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Table tennis diameter changes to competition influence quantitative analysis

Naiming Wang

Institute of Physical Education, Jilin Normal University, Siping 136000, Jilin, (CHINA)

ABSTRACT

Use probability theory and mathematic statistics method respectively to make analysis of high level table tennis players using small ball and big ball to play singles data in international major sports competitions after changing table tennis, from which it puts emphasis data statistics and handling with athlete's every one point hitting round numbers when using small ball to proceed competition and using big ball to proceed competition. The paper gets that big ball era audience appreciation quality has some improvements by comparing with small ball era and athlete competition experience quality has also been improved. On the premise of ensuring that let table tennis normally fly across net without falling out of table when hits table tennis every time, the paper assumes an athlete hitting optimum distance. Meanwhile, by Newton classical mechanical computing, it gets flight time increment; and by time increment and diameter increment relations, it gets table tennis diameter increment and flight time increment function relationship. By function relationship, the paper discusses table tennis best diameter.

KEYWORDS

Probability theory; Mathematical statistics; Newton classical mechanics; Table tennis diameter.

INTRODUCTION

Before Sydney Olympic Games in 2000(including Sydney Olympic Games) international competition ball diameter is 38mm. After Oct.1st, 2000, international competition ball is changed into 40mm diameter's big ball. In the beginning of 1980s, after Chinese team engulfing seven events champions in the 36th world table tennis championship, someone proposed a suggestion of enlarging table tennis diameter, but it hadn't been taken seriously by people at that time. After that, with table tennis techniques constantly improving, ball speed becomes faster and faster, rotation becomes stronger and stronger, which causes more athletes fighting moment round numbers reduce, sometimes, audience hasn't yet made clear while the result already came out. In this way, it greatly weakens table tennis enthusiasts' interests. Therefore, international table tennis association former chairman Ogimura Ichirō considered enlarging table tennis. After Xu Yin-Sheng took charge of international table tennis association chairman, the event was put into on agenda. In order to support table tennis reform, China Table Tennis Association-research staff of the Scientific Committee made "different diameters and weights table tennis to hitting speed and rotation influential experiments". The result showed : Comparing with small diameter table tennis, big diameter table tennis speed is slow, rotation is weak; same diameters balls, big weight and elastic force one is faster and stronger rotating than small weight and elastic force one. In Feb.23rd, 2000, international table tennis association special meeting and congress have passed 40mm big ball reform scheme in Kuala Lumpur, and decided that since Oct.1st, 2000, which was also after Sydney Olympic Games, table tennis competition will use diameter $40mm$, weight $2.7g$ big ball to replace $38mm$ small ball.

However, since table tennis "big ball era" up to now, dispute about ball diameter has never been ceased. Due to professional athlete's height, playing habits, gripping habits differences, their sensitivities to ball diameter changes are quite different, therefore the paper analyzes these two questions by modeling: whether competition using big table tennis improves athlete experience quality and audience appreciation quality by comparing with "small ball era"; table tennis best diameter length.

To athlete competition experience quality and audience appreciation quality evaluations, it mainly based on lots of statistics data handling. Therefore, to problem's solution, it needs key and useful data, and transform data, make screening analysis and comparison. Search for Sydney Olympic Games in 2000, Osaka world championship in 2001, Beijing Olympic Games in 2008 these three major sports competitions' table tennis competition hitting data, and then carry out handling, analyzing as well as drawing graphs. Analyze table tennis player's every one point round numbers (two fighting athletes respective hit the ball per time is one round) data, it can get that athlete hitting round numbers present normal distribution. By normal distribution random variable X density function and distribution function, respectively calculate small ball and big ball different hitting round numbers occurrence probabilities, and carry out comparative analysis to get conclusions. Besides, start from Newton classical mechanics, establish physical model, and make qualitative analysis of athlete hitting table tennis process. Decompose athlete's hitting tablet tennis complex process into several simple physical movement models; rely on $E = E_k + E_p$ energy conservation law to make analysis. Apply Newton classical mechanics and function relationships together to make solution, make quantitative analysis of models, and solve table tennis optimum diameters.

MODEL ESTABLISHMENT AND SOLUTION

Big table tennis whether is different from "small ball era"

The paper will complete it by two steps, firstly analyze whether current competition ball diameter improves athlete experience quality by comparing with "small ball era", and then analyze audience watching quality.

(1) Athlete experience quality analysis

By sorting Sydney Olympic Games in 2000, Osaka world table tennis championship in 2001, Beijing Olympic Games in 2008 table tennis men's singles competition records required data, make analysis of required data. In the following, it detailed describes model establishment and solution. Sort Sydney Olympic Games in 2000, Osaka world table tennis championship in 2001 men's singles data and get TABLE 1.

TABLE 1 : Data sorting result

Event	1-3rounds	4-6 rounds	7-9 rounds	>9 rounds
Sydney Olympic Games in 2000	80.6%	13.8%	5.1%	0.5%
Osaka world table tennis championship in 2001	71.5%	22.2%	5.6%	0.7%

Carry out bar chart intuitional comparison of TABLE 1 data and get Figure 1.

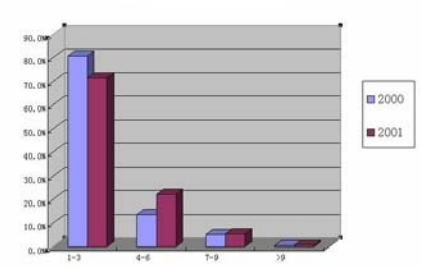

Figure 1 : Men's singles hitting round numbers comparative figure

By Figure 1 analysis, it is clear after competition ball changing into big ball in 2001, athlete different subsection hitting round numbers has relative obvious changes. From which 1-3 round numbers obviously reduce, 4-6 round numbers obviously increase, 7-9 rounds have increasements. Above nine rounds changes are not obvious.

By above analysis, it is clear after changing balls athlete hitting round numbers increase in the competition. Athlete's scoring and losing as well as continuous hitting performance increase in one competition, and the athlete obtains more performing opportunities. So that it can get conclusion that athlete experience quality has been improved. Sort Beijing Olympic Games in 2008, Osaka world table tennis championship in 2001 men's singles data and get TABLE 2 as well as Figure 2 show.

(2) Audience appreciation quality analysis

Considering in 2001, athlete first used big ball, it was hard to avoid inadaptation on ball. Therefore, select Beijing Olympic Games in 2008 athlete hitting round numbers data and Osaka world table tennis championship in 2001 hitting round numbers to make comparison. So, by Figure 2 analyzing, it is clear that in competitions after athlete adapting to competition ball, athlete hitting round numbers hasn't showed up larger changes. Thereupon, it proves Sydney Olympic Games in 2000 and Osaka world table tennis championship in 2001's comparative reference is for sure. From lots of data, it can be sure that athlete hitting round numbers conform to normal distribution. Hitting round number is random variable X probability density function that is:

$$f(x)=\frac{1}{\sqrt{2\pi}\sigma}e^{-\frac{1}{2\sigma^2}(x-\mu)^2}$$

Its distribution function is:

$$F(x)=\int_{-\infty}^{x} f(t)dt=\frac{1}{\sqrt{2\pi}\sigma}\int_{-\infty}^{x} e^{-\frac{(x-\mu)^2}{2\sigma^2}}dt\,(-\infty<x<+\infty).$$

Select one classical competition to analyze. Sydney Olympic Games in 2000 table tennis men's singles finals competition data is as TABLE 3.

TABLE 2 : Men's singles data

Event	1-3rounds	4-6 rounds	7-9 rounds	>9 rounds
Osaka world table tennis championship in 2001	71.5%	22.2%	5.6%	0.7%
Beijing Olympic Games in 2008	69.5%	22.6%	7.2%	0.7%

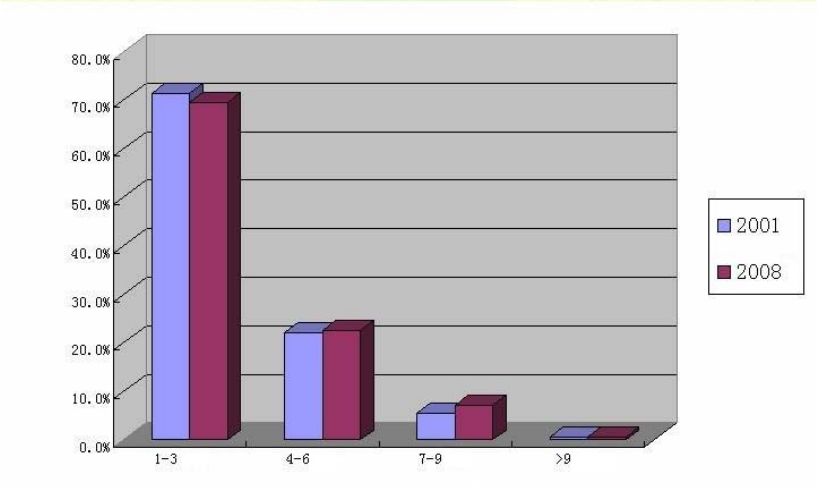

Figure 2: Men's singles hitting round numbers comparative figure

TABLE 3 : Sydney Olympic Games in 2000 table tennis men's singles finals

Score	The first game		The second game		The third game		The fourth game		The fifth game	
	Kong Ling-Hui	Waldner	Kong Ling-Hui	Waldner	Kong Ling-Hui	Waldner	Kong Ling-Hui	Waldner	Kong Ling-Hui	Waldner
1	1	2	2	3	3	3	4	1	3	3
2	2	2	8	1	3	1	3	2	1	2
3	2	2	3	3	3	3	5	2	2	5
4	4	1	3	4	4	3	3	3	2	3
5	2	4	1	3	2	1	2	8	2	5
6	2	2	5	1	3	2	4	2	2	2
7	2	1	4	3	2	2	2	4	2	8
8	3	2	3	1	2	3	2	6	2	3
9	6	11	2	3	4	1	1	1	2	5
10	2	5	3	3	1	2	1	3	1	6
11	1	2	2	2	2	4	2	3	2	1
12	1	4	2	2	4	3	3	2	2	2
13	2	1	4	4	3	3	2	6	4	3
14	6	2	4	3	4	2	2	1	2	
15	1	2	2	2	2	3		1	2	
16	3	3	7	2	7	3		4	4	
17	7		2	2	4	2		8	2	
18	2		2	1		2		1	2	
19	4		4	2		2		1	1	
20	4		2			2		2	3	
21	4		5			2		7	1	

Sort TABLE 3 data to calculate and find it conforms to normal distribution that $X \sim N(2.813,1.640^2)$. Record F_1 as the competition hitting round numbers occurrence probability's distribution function, P_1 is hitting round number occurrence probability.

The paper also makes statistics comparison of stalemate phase hitting racket numbers. According to international table tennis federation investigation, on certain condition, competition hitting racket number is in direct proportion to audience's applauses. Especially from the fifth round to the seventh round, audience applause is largest, audience appreciation quality is highest, and it can refer to following Figure 3.

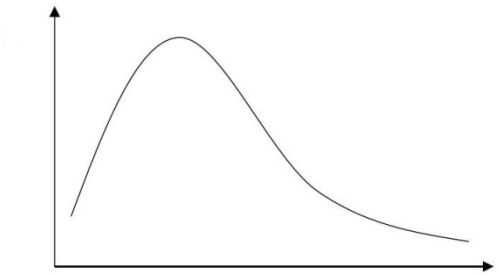

Figure 3 : Hitting racket numbers and audience applauses relations

Calculate hitting round numbers as fifth to seventh round probability:

$$P_1\{5 \le X \le 7\} = F_1(7) - F_1(5)$$

$$= \phi(\frac{7-2.813}{1.640}) - \phi(\frac{5-2.813}{1.640}) = 7.64\%$$

Select Osaka world table tennis championship in 2001 men's singles finals' competition data to sort and calculate, it is clear that hitting round numbers conform to normal distribution, that:
$X \sim N(2.934,1.493^2)$

Record F_2 as the competition hitting round numbers occurrence probability's distribution function, P_2 is hitting round number occurrence probability. Calculate hitting round numbers as fifth to seventh round probability:

$$P_2\{5 \le X \le 7\} = F_2(7) - F_2(5)$$

$$= \phi(\frac{7-2.934}{1.493}) - \phi(\frac{5-2.934}{1.493}) = 8.92\%$$

Similarly, Beijing Olympic Games fifth to seventh round probability:

$$P_3\{5 \le X \le 7\} = F_3(7) - F_3(5)$$

$$= \phi(\frac{7-2.961}{1.494}) - \phi(\frac{5-2.961}{1.494}) = 8.87\%$$

Compare three times international major sports competitions round numbers as 5-8 round probability, it can find that in competitions after changing into big ball, it appears 5-8 round hitting probability increasing. Audience can watch more two athletes' multiple times pulling, stalemating great shots. Therefore, audience appreciation quality has also been improved.

Table tennis best diameter length

At first, the paper carries out simplified discussion in case small ball diameter increases but small ball mass doesn't increase. Set air resistance to ball is in direct proportion to ball diameter's square, and ball makes linear movements along horizontal direction, we calculate table tennis flying from table one end to another end required time available increased percentage. Set smashing moment table tennis initial speed is v_0 end speed is v_t, average speed is $\overline{v}$, flight distance between table one end to another end is s, table tennis diameter is d,and air resistance is $f = kd^2$.

According to theorem of kinetic energy:

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

That: $v_0^2 - v_t^2 = 2\frac{kd^2 s}{m}$. And because average speed $\overline{v} = \frac{v_0 + v_t}{2}$, $v_t = 2\overline{v} - v_0$,that:

$$v_0 - v_t = v_0 - (2\overline{v} - v_0) = 2v_0 - 2\overline{v}$$

Among them, $v_0^2 - v_t^2 = (v_0 - v_t)(v_0 + v_t) = 2(v_0 - \overline{v}) \cdot 2\overline{v} = 2\frac{kd^2 s}{m}$。

As a result, $(v_0 - \overline{v}) \cdot \overline{v} \propto d^2$,then $\frac{(v_0 - \overline{v}_1) \cdot \overline{v}_1}{(v_0 - \overline{v}_2) \cdot \overline{v}_2} = \frac{d_1^2}{d_2^2}$. Because $d_1 = 38mm, d_2 = 40mm.$

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

Set $\overline{v}_1 : \overline{v}_2 = 1 : x$, according to international table tennis federation investigation group statistical information, when table tennis athletes pulling $38mm$ table tennis, hitting speed is nearly $26.35m/s$, ball average flight speed is nearly $17.80m/s$. Athlete hitting speed basically doesn't change with table tennis diameter changes, so

$$v_0 = 26.35m/s, \overline{v}_t = 17.80m/s$$

Then it has $\overline{v}_2 = 17.80xm/s$. So $\frac{v_0 - 17.80}{v_0 - 17.80x} \cdot \frac{1}{x} = 0.9025$, from which $v_0 = 26.35m/s$. Then it has $16.0645x^2 - 23.7809x + 8.55 = 0$

It solves $x = 0.8652, v_2 = 15.4006$. And because $\overline{v}_1 \cdot t_1 = \overline{v}_2 \cdot t_2$, $t_2 = 1.1558t_1$. So it can get that big ball pulling flight time is more than small ball flight time, flight time increases 15.58% ,that when big ball increases $2mm$,flight time increases 15.58% . By calculating, 当when big ball increases $1mm$,flight time increases 15.07% . Thereupon, it can get table tennis diameter increment and flight time increment function formula is $y = -7.28x^2 + 22.35x, (x > 0)$.

Therefore it can get when diameter increment is $x = -\frac{b}{2a} = 1.54$, table tennis flight time increment arrives at maximum, now audience appreciation quality also gets improved, so tablet tennis best diameter is $d = 39.54mm$.

CONCLUSIONS

The paper by sorting and calculating lots of data, it gets table tennis best diameter is 39.54mm. After small ball changing into big ball, the ball volume increases that lets table tennis speed, rotation,

rebound angles as others occur to corresponding changes in running, it increases athletes' hitting round times, and improves audience appreciation to table tennis, but meanwhile it also brings into new challenge to table tennis.

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