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Competitive balance trends in elite table tennis: the Olympic Games and World Championships 1988-2016

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ABSTRACT

Competitive balance is important because it enhances outcome uncertainty and therefore it promotes spectator interest, and encourages government investment in a sport. This article analyses the distribution of gold medals, medals, medal points and top eight points amongst nations in table tennis from 1988 to 2016 at the Olympic Games and the World Championships respectively. A normalised version of the Herfindahl-Hirschman Index and a coefficient of variation are calculated for each nation's share of these performance indicators. The key findings are that China dominates both events, with successful female players being more dominant than their male counterparts. The competitive balance for gold medals has declined, whilst there is a trend towards improved competitive balance for top eight points for women, suggesting that more teams are featuring in the top eight (but not necessarily the top three) placings. This research has implications for the development of table tennis competitions. Compared to other racket sports, the issue of competitive imbalance in table tennis is particularly thorny, which threatens the long-term development of this sport. Accordingly, some measures are recommended for the International Olympic Committee and the International Table Tennis Federation to propel a more balanced development of international table tennis.

ARTICLE HISTORY
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KEYWORDS
Table tennis; competitive balance; the Olympic Games; the World Championships; dominance

Introduction

Despite the globalisation of professional sport (Dickson & Malaia, 2017) and the "global sporting arms race" (De Bosscher, Bingham, Shibli, Van Bottenburg, & De Knop, 2008), there is a widespread view that table tennis has long confronted the issue of a lack of balance and diversity. Such an imbalance threatens the international character of the sport and perhaps even its inclusion in the Olympic Games itself, because the International Olympic Committee (IOC) has long endeavoured to reduce a small number of nations' dominance (Houlihan & Zheng, 2013). Furthermore, competitive balance in table tennis is highly valued because it stimulates consumer interest (Tainsky, Xu, & Yang, 2017).

In the context of sport, competitive balance is the extent to which competitors are evenly matched (Fort & Quirk, 1995). Competitive balance is important because it enhances outcome uncertainty and therefore it promotes spectator interest, and encourages government investment in a sport. According to the outcome uncertainty hypothesis (Rottenberg, 1956), higher levels of competitive balance, result in more uncertain outcomes, which increase match attendances, television audiences, overall interest and revenues (Knowles, Sherony, & Haupert, 1992; Rascher, 1999; Szymanski, 2002; Weber, Kempf, Shibli, & De Bosscher, 2017). It is therefore conducive to the long-term development of table tennis and its global diffusion. For example, Jane (2014) empirically confirmed the positive correlation between outcome uncertainty and match attendance within the National Basketball Association (NBA). Tainsky et al. (2017) measured competitive balance within the China Table Tennis Super League, motivated by concerns that competitive imbalance was contributing to the league's lack of popularity. Competitive balance research is dominated by studies on professional team sports, but studies on international sports events are still in their infancy. For example, Otamendi and Doncel (2014) conducted a multi-edition study of medal distributions at the Winter Olympic Games between 1992 and 2010. They identified differences regarding medal concentrations from one sport to another. Similarly, Weber et al. (2017) used the Herfindahl-Hirschman Index (HHI) and Przeworski, two economic indices, to analyse the competitive balance at the seven most recent Winter Olympic Games. Biathlon and short track speed skating represented the most salient examples of significant changes in competitive balance. Ramchandani and Wilson (2014) concluded that the Commonwealth Games became significantly less competitive between 1930 and 1990 and that events contested by men only were more balanced compared to both women's and mixed events. More recently, Forrest, McHale, Sanz, and Tena (2016) examined 15 individual sports at the Summer Olympic Games between 1992 and 2012, and concluded that medal distributions are less unequal in sports practised in multi-sports venues.

However, there remains a dearth of sport-specific research investigating the distribution of medals among nations at elite sport events. A notable exception is Truyens, De Bosscher and Heyndels' (2016) study on athletics which identified a decrease

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in competitive balance across all athletic events, and also amongst both men's and women's events. At the discipline-specific level, divergent trends were evident. There was an increased number of nations finishing in the top eight in women's sprint/hurdles, long-distance running and race walking. However, there was a convergence of nations winning medals in men's long-distance running. Chaplin and Mendoza (2017) analysed the competitive balance in boxing at the Commonwealth Games. Their study provided clear evidence of a reduced competitive balance in the 1980s (attributed in part to the widespread boycotts of the 1986 Games) and a steady deterioration of competitive balance since the 1990s.

There is a plethora of studies on elite table tennis that has focused on psychology (Greenlees, Bradley, Holder, & Thelwell, 2005; Poizat, Bourbousson, Saury, & Sève, 2009; Sève, Ria, Poizat, Saury, & Durand, 2007; Williams, Vickers, & Rodrigues, 2002), motor control/learning (Poolton, Masters, & Maxwell, 2006; Raab, Masters, & Maxwell, 2005), skills and techniques (Lanzoni, Di Michele, & Merni, 2014; Zhang, Liu, Hu, & Liu, 2013), and physiology (Zagatto, Milioni, Freitas, Arcangelo, & Padulo, 2016). Tainsky et al's (2017) very recent paper bridged the divide between the concept of competitive balance and table tennis, but its focus was on within-season balance measures within the China Table Tennis Super League. Table tennis is one of many sports without a detailed examination of its competitive balance at either the Olympic Games, Commonwealth Games or World Championships. To address this gap, this research analyses the competitive balance in table tennis through its distribution of gold medals, medals, medal points and top eight (i.e. athletes/teams in the quarter-finals) points at the eight Olympic Games between 1988 and 2016, and 14 World Championships between 1989 and 2016. More specifically, this paper aims to evaluate competitive balance in table tennis by (a) identifying the most successful nations; (b) quantifying the overall distribution of success across nations and identifying temporal trends in competitive balance; (c) quantifying the distribution of success across nations for men's and women's competitions, and investigating the trends for both male and female competitions; and (4) comparing the trends in competitive balance trends between male and female competitions.

Quantifying the distribution of success at major competitions is important for both the IOC and the International Table Tennis Federation (ITTF), because it enables not just an evaluation of the *status quo* of competitive balance, but more importantly a platform for policy initiatives to widen the distribution of success amongst competing nations. Improved distribution of success will likely facilitate the global development of table tennis, because a very small number of nations' dominance in the distribution of success tends to create a disincentive for large-scale investment in table tennis by governments, and for "new entries" (De Bondt, Slaets, & Cassiman, 1992, p. 41). The value of this research also resides in its quantification of China's dominance in table tennis. Despite a widespread consensus on China's dominance in table tennis, the extent of this dominance has never been quantified. A comparison of table tennis to badminton and tennis at the Olympics will permit benchmarking and subsequently, a more rigorous and objective understanding of the competitive balance problem in elite table tennis. Moreover, this paper further reifies the competitive balance issue in table tennis by investigating gender-specific characteristics, enabling a comparison between male and female competitions. Last, the use of four performance measures and two competitive balance indicators is a notable methodological feature of this article.

Methods

Data collection

A database of all top eight performances at the Summer Olympic Games and World Table Tennis Championships between 1988 and 2016 was established using data sourced from the IOC website (IOC, 2017) and ITTF database (ITTF, 2017). 1988 is selected as the starting point because table tennis did not become an official Olympic sport until then. On occasions throughout this period, the ITTF held separate World Championships for different events. Since 2003, the World Championships for five singles and doubles events were held in odd years, and (men's and women's) team-events-only-World Championships in even years. This demarcation was also evident in 1999 and 2000. For pragmatic reasons the 1999/2000, 2003/2004, 2005/2006, 2007/2008, 2009/2010, 2011/2012, 2013/2014 and 2015/2016 editions are combined. There are seven events at each (combined) World Championships. The events include men's and women's singles, doubles, and team events, and mixed doubles. In comparison, there are only four table tennis events at each Olympic Games. However, the competition format at the Olympic Games has not been consistent. Whilst men's and women's singles have been contested at all eight editions between 1988 and 2016, men's and women's doubles were played only between 1988 and 2004. The doubles format was replaced by men's and women's team events in 2008. Because of these format differences, the Olympic Games and the World Championships are analysed separately. Distinct analyses of the Olympic Games and the World Championships still enable the identification of competitive balance trends, and a comparison of these trends between the Olympic Games and the World Championships. In the cases of mixed doubles, male and female athletes are each awarded half of the gold medals, medals, medal points and top eight points.

Performance measures

The study relies on four performance measures for each competing nation: the total number of gold medals, medals, medal points and top eight points that were won. Medal points are calculated by awarding three points for each gold, two points for each silver and one point for each bronze medal awarded. Concerning top eight points, the formula is 10–8-6–5-4–3-2–1 (points) for 1–2-3–4-5–6-7–8 (ranking position), which is congruent with most existing studies that analyse elite sport success (De Bosscher et al., 2008; De Bosscher, Shibli, Westerbeek, & Van Bottenburg, 2015).

Data analysis: indicators of competitive balance

The research uses two indicators of competitive balance – a normalised version of the Herfindahl-Hirschman Index (HHIN); and a coefficient of variation (CV) in nations' market share (MS).

(Normalised) Herfindahl-Hirschman index

The HHI measures market concentration (Forrest et al., 2016; Otamendi & Doncel, 2014; Ramchandani & Wilson, 2014; Truyens et al., 2016). The HHI for a given Olympics or World Championships is the sum of the squared market shares of each nation. The market share is simply each nation's share of the medals and points on offer. The HHI can range from 0 to 1, and a high HHI reflects a large concentration of success among a small number of nations. The extreme value of 1 indicates that the market is dominated by one nation as the sole winner, and this, from an economic perspective, is defined as a "monopoly" (Mankiw & Taylor, 2010, p. 296). HHI is calculated as follows, where MS_i denotes market share (medals, medal points and top eight points) of each participating nation i;

$$HHI = \sum_i MS_i^2$$

A normalised version of HHI (HHIN) is applied in this paper because the number of nations varies in each edition. The modified HHI formula for an edition is:

$$HHIN = \frac{\left(HHI - \frac{1}{N}\right)}{\left(1 - \frac{1}{N}\right)}$$

In this study, N stands for the number of all participating nations, irrespective of the performance/non-performance distinction. The underlying premise is that every participating nation is eligible to win a medal as long as they are represented at the Olympic Games or World Championships (Forrest et al., 2016). HHIN is calculated using each of the four performance indicators for overall, male and female competitions, applicable to all specific editions.

Coefficient of variation

CV is a standardised measure of data dispersion defined as the ratio of standard deviation to the mean. CV has been used to measure the competitive balance of the Commonwealth Games between 1930 and 2010 (Ramchandani & Wilson, 2014) and athletics at the World Championships and the Olympic Games between 2000 and 2015 (Truyens et al., 2016). CV is simply calculated by dividing the standard deviation of data by its mean. In this study, the N to calculate the mean refers to all participating nations, consistent with HHIN. A low CV indicates a clustering of data around the mean (i.e. equality amongst nations and hence competitive balance). A CV is calculated for all four performance measures – gold medals won, medals won, medal points and top eight points. Consistent with HHIN, CV calculation is also applied to overall, male and female competitions for all editions included.

The descriptive analysis of the distribution of success amongst nations was conducted using Microsoft Excel. Given the non-parametric nature of the data, a two-tailed Spearman rank-order correlation between each performance indicator and the passage of time/edition determined the strength and direction of the competitive balance trends. The p-level for the Spearman correlation was set at 0.05. This analysis was conducted using SPSS (Version 24).

Results

Top 10 nations' dominance: all editions combined

Descriptive analyses on the number of gold medals, medals, medal points and top eight points won between 1988 and 2016 demonstrate that Olympic success is concentrated in only a very small number of nations (see Table 1). From the 32 gold medals awarded at the eight Olympic Games, 28 (87.5%) have been awarded to China, three (9.4%) to South Korea, and one (3.1%) to Sweden. The ten most successful nations, measured by top eight points won by each nation across all eight Olympic Games, won 95.0% of all Olympic medals and 96.4% of all medal points. With 53 medals and 126 medal points, China accounts for over half of the medals and medal points won. Top 10 nations' proportion of top eight points is notably lower than medal-related indicators, but remains high. China has a dominant share of top eight points, but this is less than the medal indicators. This is perhaps not surprising because of the strict limit on the number of athletes that each nation can send to Olympic table tennis competitions. Prior to London 2012, a maximum of three athletes from same nation could participate in the men's and women's singles event. At London 2012 and Rio 2016, the number was reduced to only two. Concerning top eight points, Chinese women are slightly more dominant than their male counterparts. It is also evident that Eastern Asian nations, including China, South Korea, Japan, North Korea, Hong Kong and Chinese Taipei have won the vast majority of gold medals, medals, medal points and top eight points.

Table 1. Top 10 nations in table tennis performance at the Olympic Games.

				% of medal points				% of top 8 points		
Name	Gold medals	Medals	Medal points	Overall	Male	Female	Top 8 points	Overall	Male	Female
China	28	53	126	64.29	58.16	70.41	500	35.41	33.00	37.82
South Korea	3	18	27	13.78	16.33	11.22	197	13.95	15.16	12.75
Japan	0	4	6	3.06	3.06	3.06	88	6.23	4.82	7.65
Germany	0	7	10	5.10	8.16	2.04	85	6.02	8.64	3.40
Hong Kong	0	1	2	1.02	2.04	0.00	77	5.45	5.24	5.67
Singapore	0	3	4	2.04	0.00	4.08	64	4.53	0.57	8.50
Sweden	1	3	6	3.06	6.12	0.00	61	4.32	8.64	0.00
North Korea	0	4	5	2.55	0.00	5.10	46	3.26	0.00	6.52
Chinese Taipei	0	2	3	1.53	0.00	3.06	37	2.62	2.12	3.12
Austria	0	0	0	0.00	0.00	0.00	31	2.20	3.54	0.85
Total	32	100	196				1,412			

Top 10 nations are identified and ranked according to their Top 8 points obtained.

Table 2. Top 10 nations in table tennis performance at the World Championships.

Name	Gold medals	Medals	Medal points	% of medal points			Top 8 points	% of top 8 points		
				Overall	Male	Female		Overall	Male	Female
China	80.5	214	433	64.24	57.86	70.62	2,024	46.38	42.07	50.69
South Korea	2.5	37.5	50.5	7.49	7.72	7.27	411	9.42	10.36	8.48
Japan	0	20	24	3.56	3.71	3.41	254	5.82	5.68	5.96
Hong Kong	0	20.5	22.5	3.34	1.48	5.19	245	5.61	3.76	7.47
Sweden	8	17	37	5.49	10.83	0.15	190	4.35	8.30	0.41
Germany	0	10	15	2.23	3.86	0.59	180	4.12	5.55	2.70
North Korea	1	10	16	2.37	1.04	3.71	135	3.09	1.74	4.45
Chinese Taipei	1	9	13	1.93	2.23	1.63	115	2.64	2.84	2.43
Singapore	1	7	11	1.63	0.00	3.26	102	2.34	0.50	4.17
France	1	5	8	1.19	2.08	0.30	76	1.74	2.84	0.64
Total	98	380	674				4,364			

Top 10 nations are identified and ranked according to their Top 8 points obtained.

Similar outcomes are evident at the World Championships (See Table 2). China again dominates the market for gold medals, medals, medal points and top eight points. China has won just over 80% of gold medals, their share of the medal market is just under 60% (compared to 53% at the Olympics), accounts for two-thirds of the available medal points and nearly half of the top eight points. China's share of top eight points is notably higher at the World Championship (46.38%) compared to the Olympic Games (35.41%). This is likely a consequence of China's ability to send more athletes to the non-team events at the World Championships compared to the Olympic Games. For example, Chinese players in mixed doubles at Eindhoven 1999 won all of the top eight places and seven Chinese players reached the quarter-finals (i.e. top eight places) in women's individuals at the Rotterdam 2011 World Championships. This degree of dominance of quarter-final places would be impossible at the Olympic Games.

The top 10 nations have won 92.1% of all World Championship medals, 93.5% of all medal points, and had a combined top eight point market share of 85.5%. Chinese women at the World Championships again outperform their male compatriots in terms of their share of top eight points.

In summary, China dominates both the Olympic Games and the World Championships across all performance indicators. The top 10 nations, mostly Eastern Asian nations, account for the vast majority of success at both events. Chinese women are slightly more dominant than the Chinese men.

Edition-specific results of competitive balance

Table 3 and Table 4 display the HHIN and CV indicators for gold medals, medals, medal points and top eight points at the Olympic Games and the World Championships respectively.

Table 3. Trends in competitive balance in table tennis at the Olympic Games.

Gender	Edition	*HHIN* (rank)				*CV* (rank)			
		Gold	Medals	Medal points	Top 8 points	Gold	Medals	Medal points	Top 8 points
Overall	1988	0.49 (1)	0.30 (2)	0.35 (2)	0.19 (6)	4.42 (1)	3.48 (2)	3.75 (2)	2.73 (2)
	1992	0.62 (2)	0.25 (1)	0.29 (1)	0.17 (4)	5.39 (2)	3.43 (1)	3.72 (1)	2.79 (4)
	1996	1.00 (4)	0.48 (7)	0.64 (8)	0.20 (8)	7.07 (5)	4.88 (7)	5.64 (8)	3.16 (7)
	2000	1.00 (4)	0.46 (6)	0.63 (7)	0.19 (7)	6.86 (4)	4.65 (6)	5.45 (6)	2.98 (6)
	2004	0.62 (3)	0.32 (4)	0.36 (3)	0.14 (1)	5.50 (3)	3.96 (3)	4.19 (3)	2.62 (1)
	2008	1.00 (4)	0.48 (8)	0.58 (6)	0.18 (5)	7.42 (7)	5.12 (8)	5.63 (7)	3.17 (8)
	2012	1.00 (4)	0.31 (3)	0.46 (4)	0.14 (3)	7.48 (8)	4.15 (4)	5.09 (4)	2.81 (5)
	2016	1.00 (4)	0.34 (5)	0.48 (5)	0.14 (2)	7.35 (6)	4.25 (5)	5.09 (5)	2.75 (3)
	Corr.	0.709*	0.381	0.310	−0.571	0.833**	0.429	0.357	0.119
	p	0.049	0.352	0.456	0.139	0.010	0.289	0.385	0.779
Male	1988	0.49 (1)	0.31 (2)	0.33 (2)	0.23 (8)	4.06 (1)	3.27 (2)	3.34 (2)	2.79 (7)
	1992	0.49 (2)	0.23 (1)	0.19 (1)	0.15 (3)	4.18 (2)	2.87 (1)	2.63 (1)	2.29 (2)
	1996	1.00 (4)	0.49 (7)	0.70 (8)	0.19 (6)	6.16 (5)	4.30 (7)	5.16 (8)	2.71 (5)
	2000	1.00 (4)	0.49 (6)	0.59 (6)	0.21 (7)	6.00 (4)	4.18 (6)	4.59 (4)	2.78 (6)
	2004	0.49 (3)	0.32 (3)	0.33 (3)	0.13 (1)	4.30 (3)	3.46 (3)	3.54 (3)	2.22 (1)
	2008	1.00 (4)	0.49 (8)	0.59 (7)	0.19 (5)	6.56 (6)	4.58 (8)	5.03 (7)	2.87 (8)
	2012	1.00 (4)	0.38 (4)	0.49 (4)	0.13 (2)	6.63 (7)	4.06 (4)	4.64 (5)	2.43 (3)
	2016	1.00 (4)	0.38 (4)	0.50 (5)	0.15 (4)	6.63 (7)	4.06 (4)	4.70 (6)	2.55 (4)
	Corr.	0.709*	0.419	0.357	−0.500	0.898**	0.419	0.524	−0.143
	p	0.049	0.301	0.385	0.207	0.002	0.301	0.183	0.736
Female	1988	0.48 (1)	0.48 (5)	0.50 (4)	0.20 (5)	3.61 (1)	3.61 (1)	3.66 (1)	2.34 (1)
	1992	1.00 (2)	0.36 (2)	0.54 (5)	0.24 (8)	6.08 (5)	3.64 (3)	4.47 (4)	3.00 (8)
	1996	1.00 (2)	0.49 (7)	0.59 (6)	0.22 (7)	6.00 (4)	4.18 (7)	4.59 (5)	2.82 (6)
	2000	1.00 (2)	0.48 (6)	0.70 (8)	0.19 (4)	5.66 (2)	3.94 (5)	4.73 (7)	2.44 (2)
	2004	1.00 (2)	0.37 (3)	0.41 (1)	0.18 (3)	5.92 (3)	3.61 (1)	3.81 (2)	2.50 (3)
	2008	1.00 (2)	0.49 (8)	0.59 (7)	0.21 (6)	6.40 (6)	4.47 (8)	4.91 (8)	2.90 (7)
	2012	1.00 (2)	0.38 (4)	0.49 (3)	0.17 (2)	6.63 (8)	4.06 (6)	4.64 (6)	2.73 (5)
	2016	1.00 (2)	0.32 (1)	0.47 (2)	0.15 (1)	6.48 (7)	3.65 (4)	4.46 (3)	2.52 (4)
	Corr.	0.577	−0.214	−0.333	−0.738*	0.762*	0.383	0.333	0.119
	p	0.134	0.610	0.420	0.037	0.028	0.349	0.420	0.779

(1) Numbers in the parentheses indicate the ranking of each edition regarding the level of competitive balance.
(2) Some figures appear the same in the table because all the figures are rounded to the second decimal place only.

Table 4. Trends in competitive balance in table tennis at the World Championships.

		HHIN (rank)				*CV* (rank)			
Gender	Edition	Gold	Medals	Medal points	Top 8 points	Gold	Medals	Medal points	Top 8 points
Overall	1989	0.30 (1)	0.28 (3)	0.25 (1)	0.19 (3)	4.88 (1)	4.76 (3)	4.47 (1)	3.87 (2)
	1991	0.38 (2)	0.24 (2)	0.28 (3)	0.15 (1)	5.48 (2)	4.34 (1)	4.72 (2)	3.48 (1)
	1993	0.38 (3)	0.22 (1)	0.25 (2)	0.18 (2)	5.79 (3)	4.36 (2)	4.73 (3)	3.98 (3)
	1995	1.00 (10)	0.45 (13)	0.56 (13)	0.25 (6)	8.78 (6)	6.12 (7)	6.79 (5)	4.63 (4)
	1997	0.75 (7)	0.37 (10)	0.44 (5)	0.28 (10)	9.06 (7)	6.36 (9)	6.90 (7)	5.55 (10)
	1999/2000	0.75 (5)	0.35 (5)	0.49 (8)	0.28 (9)	8.23 (4)	5.63 (4)	6.66 (4)	5.04 (6)
	2001	1.00 (10)	0.36 (7)	0.50 (9)	0.29 (11)	9.75 (10)	5.83 (5)	6.86 (6)	5.21 (7)
	2003/2004	0.75 (6)	0.41 (12)	0.48 (7)	0.28 (8)	9.22 (8)	6.77 (10)	7.36 (10)	5.63 (11)
	2005/2006	1.00 (10)	0.40 (11)	0.53 (12)	0.29 (12)	11.09 (13)	7.00 (13)	8.04 (12)	5.99 (12)
	2007/2008	1.00 (10)	0.36 (8)	0.52 (11)	0.27 (7)	10.39 (11)	6.27 (8)	7.53 (11)	5.37 (9)
	2009/2010	0.75 (8)	0.48 (14)	0.58 (14)	0.30 (14)	9.47 (9)	7.56 (14)	8.31 (14)	6.00 (13)
	2011/2012	1.00 (10)	0.36 (9)	0.52 (10)	0.30 (13)	11.27 (14)	6.81 (11)	8.16 (13)	6.18 (14)
	2013/2014	0.55 (4)	0.35 (6)	0.39 (4)	0.20 (4)	8.60 (5)	6.90 (12)	7.29 (9)	5.22 (8)
	2015/2016	0.87 (9)	0.30 (4)	0.44 (6)	0.20 (5)	10.58 (12)	5.96 (6)	7.29 (8)	4.86 (5)
	Corr.	0.492	0.327	0.429	0.451	0.749**	0.697**	0.811**	0.648*
	p	0.074	0.253	0.126	0.106	0.002	0.006	0.000	0.012
Male	1989	0.42 (2)	0.22 (3)	0.21 (1)	0.14 (1)	5.62 (2)	4.09 (1)	3.94 (1)	3.19 (1)
	1991	0.75 (7)	0.22 (2)	0.32 (4)	0.15 (2)	7.36 (3)	4.16 (3)	4.92 (3)	3.30 (2)
	1993	0.34 (1)	0.20 (1)	0.24 (2)	0.18 (3)	5.37 (1)	4.13 (2)	4.48 (2)	3.94 (3)
	1995	1.00 (8)	0.41 (13)	0.51 (12)	0.23 (7)	9.22 (8)	5.88 (7)	6.57 (7)	4.43 (4)
	1997	0.59 (5)	0.24 (4)	0.29 (3)	0.21 (6)	7.97 (7)	5.08 (4)	5.55 (4)	4.79 (7)
	1999/2000	0.59 (4)	0.29 (5)	0.43 (7)	0.23 (8)	7.43 (4)	5.18 (5)	6.35 (6)	4.69 (6)
	2001	1.00 (8)	0.34 (8)	0.48 (8)	0.29 (11)	9.70 (9)	5.67 (6)	6.70 (8)	5.24 (10)
	2003/2004	0.59 (6)	0.36 (10)	0.38 (6)	0.26 (10)	7.89 (6)	6.13 (10)	6.33 (5)	5.26 (11)
	2005/2006	1.00 (8)	0.37 (11)	0.48 (9)	0.30 (13)	10.95 (14)	6.68 (13)	7.61 (12)	5.98 (13)
	2007/2008	1.00 (8)	0.34 (9)	0.51 (11)	0.24 (9)	10.25 (10)	6.00 (8)	7.29 (11)	5.04 (8)
	2009/2010	1.00 (8)	0.54 (14)	0.65 (14)	0.33 (14)	10.86 (13)	7.96 (14)	8.73 (14)	6.22 (14)
	2011/2012	1.00 (8)	0.38 (12)	0.53 (13)	0.30 (12)	10.77 (12)	6.59 (11)	7.86 (13)	5.86 (12)
	2013/2014	0.42 (3)	0.33 (6)	0.34 (5)	0.19 (4)	7.48 (5)	6.62 (12)	6.74 (9)	5.07 (9)
	2015/2016	1.00 (8)	0.34 (7)	0.48 (10)	0.21 (5)	10.30 (11)	6.01 (9)	7.17 (10)	4.63 (5)
	Corr.	0.491	0.543*	0.626*	0.512	0.692**	0.837**	0.837**	0.675**
	p	0.075	0.045	0.017	0.061	0.006	0.000	0.000	0.008
Female	1989	0.75 (4)	0.42 (8)	0.45 (3)	0.29 (6)	6.66 (3)	4.97 (3)	5.13 (2)	4.12 (3)
	1991	0.58 (1)	0.42 (7)	0.49 (5)	0.25 (4)	5.77 (1)	4.71 (2)	5.15 (3)	3.73 (1)
	1993	0.59 (2)	0.27 (1)	0.32 (1)	0.21 (1)	6.40 (2)	4.35 (1)	4.72 (1)	3.81 (2)
	1995	1.00 (7)	0.50 (13)	0.63 (13)	0.29 (7)	7.41 (5)	5.72 (7)	6.26 (5)	4.42 (5)
	1997	1.00 (7)	0.60 (14)	0.69 (14)	0.39 (14)	9.00 (8)	6.98 (14)	7.50 (13)	5.65 (13)
	1999/2000	1.00 (7)	0.46 (10)	0.59 (10)	0.35 (13)	8.31 (7)	5.64 (6)	6.37 (6)	4.93 (7)
	2001	1.00 (7)	0.41 (6)	0.53 (8)	0.30 (8)	7.94 (6)	5.09 (4)	5.78 (4)	4.32 (4)
	2003/2004	1.00 (7)	0.50 (12)	0.63 (12)	0.32 (12)	9.17 (9)	6.46 (11)	7.26 (11)	5.21 (11)
	2005/2006	1.00 (7)	0.46 (11)	0.60 (11)	0.30 (9)	9.38 (11)	6.39 (10)	7.24 (10)	5.18 (10)
	2007/2008	1.00 (7)	0.40 (5)	0.56 (9)	0.31 (10)	9.27 (10)	5.89 (8)	6.92 (9)	5.14 (9)
	2009/2010	0.59 (3)	0.43 (9)	0.53 (6)	0.28 (5)	7.23 (4)	6.20 (9)	6.85 (8)	5.01 (8)
	2011/2012	1.00 (7)	0.38 (3)	0.53 (7)	0.32 (11)	10.77 (14)	6.64 (12)	7.84 (14)	6.09 (14)
	2013/2014	0.75 (6)	0.40 (4)	0.47 (4)	0.23 (3)	9.47 (12)	6.93 (13)	7.49 (12)	5.23 (12)
	2015/2016	0.75 (5)	0.28 (2)	0.40 (2)	0.21 (2)	9.54 (13)	5.37 (5)	6.55 (7)	4.58 (6)
	Corr.	0.224	−0.345	−0.081	−0.033	0.829**	0.547*	0.662**	0.626*
	p	0.442	0.227	0.782	0.911	0.000	0.043	0.010	0.017

(1) Numbers in the parentheses indicate the ranking of each edition regarding the level of competitive balance.
(2) Some figures appear the same in the table because all the figures are rounded to the second decimal place only.

The gold medal distribution for female competitions is monopolistic (i.e. HHIN = 1) at seven of the eight Olympic editions and for five editions for male competitions. In the case of the World Championships, HHIN values of 1 are evident in five of the 14 editions, including seven editions for male competitions and eight editions for female competitions. These findings reflect China's dominance.

A comparison between the Olympic Games and the World Championships reveals a wider variation of figures at the World Championships. The HHIN results between the Olympic Games and World Championships are largely at the same level for overall, male and female competitions. In comparison, CV results for the World Championships across all four measures are considerably higher than the Olympic Games, indicating a higher level of competitive imbalance at the World Championships than at the Olympic Games.

Combining both HHIN and CV across all eight Olympic Games, the Seoul 1988 and Barcelona 1992 editions were characterised by a high degree of competitive balance in the distribution of medals. The distribution of top eight points also tended to be balanced at Athens 2004 compared to other editions. Beijing 2008, at which China won all the four gold medals and dominated top three in both men's and women's singles, had a very low degree of competitive balance across all four measures, with the figures being the highest or second highest across most indicators particularly CV. The distribution of success was imbalanced at Atlanta 1996 and Sydney 2000 with most figures ranking sixth to seventh. Competitive balance in Olympic table tennis has slightly improved at the most

recent London 2012 and Rio de Janeiro 2016 in particular regarding the distribution of medals, medal points and top eight points. CV reflects a high degree of imbalance in the distribution of gold medals at the three most recent Olympic Games in 2008, 2012 and 2016.

Similar to the Olympic Games, competitive balance at the World Championships tends to be the highest in the three earliest editions (1989, 1991 and 1993). There are some exceptions, for example, HHIN Gold for male in 1991 (7th), and HHIN Medals for female in 1989 (8th) and 1991 (7th). Both HHIN and CV results indicate that competitive balance was relatively low between 2003/2004 and 2011/2012 for overall and male competitions. The pattern for female competitions manifests notable differences between measures (gold medals, medals, medal points and top eight points) and indicators (HHIN and CV). The 1997 World Championships witnessed the lowest or the second lowest degree of competitive balance in the distribution of medals, medal points and top eight points, but the CV Gold in 1997 tends to be medium amongst all 14 editions. The most notable differences between HHIN and CV in female competitions is that HHIN results all reflect a reasonably high degree of competitive balance in 2011/2012 and 2013/2014, while CV presents a counter pattern.

Trends in competitive balance

According to Table 3, significant positive correlations are evident in the cases of HHIN Gold ($\rho = 0.709$, $p = 0.049$) and CV Gold ($\rho = 0.833$, $p = 0.010$), which both indicate a growing imbalance for overall competitions at the Olympic Games. The HHIN trends for medals, medal points and top eight points are not significant, measured by Spearman correlations.

Concerning gender-specific results, the analysis of male competitions identifies a significant and positive result for CV Gold ($\rho = 0.898$, $p = 0.002$). Commensurately, there is also a significant and positive correlation for HHIN Gold ($\rho = 0.709$, $p = 0.049$), indicative of a significant trend towards a deteriorated competitive balance of the distribution of gold medals amongst male table tennis players at the Olympic Games from Seoul 1988 to Rio de Janeiro 2016.

On the contrary, the analysis of female competitions shows a significant negative HHIN trend for top eight points ($\rho = -0.738$, $p = 0.037$). When considered in the context of the small number of nations winning medals, this finding indicates that there has been an increasing number of teams finishing fourth to eighth. It should be noted that whilst the direction of this trend is the same for male and male-female combined (i.e. overall), the result is insignificant. Consistent with overall and male analyses, the CV analysis for females also identifies a significant positive trend for gold medals ($\rho = 0.762$, $p = 0.028$).

Concerning the World Championships (Table 4), overall, there are no significant trends for any of the HHIN analyses. However, the CV analyses are all significant and positive – Gold ($\rho = 0.749$, $p = 0.002$), Medals ($\rho = 0.697$, $p = 0.006$), Medal points ($\rho = 0.811$, $p = 0.000$), and Top 8 points ($\rho = 0.648$, $p = 0.012$). All of these confirm a decreased dispersion of the distribution of success (or deteriorated competitive balance), as noted earlier.

For male competitions, the HHIN trends for both Medals ($\rho = 0.543$, $p = 0.045$) and Medal points ($\rho = 0.626$, $p = 0.017$) are both significant and positive. All of the male CV trends are significant and positive – Gold ($\rho = 0.692$, $p = 0.006$), Medals ($\rho = 0.837$, $p = 0.000$), Medal Points ($\rho = 0.837$, $p = 0.000$), and Top 8 points ($\rho = 0.675$, $p = 0.008$).

For female competitions, consistent with overall and male analyses, the CV analyses are also all significant and positive – Gold ($\rho = 0.829$, $p = 0.000$), Medals ($\rho = 0.547$, $p = 0.043$), Medal points ($\rho = 0.662$, $p = 0.010$), and Top 8 points ($\rho = 0.626$, $p = 0.017$). However, compared to male analyse, there are no significant trends for any of the HHI analyses for the female competitions.

Discussion

This study measures competition in elite table tennis using data from the Olympic Games and the World Championships between 1988 and 2016. The key findings of the research are that China dominates both the Olympic Games and the World Championships. At these events, China's female table tennis players are more dominant than their male compatriots. At the Olympic Games, China's market share of gold medals has been monopolistic at most editions for both male and female competitions. In terms of overall gold medal distributions, both the HHIN and CV provide evidence of a decreased competitive balance. This trend is also evident for HHIN and CV for male competitions, and CV for females. There is evidence of increased competitive balance for top eight points for women, suggesting that more teams are featuring in the top eight placings (but not necessarily the top three placings).

China's dominance of table tennis at both the Olympic Games and the World Championships cannot be understated. At the seven most recent Summer Olympic Games (between Barcelona 1992 and Rio de Janeiro 2016), China's combined market share of gold medals and all medals is 93% and 55% respectively. China's gold medal dominance is making it more difficult for new nations to be capable of winning medals in particular gold medals. This is particularly the case for female table tennis. It is very likely that, if there were no China, the distribution of success would be more balanced among a wider set of nations.

To put China's dominance of table tennis at the Olympic Games into perspective, some simple comparisons to Olympic badminton and tennis over the roughly same period are made. The most dominant nations in badminton (i.e. China) and tennis (i.e. USA), account for only 53% and 40% of gold medals won, and 39% and 20% of all medals won (between 1992 and 2016). In addition, almost all edition-specific HHIN and CV results for badminton and tennis are lower than the corresponding table tennis figures for overall competitions at the seven most recent Summer Olympic Games between 1992 and 2016 (see Table 5). There has been only one instance of a nation monopolising the distribution of gold medals in badminton, and the distribution of medals and medal points are significantly more balanced in tennis, particularly when measured by HHIN. All the correlations for (gold) medal-related indicators are positive for overall competitions in table tennis, including the significant correlation of HHIN Gold and CV Gold, indicating a declined competitive balance. In

Table 5. Trends in competitive balance in badminton and tennis at the Olympic Games: Between Barcelona 1992 and Rio de Janeiro 2016.

		HHIN (rank)			*CV* (rank)		
Sport	Edition	Gold	Medals	Medal points	Gold	Medals	Medal points
Badminton	1992	0.49 (5)	0.24 (4)	0.29 (4)	4.12 (4)	2.93 (4)	3.17 (5)
	1996	0.26 (1)	0.21 (3)	0.22 (2)	3.06 (1)	2.78 (3)	2.81 (3)
	2000	0.67 (6)	0.33 (6)	0.37 (6)	4.25 (5)	2.97 (5)	3.15 (4)
	2004	0.42 (3)	0.21 (2)	0.25 (3)	3.62 (3)	2.56 (2)	2.76 (2)
	2008	0.43 (4)	0.36 (7)	0.36 (5)	4.58 (6)	4.18 (7)	4.18 (6)
	2012	1.00 (7)	0.31 (5)	0.46 (7)	7.07 (7)	3.94 (6)	4.77 (7)
	2016	0.26 (2)	0.12 (1)	0.13 (1)	3.45 (2)	2.31 (1)	2.42 (1)
	Corr.	0.039	−0.143	0.000	0.250	−0.036	−0.071
	p	0.939	0.760	1.000	0.589	0.939	0.879
Tennis	1992	0.36 (3)	0.11 (3)	0.14 (3)	4.12 (3)	2.32 (1)	2.54 (2)
	1996	0.62 (7)	0.17 (7)	0.21 (7)	5.78 (7)	2.99 (7)	3.38 (7)
	2000	0.36 (4)	0.12 (4)	0.15 (5)	4.30 (5)	2.49 (5)	2.80 (6)
	2004	0.36 (4)	0.11 (2)	0.13 (2)	4.30 (5)	2.35 (2)	2.60 (3)
	2008	0.23 (2)	0.13 (5)	0.15 (4)	3.32 (2)	2.52 (6)	2.65 (4)
	2012	0.43 (6)	0.14 (6)	0.17 (6)	4.28 (4)	2.42 (4)	2.69 (5)
	2016	0.19 (1)	0.10 (1)	0.09 (1)	3.19 (1)	2.39 (3)	2.26 (1)
	Corr.	−0.378	−0.250	−0.321	−0.559	0.036	−0.321
	p	0.403	0.589	0.482	0.192	0.939	0.482

(1) Numbers in the parentheses indicate the ranking of each edition regarding the level of competitive balance.
(2) Some figures appear the same in the table because all the figures are rounded to the second decimal place only.

comparison, there are a number of (insignificant) negative correlations in badminton and tennis, implying improved competitive balance. The magnitudes of the three positive correlations (HHIN Gold and CV Gold for badminton and CV Medals for tennis) are notably smaller than in table tennis (HHIN Gold: 0.709 for table tennis vs. 0.039 for badminton, CV Gold: 0.833 for table tennis vs. 0.250 for badminton, and CV Medals: 0.429 for table tennis vs. 0.036 for tennis). These comparisons highlight the competitive balance problem in table tennis at the Olympic Games.

This research provides another Olympic sport example to illustrate the rich tapestry, and complexity in trends in relation to competitive balance of varying Olympic sports and disciplines at different sports mega events. Table tennis has experienced declined competitive balance, similar to what for example elite athletics underwent from 2000 to 2015 (Truyens et al., 2016), and in boxing at the Commonwealth Games since the 1980s (Chaplin & Mendoza, 2017). However, compared to athletics and boxing, the distinctiveness of elite table tennis is its extremely high level of dominance and skewed pattern of (gold) medal distribution amongst nations. Truyens et al's (2016) research on competitive balance in athletics, combining the Olympic Games and the World Championships, presented year-to-year CV results for elite athletics. For CV medals and top eight points regarding athletics, the results range from 1.0 to 1.9, with an average of approximately 1.41 for CV medals and 1.55 for CV top eight points respectively. There is a much higher degree of competitive imbalance in elite table tennis. For table tennis, edition-specific overall results range between 3.4 and 5.5 (4.2 on average) for CV medals at the Olympic Games, between 2.6 and 3.2 (2.9 on average) for CV top eight points at the Olympic Games, between 4.3 and 7.6 (6.0 on average) for CV medals at the World Championships, and between 3.4 and 6.2 (5.1 on average) for CV top eight points at the World Championships. In other words, the degree of competitive imbalance in table tennis is more than three times higher than in athletics in relation to the distribution of medals, and at least double in the case of top eight points. However, Truyens et al. (2016) employed HHI rather than HHIN. Therefore, the HHI(N) results are not comparable between table tennis and athletics. Similar difference applied to Chaplin and Mendoza's (2017) research on competitive balance in boxing at the Commonwealth Games, where HHI, instead of HHIN, was used, and furthermore, no edition-, or year-specific results were specified. This also reflects the different approaches that have been used to evaluate competitive balance in single sport-based competitive balance studies thus far.

This study uses two competitive balance indicators – HHIN and CV. Both indicators have been applied in most existing competitive balance studies on elite sport performance and they measure competitive balance from complementary angles. However, the results are inconsistent particularly in the case of the World Championships. As Joo and Oh (2015) pointed out, indices using the ratio of deviation such as CV are influenced by the number of participants while indicators using market shares such as HHI(N) have invariant results when the number of teams changes. In this study, more significant trends towards competitive imbalance are observed at the World Championships but HHINs vary insignificantly across the same period. Over the period 1988–2016, the distribution of success has not changed significantly. In brief, China and other Eastern Asian countries' dominance at the World Championships has been more "hegemonic" than at the Olympic Games, while the number of participating nations has increased over time. In nature, CV concentrates on the measurement of "dispersion" (Brown, 1998, p. 155), whilst HHI (N) focuses on "concentration" (Rhoades, 1993, p. 188). Therefore, in HHI(N), the distribution of medals is less diffused with time but nations' market share of medals remains relatively stable, where only a few, mainly Eastern Asian nations, have long dominated. This explains the more notable inconsistency found at the World Championships which involves a larger number of nations. In comparison, the trend of changes for HHIN and CV is highly similar at the Olympic Games which involves a relatively limited number of participating nations.

The greater sensitivity of CV to changes in the number of participating nation also explains why there are more significant correlations for CV than HHIN at the World Championships (see Table 4). The number of participating nations at the World Championships increased from 81 in 1989 to 127 in 2013/2014. However, the distribution pattern of gold medals, medals and to a lesser extent, top eight points was largely stable over this period. This means that the vast majority of the new participating nations failed to win any (gold) medal or point, a feature which is reflected in the in lower CV-based competitive balance values at the World Championships. In comparison, the increased number of participating nations at the Olympic Games has been more modest, increasing from 41 in 1988 to 55 in 2016. Therefore, most CV-based correlation trends at the Olympic Games, including all non-gold trends, are insignificant. Despite the differences, HHIN and CV are instrumental in providing a fuller and more thorough understanding of the distribution of success in international table tennis during the period 1988–2016, compared to the adoption of a solitary indicator. In addition, despite the varying degree of significance of the trends, the general trends towards competitive imbalance are consistent between the two indicators according to most indicators at the Olympic Games and the World Championships.

Implications

The ITTF may consider implementing a double-bronze policy at the Olympic Games, as it once did in table tennis at the 1992 Barcelona Olympic Games, and as combat sports such as judo and boxing have long adopted. This will not change the distribution of gold medals, but it will enhance the probability that more nations win at least one medal, because China can win at most two medals in singles events, following the two athlete-maximum policy. A more radical suggestion is to limit the number of events that any single nation can enter at the Olympic Games. This will ensure that at least one of the four events excludes a Chinese entrant. This format is not without precedent. Both taekwondo and weightlifting have such policies according to which any single nation can participate in at most five of eight taekwondo events (a maximum of four events between Sydney 2000 and London 2012 and the increased limit to five events at Rio de Janeiro 2016) and can send a maximum of four weightlifters in women's weightlifting out of seven events at the Olympic Games. China's resistance to such a policy may be reduced by adding mixed doubles (male + female) to the competition schedule, as is the case in badminton (since Atlanta 1996) and tennis (since London 2012). This would create five table tennis events and provide China with the ability to maintain its four-gold performance, which is what they can win under the four-event format.

Limitations and suggestions for future research

One limitation of this study is that it analyses the distribution of (gold) medals and top eight places, but does not evaluate the score difference within matches at the micro level. It is possible for a nation to win every gold medal, but if these matches are won 4–3, and the score in each set is 11–9, then this paints a very different picture of the competitive balance. Future research on measuring competition in table tennis at the Olympic Games and the World Championships can seek to quantify the difference in the winning and losing scores. A second limitation is that the analysis is not event-specific. In other words, this research does not differentiate between singles, doubles and team events. Research in the future is advised to provide a more nuanced examination of competition within these events. Nevertheless, the results of this paper provide a robust assessment of the competitive balance trends at the two most important international table tennis tournaments.

Conclusions

China has dominated table tennis at the Olympic Games and the World Championships between 1988 and 2016. Restriction on the number of participating athletes in the case of the Olympic Games means that China's dominant market share of gold medals and all medals, is not reflected in the distribution of market shares for top eight points. It is within this top eight performance indicator that there is a more diverse representation of participating nations. Furthermore, the trend towards a decreased competitive balance tends to be more significant for male than for female competitions. In addition, there are differences between competitive balance indicators (HHIN and CV). The challenge for the ITTF is to find a way of restricting China and developing the capacity of the other nations' medal winning capabilities. Policies are available to facilitate a more balanced competition in elite table tennis, and to erode the dominance of the "Chinese Empire" in international table tennis. This is a daunting prospect, but not every empire lasts forever.

Disclosure statement

No potential conflict of interest was reported by the authors.

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