International table tennis association has made statistics: in every section competition, two parties' athletes fighting round numbers are few, fighting time is short, which causes some players' levels cannot play, some audiences also feel inexplicable when watching, and the competition is over without understanding. Two parties' athletes fighting round numbers get more, fighting time is long, which will cause some players physical abilities reduce and abnormally playing, and some audiences will also generate visual fatigue and it is very tired when watching. Only when two parties' players fighting round numbers are proper, fighting time is proper, audiences' emotion will become very stimulated, applauds will not cease. Applauds represent audiences' emotions and satisfaction degree to great extent, which is also audience appreciation quality.

Respectively input big and small table tennis diameters $D = 38mm, 40mm$ into above chart fitting equation.

When $D = 38mm$, it can get: $N = 16$

When $D = 40mm$, it can get: $N = 17$

Respectively input big and small table tennis diameters $D = 38mm, 40mm$ into formula

$$D^2 = \frac{1912113.56}{t} - \frac{554989490.5}{t^2}$$

When $D = 38mm$, it can get: $t = 429s$

When $D = 40mm$, it can get: $t = 497s$

By above result, it is clear after using big ball replacing small ball, within every section competition time change ranges, players' physical abilities consumption is equal, athletes levels can still normally play, athletes' experience qualities almost unchanged. And audience every section applauds times obviously rise, it obviously improves audience appreciation quality. The conclusion is consistent with above qualitative analysis conclusion, correspondingly, it verifies above conclusion accuracy.

By observing above Figure 4, it is clear when table tennis diameter is $41mm$, audience every section applauds times are the most, it arrives at every section applauds 17.15 times. That is to say, when table tennis diameter is $41mm$, audience appreciation quality is the highest. By calculating, now every section competition time is nearly around s , players' health is not fatigue, which is beneficial to athletes' normal playing.

CONCLUSIONS

Table tennis size changes have larger influences on athletes' heights and gripping habits, and it hasn't large influences on athletes playing by strength, on a whole, diameters enlarging is more beneficial to athletes' receiving, add fighting rounds, only a lot of practices can overcome himself inconvenience to diameter enlarging. "Big ball era" promotes athletes' experience qualities. After that, adopt quantitative analysis method on audience appreciation quality, by searching audience applauds times and time's relations, establish linear least square method model, on the premise meet minimum residual squares sum, apply MATLAB software fitting toolbox getting audience appreciation quality and table tennis diameters sizes mathematical relation chart. By observing relation chart, it can get that when table tennis diameter is around $41mm$, it can let audience appreciation quality arrive at maximum, and then substitute the result back to athletes' experience quality relationships, it gets athletes experience quality can also get better result. Finally, it gets when best diameter is $41mm$, it conforms to higher quality to athletes and audiences.

REFERENCES

- [1] Li Jianshe; Effect of Mechanical Parameters on the Length of the Long Jump. Journal of Zhejiang University (Sciences Edition), **17(3)**, 370-374 (1990).
- [2] Yin Zengqian, Xu Donghai; Theoretical Analysis of Air Resistance. Physics and Engineering, **6**, (1998).
- [3] Li Hong-de; The Dynamics in the Movement of Right-Up Revolving Pingpong. Journal of Henan Mechanical and Electrical Engineering College, **18(6)**, 40-41 (2010).
- [4] Jiang Fu-gao, Li Xiang-chen, Xu Quan-yong; Flight Simulation of Table Tennis Ball. Journal of Qufu Normal University (Natural Science), **34(1)**, 104-106 (2008).
- [5] Yang Hua, Guan Zhi-ming; Simulation of Ping-pong Trajectory Based on ODE. Computer Simulation, **28(9)**, 230-232 (2011).
- [6] Cai Zhi-dong, Lu Jian-long; Parameter equation and practical equation of optimum putting angle of a shot in considering air resistance. College Physics, **25(10)**, 16-22 (2006).