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Research on the quality evaluation of the table tennis competition based on the optimization theory

Wei Xiong*, Cheng Yang
Department of Physical Education, Southwest Petroleum University, Chengdu 610500, Sichuan, (CHINA)

ABSTRACT

Through the research on the athletes' skills play and physical agility consumption in Sydney Olympics and the 49th World Table Tennis Championships, this paper studies the impact of changes in the size of table tennis on the athletes, obtains that the bigger table tennis will lower the athletes' competition quality, establishes the indicator system of the audience to appreciate the competition quality, and analyzes the changes in the audience to appreciate the game. On this basis, it uses the optimization theory, builds relationship between the intensity degree of audience's applause and the plate number and the relationship between the competition time and athletes' satisfaction degree, and puts forward reasonable proposals for the table tennis players.

KEYWORDS

Table tennis diameter;
Optimization;
Physical agility exertion;
Index system.

INTRODUCTION

In 2000, the International Table Tennis ITTF increased the official ball's diameter from 38mm to 40mm in the international professional events. This increases the air resistance of the ball in the air, slows the moving speed of the ball in the game, so as to achieve the purpose of further increasing and enriching the hitting technologies and techniques of professional tennis players, and ultimately increases the overall ornamental degree of table tennis tournament. However, since table tennis "big ball era" comes, controversy about the diameter of the ball has not stopped.

The larger diameter of the table tennis directly affects the changes of quality, speed and rotation speed of the table tennis. These changes of the table tennis nature would affect the skills play of athletes in the competition and athletes' physical endurance. During the race the athletes' scoring rate will directly reflect the skill play of athletes, and the body's energy consumption will reflect the athletes' physical endurance. Therefore, this paper surveys some related data, and takes the scoring rate and the energy consume of the athletes' body as some important indicators of the athletes' experience quality, and obtains the changes of athletes' experience quality after comparing. Because the length of table tennis' diameter has relationship with the competition experience quality of athletes and the ornamental degree of spectators, it needs to find the best length of a table tennis' diameter and make the experience quality of athletes and viewing quality of spectators reach a balance, thus the athlete can make the technology and power into full play for every game, the audience can be engrossed into the game and see fun.

Because the longer the competition time is, the greater the burden of the athletes' body is, this paper establishes a relationship between the game time and the players' experience quality. Game time and the audience ornament have a certain relationship, you can find the best time to improve the spectator's ornamental degree and the competition experience quality of the athlete. First, through the data processing we can find the optimal relationship between the game time and the athletes' experience quality, and the audience' ornamental degree, and then find the best length of the table tennis' diameter by integrating the values of the two indexes.

ANALYSIS ON THE EXPERIENCE QUALITY AND ORNAMENTAL DEGREE OF THE COMPETITION

After the small ball changes into larger ball, ball's speed and rotation speed will be smaller from the macro analysis, it has higher demands on athletes' strength; and these will affect the skills play of athletes in the game and athletes' physical endurance ability. This article takes these factors as some important indicators of the athletes' experience quality, conduct data processing to reflect the changes in the experience quality for athletes. For the audience, after the small ball changes into the ball, the number of rounds increases, the game is more intense, the aspect in the competition increases, which will undoubtedly raise ornamental degree.

Based on the analysis of changes in the diameter of the table tennis, this paper obtains the changes of various indicators in the "big ball era" table tennis game, arrives at the changes of athletes' experience quality and spectators' ornamental value.

The property analysis of large balls

Changes in quality after the reform

It is known that the spherical shell's thickness of the original $38\ \text{mm}(2R_1)$ table tennis is 0.39 mm, the external radius is $19\ \text{mm}(R_1)$, the inner radius is $18.61\ \text{mm}(R_2)$, and the mass of the ball is $2.5\text{g}(m_1)$. The material volume of the sphere is V_1, the calculation formula is:

$$V_1 = \frac{4}{3}\pi R_1^{\ 3} - \frac{4}{3}\pi R_2^{\ 3} = 1.7323(\text{cm}^3)$$

Suppose the material density of the ball is ρ:

$$\rho = \frac{m_1}{V_1} = \frac{2.5}{1.732.3} = 1.4432(\text{g}/\text{cm}^3)$$

It is known that the diameter of the large ball is 40 mm, the outer radius is $20\ \text{mm}(r_1)$, the inner radius is $19.61\ \text{mm}(r_2)$, and the material volume V_2 and the mass m_2 of the large ball are respectively:

$$V_2 = \frac{4}{3}\pi r_1^{\ 3} - \frac{4}{3}\pi r_2^{\ 3} = 1.8443(\text{cm}^3)$$

$$m_2 = V_2\rho = 2.6617(\text{g})$$

The mass difference of the two balls is Δm:

$$\Delta m = m_2 - m_1 = 0.1617(\text{g})$$

It can be obtained that the quality has increased 6.47%.

Changes of the rotational speed after the small ball changes into larger ball

If an athlete hits the two balls with the same manner and same force, due to that the moment of inertia of the large ball and the small ball is different, and the rotation speed of the ball will be significantly changed.

Through referring to information[1], the sphere may be seen as composed of many small rings, as shown in Figure 1.

Select a small circular ring to consider, the quality of the small ring is:

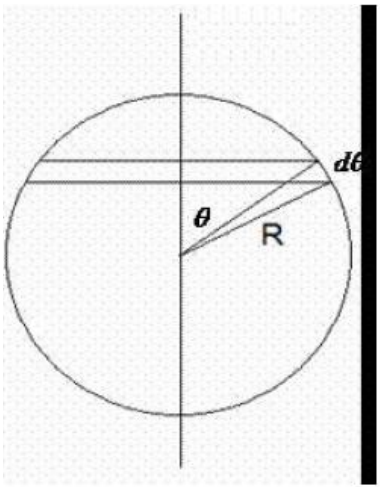

Figure 1 : Illustrative Figure

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$$dm = \rho dS = \rho \times 2\pi(R\sin\theta) \times Rd\theta$$

The rotational inertia of the mass element:

$$dJ = (R\sin\theta)^2 dm = 2\pi\rho R^4 \sin^3\theta d\theta$$

The rotational inertia of the entire spherical shell:

$$J = \int dJ = \int_0^{\pi} 2\pi\rho R^4 \sin^3\theta d\theta$$

$$= 2\pi\rho R^4 \int_0^{\pi} \sin^3\theta d\theta$$

$$= 2\pi\rho R^4 (\cos 3\theta / 3 - 3\cos\theta)/4 \Big|_0^{\pi}$$

$$= \frac{2}{3} mR^2$$

The rotational inertia of the two kinds of balls is calculated as:

$$I_1 = \frac{2}{3} m_1 r_1^2 = 6.017(g \cdot cm^2)$$

$$I_2 = \frac{2}{3} m_2 r_2^2 = 7.098(g \cdot cm^2)$$

According to the speed $50\ r/s$ of the small ball and the moment of momentum theorem, the rotational speed ω_2 of the big ball can be calculated:

Because: $I_1\omega_1 = I_2\omega_2$

Then: $\omega_2 = \frac{I_2\omega_1}{I_2} = 42.39(r/s)$

Angular velocity difference of the two balls is:

$$\Delta\omega = \omega_2 - \omega_1 = 7.61(r/s)$$

By calculation, when hitting the two balls of different sizes in the same way, the rotational speed of the large ball reduces about $7.61(r/s)$ compared to the rotational speed of the small ball (reduction rate is approximately 15.22%).

Changes of flying speed after changing the small ball into larger ball

Objects will suffer the effect of resistance when moving in medium (such as water, air and other), the direction is in the opposite direction of its speed, the size of medium resistance determines the flight speed of the table tennis, media air's temperature, density, viscosity, etc., it can be represented by the following formula $f = c\rho S\varphi(v)$.

Here, the parameter ρ is the density of the medium air, $\varphi(v)$ is a function of the object's speed v, the form is uncertain. Further, although the resistance is related to the object's size and shape, considering the size and shape, the object only can be seen as a rigid body, and then the situation will be more complex, here the object is seen as a particle, which is the scope of particle mechanics. In specific discussion, because the table tennis is indoor sport, assuming the air is still, table tennis does not change size and shape during flight, so $c\rho S = k_1$, and $\varphi(v)$ is relatively complex, $\varphi(v)$ is only speed-related function $\varphi(v)$ increases with the increase of v, the related expression is shown in TABLE 1 below.

TABLE 1 : The relational tables between $\varphi(v)$ and v

Speed m/s	0-10	10-311	Above 311
Expression of $\varphi(v)$	k_2v^1	k_2v^2	k_2v^n

After query the corresponding expression to the table tennis' speed is:

$$\varphi(v) = k_2 v^2$$

In summary the air resistance of the table tennis suffered in the flight is:

$$f = k_1 k_2 v^2$$

When the two balls move with the same speed v_0, the ratio of the air resistance is:

$$\frac{f_1}{f_2} = \frac{c\rho S_1 v_0^2}{c\rho S_2 v_0^2} = \frac{S_1}{S_2} = \frac{\pi r_1^2}{\pi r_2^2} = 0.9025$$

As the table tennis receives only air resistance in the movement direction during the flight, by calculating it can be obtained that by the air resistance of the large ball increases for about 9.75% than that of the small ball, namely the horizontal flight speed decreases about 9.75% after the small ball changes into larger ball, as shown in TABLE 2.

By the analysis of the data in TABLE 2, after the

TABLE 2 : Corresponding changes in each index after changing the small ball into larger ball

Factor	Quality	Rotation speed	Horizontal velocity
Percentage of change	6.47%	−15.22%	−9.75%

small balls change into larger ball, the mass increases, the rotation speed reduces, the horizontal speed reduces, thus it makes the speed, and rotation and strength in the winning factor of the table tennis undergo a qualitative change. Due to the limitation of the speed and rotation, some athletes' technologies will also receive some impact.

The Chinese delegation consultant Zhang Xielin believes that when the ball slows down, skill-based athletes will eat some losses. For players that are good at leveraging ball when using the small ball, such as Kong Linghui's backhand and Liu Guoliang's block, it is not easy to leveraging after changing into the big ball, it needs active force to play back high-quality ball. The weakened rotation of the ball will have a negative impact on athletes that have good serve and many changes, these adverse effects will directly influence the athletes' play during the game, affect competition results, and lead to a decline in the experience quality of athletes.

Therefore, this article studies the scoring rate of all stages in the "big ball era" before and after the reform, further illustrates the changes in the experience quality for the athletes with the data.

Comparison on the scoring rate before and after the "Big ball era" reform

The scoring rate statistics of each plate

First, this paper conducts statistical data on the score in the final stage of the Sydney Olympic Games and the 49th World Table Tennis Championships, combines with the data[2] to obtain the scoring rate of the various stages, and conducts comparison as shown in TABLE 3.

TABLE 3 : The statistical table of the scoring rate at the various stages in finals of Sydney Olympic Games and the 49th World Table Tennis Championships

	Service point average	Serve and attack scoring rate	Receive and serve scoring rate	Receive, serve and attack scoring rate
Sydney Olympic Games	14.7%	20.7%	10.9%	6.5%
The 49th World Table Tennis Championships	8.2%	24.8%	3.3%	8.3%
	5-6 plates scoring rate of the stalemate ball	**7-8 plates scoring rate of the stalemate ball**	**9-15 plates scoring rate of the stalemate ball**	**15 plates scoring rate of the stalemate ball**
Sydney Olympic Games	34.3%	6.0%	6.5%	0.5%
the 49th World Table Tennis Championships	41.7%	8.3%	8.3%	1.7%

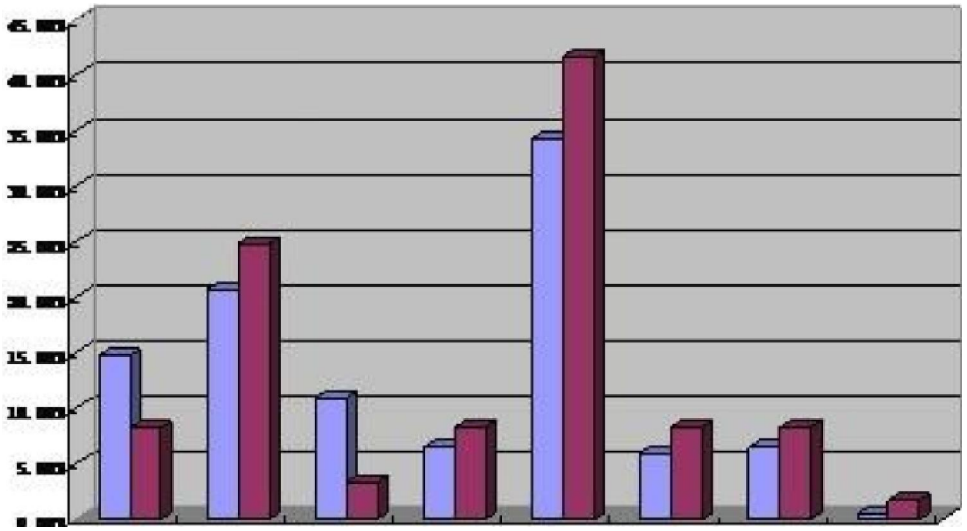

Figure 2 : Comparison chart on the scoring rate of various stages in the finals of Sydney Olympic Games and the 49th World Table Tennis Championships

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From the above TABLE 3, histogram 2 is obtained that is relatively easy and intuitive to observe.

As can be observed from the histogram, after the small ball changes into the larger ball, the scoring rates of the rest stage raise in the two events in addition that service scoring rate drops. For table tennis players, the scoring probability of one plate decreases, the scoring probability of the stalemate stage increases, so it reduces the chance of one plate scoring rate, affects the players' technology play, increases the challenge for the players; the players must greatly improve their own skills to adapt to the game in the "big ball era". Therefore, the "big ball era" is currently a more difficult process for athletes; visibly changes of the scoring rate in the various stages may also prove the reducing of the experience quality for the athletes.

Changes in the experience quality of athletes after the "big ball" era

The small ball changing into larger ball directly leads to an increase of the table tennis' weight, and the athletes have to pay more power for every swing. Meanwhile, the small ball changing into larger tennis ball will significantly reduce the rotation and speed of the table tennis. Thus, we speculate that it would effectively slow the progression of the game, result in an increase of game time, and make the athlete bear more pressure on the body. Here, we use video analysis method and theoretical analysis[3] to judge the competition time, and draw the concrete theoretical results.

This paper edits the videos for the 49th World Table Tennis Championships (the race uses the big ball) and the 2000 Sydney Olympic Games table tennis tournament (the race uses the small ball), selects the men's single finals as the study object, conducts statistical analysis on the time of each inning and obtains the TABLE 4 below.

Since September 1, 2001 the ITTF implemented "11-point" system and abolished the original "21-point" system. The 2000 Sydney Olympic Games table tennis competition conducted in accordance with the "11-point" system, and the 49th World Table Tennis Championships implemented the "21-point" system under the new reforms. To facilitate comparison and calculate the scoring time of the two tournaments, here we use artificially unified point-system for these two events, set as "11 points" system, the process is as follows:

The average time of the 21 points system in 2000 Sydney Olympic Games table tennis tournament is $\frac{10+12+10+9+11}{5}=10.4\,\text{min}.$

TABLE 4 : The duration statistics table of every inning

事赛 \ 局次	First Inning (min)	The second inning (min)	The third inning (min)	The fourth Inning (min)	The fifth Inning (min)	The sixth Inning (min)	The s Inning (min)
The 49th world Table Tennis hampionships	10	8	7	7	6	7	5
Sydney Olympic Games	10	12	10	9	11	——	——

TABLE 5 : The comparison statistical table of the plate number and the intensity degree of the applause in each round

Round plate number	Intensity degree of the applause
1-2 plates	75
3-4 plates	80
5-6 plates	95
7-8 plates	85
9-15 plates	85
More than 15 plates	80

The average time of the 11 points system in the 49th World Table Tennis Championships is $\frac{10+8+7+7+6+7+5}{7}=7.14\,\text{min}.$

Then, the average time of the 11 points system in 2000 Sydney Olympic table tennis is $10.4\div\frac{21}{11}=5.45\,\text{min}.$

It is apparent that the time to score in the 49th World Table Tennis Championships is greater than that of the 2000 Sydney Olympic Games table tennis tournament. Through literature method, we learn that in an inning of table tennis competition, the average energy consumption for athletes is 18.2 kcal, and the average game time is 5 minutes[4]. This can be roughly inferred that before using the "big ball", the energy consumption for athletes to kick a inning is probably 24.8 kcal; and after using the "big ball" the energy consumption for athletes to kick a inning is probably 32.5 kcal.

After the analysis of the obtained data, from the physical exertion and endurance ability of athletes, the burden on the athlete's body aggravates after using the "big ball". The increasing of the role in aspect of the physical agility increases the physical exertion of players in a game, lengths the recovery time, reduces the experience quality of athletes.

Impact of the "big ball era" on the ornamental degree of spectators

From TABLE 3, we compare the scoring rate of each phase in the Sydney Olympics and the 49th World Table Tennis Championships final, and conduct statistical calculations on the average plate number for each point in the two events.

The average plate number of each point in Sydney Olympic Games:

$$1\times 14.7\% + 2\times 20.7\% + 3\times 10.9\% + 4\times 6.5\% + 5\times 34.3\% + 7.5\times 6.0\% + 12\times 6.5\% + 15\times 0.5\% = 3.7$$

The average plate number of each point in the finals of the 49th World Table Tennis Championships:

$$1\times 8.2\% + 2\times 24.8\% + 3\times 3.3\% + 4\times 8.3\% + 5\times 41.7\% + 7.5\times 8.3\% + 12\times 8.3\% + 15\times 1.7\% = 5.0$$

Data results show that, the average plate number of one point after the "big ball era" increases, that is the round number of athlete to win a point increases, it avoids the phenomenon that the round number of athletes in "small ball era" is small, sometimes the ball flies as lightning, the audience has not yet see clearly, but the outcome has been decided. The increase of round enhances the interest of table tennis enthusiasts, plus the skill upgrading of the athletes that the game requires, so competition will be fiercer and more exciting than ever before.

In addition, if the number of plates per round is too small, the audience cannot see the fun, too many plates will produce visual fatigue situations, you can find the best plate number of each round for the audience to show a higher ornamental degree. Therefore, we look through the video and give the statistics of the relationship between the intensity degree of audience applause

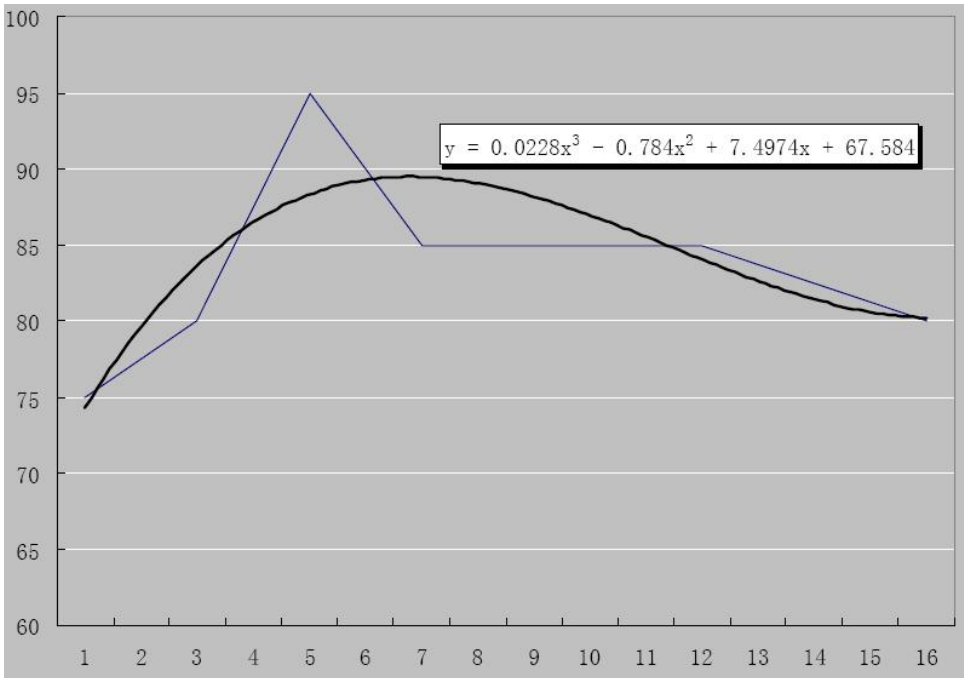

Figure 3 : The relationship diagram between the plate number and the intensity degree of the applause in each round

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and the plate number of each round, as shown in TABLE 5.

From the above TABLE 5, when the plate number in each round reaches 5-6, the intensity degree of the audience's applause will be very high; when the plate number is 7-15, the intensity degree is second; when the plate number is 3-4, the intensity degree of the applause is moderate. The average plate number of each point in Sydney Olympics is 3.7 plates; The average plate number of each point in the 49th World Table Tennis Championships Finals is 5 plates; by comparing, the intensity degree of the audience's applause in "big ball era" is higher than that in the "small ball era". Therefore, the "big ball era" enhances the viewing quality of audience.

In addition, the "big ball era" brought new hope to athletes with better physical agility, particularly athletes in Europe. In the "big ball era", when European players compete against Asian players, number of rounds is more than that in the past, the score is relatively close. This indicates that, on the balance of the Eurasian confrontation, the big ball will give Europe a little heavier weight in the future. Europe players have the opportunity to challenge the previous table tennis champion, it also increases the richness of the event, and it will further motivate athletes to improve skills and make the game have more viewing value; so summarize from all aspects, you can obtain the theoretical results, the "big ball era" improve the ornamental quality of the audience to a certain extent.

RESEARCH ON THE BEST LENGTH OF TABLE TENNIS

After the small ball changes into big ball, the experience quality of athletes has decreased, but the audience's ornamental quality has improved. If you can find the best length of the table tennis' diameter, it will make the athletes' experience quality and audience's ornamental quality reach a balance point, so that the athletes can full play their technology and power every game; the audience can fling themselves into the game and enjoy themselves to the full. Through mathematical statistics and theoretical analysis, this paper conducts research on the best length of the table tennis' diameter.

Research on ornamental quality

Figure 3 can be obtained from the statistical data in TABLE 5.

Through the Figure 3 fitted by excel, the relationship between the intensity degree of the applause y_1 (which is on behalf of ornamental degree) and the

TABLE 6 : The statistics table of the best table time for every inning through the questionnaire survey on the table tennis players

the competition time of each inning (minutes)	3	4	5	6	7	8	9	10
Satisfaction degree of players	1%	5%	4%	28%	40%	20%	3%	1%

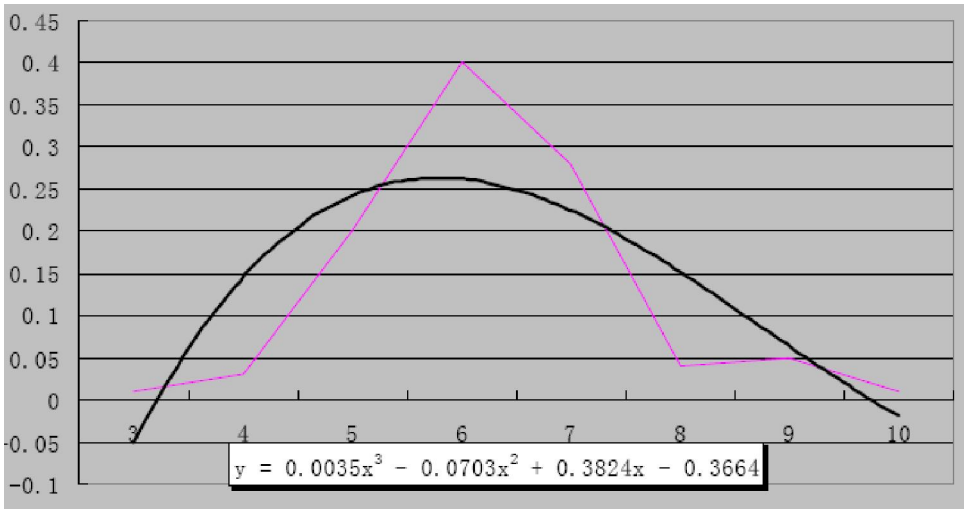

Figure 4 : The statistic chart of player's satisfaction degree on the time of each inning

TABLE 7 : Comparison table between the intensity degree of the applause and athlete's satisfaction degree before and after the "Big ball era"

	The average plate number of single round	Intensity degree of the applause	The average time of single inning	Satisfaction degree of athletes
Sydney Olympics	3.7	85.75	5.45	18.4%
The 29th world championship	4.97	88.32	7.14	24.6%

TABLE 8 : The maximum values of y_1, y_2

	Satisfaction degree of the field audience		Satisfaction degree of the player	
Interval of independent variable x	5 plates	5.5 plates	6.5min	7min
Maximum value of y	88.61		0.25	

plate number x_1 is:

$$y_1 = 0.0228x_1^3 - 0.784x_1^2 + 7.4974x_1 + 67.584$$

Research on quality of experience

The time of each inning directly impacts athlete's physical exertion, so athletes' satisfaction degree on the expense in each game reflects the experience quality of athletes, namely the best time of each inning that tennis players recognize can be regarded as the indicators of an athlete's experience quality.

Through questionnaire surveys[5] the best time for each inning that the table tennis players recognize are in TABLE 6.

As can be seen in the above TABLE 6, the support rate of $6 \sim 8\,\text{min}$ for each game accounts for 88%, the support rate of $3 \sim 5\,\text{min}$ is 10%, the support rate of $9 \sim 10\,\text{min}$ is 4%, it can be seen that the competition time of each game that most athletes want to use is $6 \sim 8\,\text{min}$, you do not want the time is too short and it is not fun to play, you do not want the time is too long and result in insufficient strength.

Figure 4 can be obtained from TABLE 6.

Through the Figure 4 fitted by Excel, the relationship between the athlete's satisfaction degree y_2 and the time x_2 of each inning can be obtained:

$$y_2 = 0.0035x_2^3 - 0.0703x_2^2 + 0.3824x_2 - 0.3664$$

Substitute the average plate number of each round and the time (minutes) of each inning in the Sydney Olympics and the 29th World table tennis Championship into the above two equations, and obtain the applause's intensity degree and athletes' satisfaction degree of the two events, the compared summary is in the TABLE below 7.

The relationship between table tennis' diameter and the experience quality and the ornamental degree

The changes of applause's intensity degrees and athletes' satisfaction degree are known, and these two values are respectively the experience quality and ornamental degree indicators. By establishing the relationship between the table tennis' diameter and the final two items, we can find the relationship the table tennis' diameter and the experience quality and the ornamental degrees.

Assuming table tennis' diameter (D) meet in the following relationship between the intensity degree of the applause (y_1) and satisfaction degree of the athletes (y_2):

$$D = a \cdot y_1 + b \cdot y_2 .$$

From three data in TABLE 7, we have:

$$\begin{cases} 38 = 88.32 \cdot a + 0.184 \cdot b \\ 40 = 85.75 \cdot a + 0.256 \cdot b \end{cases}$$

Get: $a = 0.42, b = 12.97$

And substitute it into equation $D = a \cdot y_1 + b \cdot y_2$

Thus arrive at the relationship expression between the size of table tennis and the players' experience quality and spectators' ornamental degree:

$$D = 0.42 \cdot y_1 + 0.256 \cdot y_2$$

The range of plate number x_1 and the time x_2 of each inning is given, and their relationship with the applause's intense degree y_1 and the athletes' satisfaction degree y_2 is known, by using the optimization theory

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we obtain the corresponding value interval x_1 of x_2 and when the y_1 and y_2 take the maximum value:

$$\max \quad y_1 = 0.0228x_1^3 - 0.784x_1^2 + 7.4974x_1 + 67.584$$

$$\text{s.t..} \begin{cases} x_1 \geq 1 \\ x_1 \leq 16 \end{cases}$$

$$\max \quad y_2 = 0.0035x_2^3 - 0.0703x_2^2 + 0.3824x_2 - 0.3664$$

$$\text{s.t.} \begin{cases} x_2 \geq 3 \\ x_2 \leq 10 \end{cases}$$

And solve the maximum values of y_1 and y_2 within the interval of x_1 and x_2, as shown in TABLE 8 below:

When the $y_1 and y_2$ take the best value, we substitute the corresponding $x_1$and x_2 into the above formula and can conclude: When the diameter of the table tennis is $39.37mm \sim 40.23mm$, which makes the athletes' experience quality the best and the audience' ornamental degree higher.

CONCLUSIONS

The model established in this paper is simple and easy. This paper accurately analyzes the impact of ball diameter's changes on the experience quality of athletes and the ornamental quality of the audience, by the idea of optimization, first gets the best plate number and the best time of each inning, finally obtains the best diameter of the table tennis. In the model, athletes just do a preliminary exploration in problems of skills play. In future studies, changes in table tennis' diameter can influence different skills, thus it can reflect the changes of athletes' experience quality in detail. With the increase of the table tennis' diameter, requirements of the players' physical fitness and skill have also increased. So we should strengthen the training of offensive skills, enhance the ability to rally, and improve the ability to attack and pull, increase the proportion of physical training to improve the physical agility and skills of athletes.

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