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While most research on elite sport success focuses on sport policy factors or the explanatory powers of macro-level factors such as wealth and population, sporting success of countries is also determined by the competitive environment of a sport. This paper identified trends in competitive balance in athletics at world championships and Olympic Games between 2000 and 2015. Using Spearman rank correlations between multiple indicators of competitive balance and the passage of time, a systematic decrease in competitive balance was found for athletics in general, men's and women's competition. At discipline-specific level, divergent trends in competitive balance were identified. Based on top-8 point market shares, women's sprint/hurdles, long-distance running and race walking became systematically more unbalanced, while the medal competition in men's long-distance running became significantly more balanced. This study informs policymakers on shifting opportunities for success caused by dynamic changes in the competition and the systematic reduction of competitive balance in specific disciplines.

Keywords: athletics, dominance, Spearman's rank

The 'global sporting arms race' describes the growing investment of countries and the institutionalisation of elite sport leading to the intensification of international competition (De Bosscher, Bingham, Shibli, van Bottenburg, & De Knop, 2008; Green & Houlihan, 2005). Large sport events like world championships are in essence competitions among countries. This is evidently so in competitions between national teams (e.g. the football or rugby world cup). But also events in individual sports (world championship in gymnastics or athletics) and certainly multisport events like the Olympic Games tend to be regarded as competitions among countries, or rather among athletes representing their country.

A plethora of studies has analysed determinants of sporting success of countries. Historically, sporting success has mainly been researched or explained by focusing on the predictive value of macro-level determinants such as population and wealth (e.g. Bernard & Busse, 2004; Johnson & Ali, 2002; Shibli, Gratton, & Bingham, 2012) or elite sport policies (e.g. Bergsgard, Houlihan, Mangset, Nødland, & Rommetveldt, 2007; De Bosscher, Shibli, Westerbeek, & van Bottenburg, 2015; Green & Houlihan, 2005; Oakley & Green, 2001). However, the strategy of a country cannot be understood independently of the competitive environment in which it operates (Spanos & Lioukas, 2001). Henderson and Mitchell (1997) emphasise that organisational capacity, strategy and performance are fundamentally endogenous: competition shapes organisational capacity, which in turn shapes competition.

National successes, the outcome of the competition between countries, tend to differ. While many countries participate in Olympic Games or world championships – in the 2012 Olympic Games athletes from no less than 204 countries were present –

success tends to be concentrated. For example, the US team topped the London Olympic medal table, winning over 11% of medals. This is in large contrast to 119 countries not winning any medal at all. Similar imbalances are observed in other major events: while 32 countries participate in the FIFA World Cup (and 207 participated in the qualification stage), finalists and world champions typically are from a small subset of countries.

Such an imbalance may be seen to threaten the international character of these events. It might be expected that in the long run, public interest and attention might be positively correlated with the obtained success of the public's home athletes. Being aware of this, the organisers have introduced various measures, for example the country quota. By allowing only a limited number of athletes per country, extreme dominance is avoided. As the international character of these events is fundamental – in the case of the Olympic Games already explicitly mentioned by Pierre de Coubertin – a clear view on any potential trends towards unbalanced competitions is of utmost importance.

The concentration of success – and the implied competitive imbalance – has been widely analysed (see Szymanski, 2003). The focus has, however, been on team sports and national competitions. Attention for individual sports is rather limited and so is the attention for competitive balance at the event level. Ramchandani and Wilson (2014), however, analysed trends in competitive balance at the Commonwealth Games, while Otamendi and Doncel (2014) explained (concentration of) market shares (MSs) in the Winter Olympic Games.

As argued, the threat of unbalanced competitions applies to national competitions or international events as well as team or individual sports. The current article concentrates on the evolution of competitive (im)balance in an individual sport at the event level. More precisely, the purpose of this article is to identify possible trends in competitive balance in athletics at the world championships and in the Olympic Games over the period 2000–2015. The study addresses how success – defined as medal winning and top-8 places, respectively – has the tendency to become more or less concentrated among a subset of countries (static approach) and to which extent this subset is stable over time (dynamic approach). Medals and top-8 places, represented in medal tables and placing tables for international sporting events, are the most common measures of success (Shibli, De Bosscher, van Bottenburg, & Westerbeek, 2013).

A rationale for focusing on one sport is that it has been shown that countries' successes tend to be concentrated in specific sports (SIRC, 2002). Selecting athletics is 'natural' as it is the most international sporting competition at the Olympic level and – given that it comprises no less than 47 events – allows for relatively large numbers of observations. Using International Association of Athletics Federation (IAAF) top-100 data, Du Bois and Heyndels (2008) document clear internationalisation in athletics over the period 1984–2006. The average MS (i.e. the share that a country has in top 100) has systematically decreased. The focus on top 100 allows for a general view on trends. Our analysis of successes at the Olympic Games and World championships allows verifying whether these general tendencies can also be witnessed at the highest level.

Competitive Balance

The concept of competitive balance has been the subject of theoretical development and practical application among many sports, especially in American professional team sports (e.g. Maxcy & Mondello, 2006; Zimbalist, 2002) and European football or soccer (e.g. Goossens, 2006; Montes, Sala-Garrido,

& Usai, 2014; Szymanski, 2003). Additionally, some studies focused on the level of competitive balance in rugby (Williams, 2012), road cycling (Rodriguez, Perez, Puente, & Rodriguez, 2012), tennis (Del Corral, 2009; Du Bois & Heyndels, 2007) and athletics (Du Bois & Heyndels, 2008).

The main issue of competitive balance is that different opponents are of equal ability such that the outcome of competition or championship is uncertain (Sanderson, 2002). Both competitive balance and uncertainty of outcome have gained scientific interest. Especially in American sports leagues, specific measures such as salary caps, revenue sharing, geographical relocations of teams and a restructured draft system are ways to constrain competition which are more common overseas (Sanderson & Siegried, 2003). A competition among competitors with a high degree of variation in their level of sporting success is considered to have a lower degree of competitive balance. As a result, the success will be for the significant stronger opponent, and the uncertainty surrounding the outcome is threatened (Owen, 2013). In case of perfect competitive balance, every team or participant would have an equal chance of winning. Perfect competitive balance means equality of outcome probabilities, not equality of observed outcome (Kringstad & Gerrard, 2004). Multiple authors have developed different quantifications or indices to represent the absence or presence of a balanced competition in a professional sports league structure (Kringstad & Gerrard, 2004; Montes et al., 2014). Even though it is widely accepted that competitive balance is multidimensional, no single measure can enclose all aspects of competitive balance (Owen, 2013). Furthermore, there is an evident gap in the literature on individual sports or multisport events in existing research on competitive balance (Ramchandani & Wilson, 2014).

Three studies which complied to the need on the analysis of individual or multisport events and do provide insight in competitive balance are published by Du Bois and Heyndels (2008); De Bosscher, Du Bois, and Heyndels (2012) and Ramchandani and Wilson (2014).

Du Bois and Heyndels (2008) made an analysis of the level of internationalisation in athletics between 1984 and 2006 by comparing IAAF top 100 rankings. While static internationalisation refers to the change in the market in two points of time, dynamic internationalisation refers to the degree to which individual countries keep or lose their MS (Du Bois & Heyndels, 2008). Based on different indicators for static and dynamic internationalisation, they found evidence of strong internationalisation in athletics. The MS of the best four countries in the top-100 list (i.e. the concentration ratio of the best four countries or CR4) decreased, while the number of ranked countries increased between 1984 and 2006. Additionally, competitiveness differed between events. While most events became more international, men's long-distance running became less international as new countries like Kenya and Ethiopia 'overtook' the market. Additionally to these findings, De Bosscher et al. (2012) found evidence that the improvement of performance levels among male athletes has been driven by the growing competitiveness, as indicated by indicators of dynamic internationalisation.

While Du Bois and Heyndels (2008) and De Bosscher et al. (2012) evaluated internationalisation and competitiveness in athletics, Ramchandani and Wilson (2014) evaluated competitive balance by measures applied to the medal MS of countries in a specific multisport event, namely the Commonwealth Games. They used three indicators of competitive balance (the proportion of medal point-winning countries (PMW), the coefficient of variation (CV) and the Herfindahl–Hirschman index (HHI)) to map the evolution of competitive balance at the Commonwealth Games between 1930 and 2010.

Two indicators (PMW and CV) provide evidence of a systematic decline of competitive balance. Medal success at the Commonwealth Games is shared among a deceasing number of countries. The HHI indicator revealed an improving but insignificant trend in competitive balance. The analysis of six specific sports (athletics, boxing, cycling, diving, swimming and weightlifting) provided evidence of a moderate or strong decline of balance between 1950 and 2010. Of the six sports compared, boxing and athletics were identified as most balanced, while diving was identified as most imbalanced. It can be stated that these sports represent different entry barriers for countries or various levels of specialisation which can have an influence on sport's competitiveness. Finally, comparisons between the different event types (men only versus women only versus mixed/open) suggest that competition in 'men only' events is stronger than that in 'women only' events.

These studies and their results make valuable contributions to evaluate levels of competitive balance in international competition. Du Bois and Heyndels (2008) found that competitiveness differs between athletic events, while De Bosscher et al. (2012) succeeded to provide evidence on the growing competitiveness in athletics as a driver of athletic performance between 1984 and 2006. Evidence of dynamic internationalisation and an increase in the number of countries able to develop top 100 athletes in athletics were found. Such a competitive environment resulted in a performance increase among events characterised by high dynamic internationalisation. Even though this study provided evidence that the performance level of a growing number of elite athletes improved, the influence of the internationalisation of athletics on the competitive balance between countries in medal events (like world championships and Olympic Games) remained unanswered.

Ramchandani and Wilson (2014) evaluated how balanced medal success has been shared at Commonwealth Games between 1930 and 2010. By different measures of competitive balance, these authors provided insight on the changing market conditions for countries to be successful at a general and sport-specific level.

METHOD

Data Collection

To measure and evaluate competitive balance in elite athletics, we focus on world championships and Olympic Games between 2000 and 2015 (see Appendix 1). This timeframe includes 12 competitions (eight world championships and four Olympic Games) and enables a comparison of change in competitive balance over multiple competitions. The 2000 Sydney Olympics was chosen as a starting point, as three athletic events were added to women's athletic competition: pole vault, hammer throw and the 20-kilometre race walk. As such, the number of events is relatively stable in the sample (with the exception of the introduction of women's 3000 m steeple chase from 2005 onwards), grouping 46 and – from 2005 onwards – 47 events. An analysis was made not only at the general level for men's and women's competition, but also at a disaggregated level where eight discipline groups are identified: sprint/hurdles, middle-distance running, long-distance running, jumping events, throwing events, race walking, relays and decathlon or heptathlon. All data were collected from the IAAF website.

Indicators of Changes in Competitive Balance

A longitudinal and cross-sectional analysis was applied to athletics to measure the evolution of competitive balance and the differences between athletic disciplines. Indicators and methods used by Du Bois

and Heyndels (2008) and Ramchandani and Wilson (2014) to evaluate the competitiveness of athletic performances or the competitive balance in the Commonwealth Games will be applied in elite athletics. First, the proportion of medal and top-8 winning countries will be analysed. Additionally, other measures use MS of countries as a starting point. MS represents the proportion of medals or top-8 points won by a given country against the total number of points available for a particular event (Shibli, Bingham, & Henry, 2007). Medal points (3-2-1) and top-8 points (8-7-6-5-4-3-2-1) attributed to medal and top-8 positions were used to calculate MSs for all countries in each discipline among the 12 competitions. In this analysis, successful countries will be described as medal or top-8 'point-winning countries' in athletics. According to SIRC (2002), MS is the best measure of success, as it facilitates time series analysis.

Competitive balance for each competition is measured through a series of widely used indicators, each capturing the concentration of success among countries: (a) the proportion of medal winning countries (PMW) and top-8 winning countries (PT8), (b) the concentration ratio 4 (CR4), (c) CV, (d) the HHI and (e) the Hymer−Pashigian (HP) index (Table 1). Medal and top-8 MSs will be applied at a general level (including all 46 or 47 events), while only top-8 MSs will be discussed at a discipline-specific level.

To evaluate and compare levels of competitive balance at a certain moment in time, the concentration ratio of the top 4 performing countries (CR4) was analysed. CR4 is defined as the sum of the four highest MSs in a competition, where S_i is the MS of country i;

$$CR_4 = \sum_{i=1}^{4} S_i. \tag{1}$$

A high value of CR4 refers to a situation of dominance of the four most successful countries (i.e. an unbalanced competition),

Table 1. Overview of the Indicators of Competitive Balance

Indicator	Meaning
Proportion of medal winning (PMW) or top-8 winning countries (PT8)	The ratio of the number of medal winning or top-8 winning countries against all countries participating in the competition. A higher value is indicative of greater competition for medals or top-8 places among countries.
Concentration ratio 4 (CR4)	The CR4 is the sum of the four highest MSs in a competition. A high CR4 represents a dominant position of the best four performing countries.
CV	The CV represents the ratio of the standard deviation to the mean. A low CV refers to a situation of MSs clustered closely around the mean (cfr. equality among countries).
HHI	The HHI represents the sum of the squared MSs of all countries. A high value refers to a situation of greater concentration of success among a small number of countries.
HP index	The HP index indicates how the distribution of MS changes over two moments of time. It represents the degree to which individual countries keep or lose their MS. A high score refers to a situation when new countries in competition won a great share of the market.

while a low value of CR4 refers to a balanced competition.

While the CR4 index focuses only on the four most successful countries (in terms of athletic success), the CV and the HHI take a broader view and measure (im)balance among all countries with a positive MS. Note that taking into account all (point-)winning countries excludes those countries that do not obtain a single medal/top-8 place. It could be argued that *all* countries – also those that do not obtain any medal or top-8 points – should be included. Technically, this is actually happening for the HHI (the value including point-winning countries only is identical to the value for the total population as countries that have a MS of 0% do not affect the value of HHI). For the CV, considering point-winning countries or all countries does play a role. Still, as the number of point-winning countries (as is the number of countries in general) is relatively stable over the period considered (see below), there is no systematic bias from choosing either approach. For our further analysis, we thus consider only those countries with a positive MS.

CV is the ratio of the standard deviation to the mean of this data set:

$$CV = \frac{\sigma}{\mu} \ . \qquad (2)$$

A low CV refers to a situation of MSs clustered closely around the mean. CV takes a minimum value of 0 when all 'point-winning' countries have an identical MS. A high CV points at a situation with great disperse between performances of competitors.

The HHI represents the sum of the squared MSs of all n countries (either successful or not):

$$HHI = \sum_{i=1}^{n} s_i^2. \qquad (3)$$

The index – ranging between 0 and 1 – is referred to as 'a numbers-equivalent of firms', as the index equals $1/N$ with N equal-size firms (Besanko, Dranove, Shanley, & Schaefer, 2006). Higher values represent a greater concentration of success among a small number of competitors.

The proportion of medal winning (PMW) and proportion of top-8-level countries (PT8) represent the proportion of countries winning medals or top-8 positions against the total number of countries participating. As there were no figures available on the number of countries participating in the specific athletic events at world championships, these two indicators were only used at a general level, including all 47(46) events.

As our interest lies mainly in the analysis of long-term trends, we compare the observed competitive imbalance at the start and end years of our sample (2000 and 2015). This reflects a static view on the evolution in competitive balance (Du Bois & Heyndels, 2008): it allows to establish whether the competition has become more balanced (or not). A dynamic view on competitive balance (Du Bois & Heyndels, 2008), however, should explain the degree to which individual countries keep or lose their MS to other competing countries. For example, a situation where CR4 remains constant over time can represent a situation where the share of medal (top-8) points by the four most successful countries is stable. Still, this may also be a result of four new countries topping the medal (top-8) tables. Where the former situation reflects absolute stability, the latter clearly reveals (dynamic) imbalance and lack of any lasting dominance. To capture this notion of dynamic balance, we use the HP index. The HP index indicates how the distribution of MS changes over two moments in time (2000 and 2015). The HP index, ranging between 0 and 1, represents the degree to which individual countries keep or lose their MS to competing countries (Du Bois & Heyndels, 2008). A 0 score refers

to a situation in which MSs did not change and each country obtained the same MS. A score of 1 would refer to a situation when new countries in competition collected all success. The HP is defined as:

$$HP_{2000-2015} = \frac{1}{2} \sum_{i=1}^{n} | S_{i, 2000} - S_{i, 2015}|. \quad (4)$$

Trends in Competitive Balance

Comparing two points in time may not allow for definite conclusions on the presence (or absence) of any systematic trend in competitive balance. For example, a consecutive decrease and increase in CR4 or a systematic increase can result in the same final score, but do represent different trends. To identify a trend, Spearman rank correlation analysis was used to examine the change in competitive balance over time. Rank correlations were calculated for three indicators (CR4, CV and HHI) and the passage of time (2000–2015). Medal and top-8 MSs will be applied at a general level (including all 46 or 47 events), resulting in six different indicators, while only top-8 MSs will be discussed at a discipline-specific level.

For each of the indicators, scores for the 12 competitions were ranked, with rank = 1 representing the most balanced edition and rank = 12, the most unbalanced. The process was repeated for the different disciplines and men's and women's competition. To evaluate the trend of competitive balance, correlations between these rankings and the ranked competitions between 2000 (rank = 1) and 2015 (rank = 12) were calculated. Positive correlations between ranks for these indices and the passage of time imply a decrease in competitive balance or an increasing dominance. Negative correlations are interpreted as an increase in competitive balance and a more open competition where dominance decreased. In a later stage, the competitive

balance between the eight discipline groups was compared by ranking the disciplines for every competition according to their CR4 top-8. In the end, average scores were calculated.

RESULTS

Figure 1 provides an overview of the proportion of the medal and top-8 winning countries in athletics. The proportion of medal winning athletes shows a decreasing trend between 2000 and 2015. Additionally, the proportion of countries obtaining at least one top-8 position fluctuated between 28.50% in 2000 and 34.33% in 2012. Both measures witnessed a small decrease in 2013, followed by an increase in 2015. Additionally, the level of medal and top-8 winning countries does not seem to differ between world championships and Olympic Games.

Before trends in competitive balance will be identified, Tables 2–5 will provide insights on the changes in competitive balance according to medal versus top-8 MS (Table 2), Olympic Games versus world championships (Table 3) and men's versus women's competition in athletics (Tables 4 and 5). To identify levels of competitive balance, the four measures of competitive balance, applied to the Sydney Olympics in 2000 (the starting point of our analysis) and
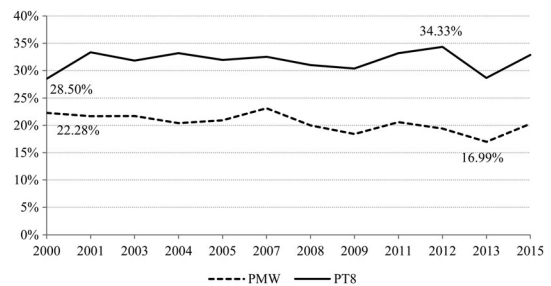
Fig. 1. Proportion of Medal Winning Countries (PMW) and Proportion of Top-8-Level Countries (PT8) Between 2000 and 2015

Table 2. Levels of Competitive Balance for Medal and Top-8 MSs in 2000 and 2015

	Medal		Top-8	
	2000	2015	2000	2015
CR4	31.52%	41.84%	31.27%	36.94%
CV	1.04	1.36	1.13	1.62
HHI	4.46%	6.47%	4.64%	5.24%
HP	40.24%		36.69%	

Table 3. Levels of Competitive Balance for Top-8 MSs at Olympic Games and World Championships between 2000−2012 and 2001−2015

	Olympic Games		World Championships	
	2000	2012	2001	2015
CR4	31.27%	41.37%	31.10%	36.94%
CV	1.13	1.90	1.30	1.62
HHI	4.64%	6.62%	4.19%	5.24%
HP	34.80%		36.78%	

the world championships in 2015 (the end point of our analysis), are presented in Table 2 for the medal MS (left) and the top-8 MS (right).

Both for medal MS and top-8 MS, all indicators increased between 2000 and 2015. This refers to a more unbalanced competition in 2015 than in 2000. This means that success is more concentrated and there is less competition between countries. The best performing countries improved their medal MS (CR4) from 31.52% to 41.84% in 2015 and succeeded to obtain 36.94% of all top-8 points in 2015, which represents a performance increase of 5.67%. Additionally, the CV increased for both medal and top-8 MS, indicating a greater dispersion between competitors. The HHI increased by 2.01% for medal points and 0.60% for top-8 points. The HP index shows that for both medal and top-8 MSs, large medal MSs (40.24%) and top-8 MSs (36.69%) shifted between competitors. Generally, comparable changes are detected based on medal and top-8 MSs between 2000 and 2015.

Additionally, differences between 2000 and 2012 (for Olympic Games) and 2001 and 2015 (for world championships) are reported in Table 3. Similar to the results presented in Table 2, the four indicators provide evidence of greater dominance by the best four performing countries and greater variance between competitors at both competitions. Changes in competitive balance are larger for Olympic Games than for world championships. Furthermore, comparable MS changes between countries have been identified for both the Olympic Games (34.80%) and the world championships (36.78%).

Table 4. Changes in Competitive Balance According to Four Indicators, Based on Top-8 MSs Between 2000 and 2015 for Men's Competition

	CR4 2000	CR4 2015	ΔCR4	ΔCV	ΔHHI	HP
Athletics	33.10	36.81	3.71	0.297	1.27	38.43
Sprint/hurdles	60.56	58.89	−1.67	−0.201	−3.01	56.94
Middle-distance running	62.04	79.63	17.59	0.553	19.63	49.54
Long-distance running	82.41	69.44	−12.97	−0.737	−9.67	48.15
Jumping events	58.33	45.83	−12.50	−0.125	−3.56	53.82
Throwing events	47.22	51.39	4.17	0.205	1.25	61.81
Race walking	72.22	59.72	−12.50	0.085	−3.43	83.33
Relays	47.22	48.61	1.39	−0.011	1.29	49.31
Decathlon/heptathlon	91.67	86.11	−5.56	−0.081	−1.38	72.22

Table 5. Changes in Competitive Balance According to Four Indicators, Based on Top-8 MSs between 2000 and 2015 for Women's Competition

	CR4 2000	CR4 2015	ΔCR4	ΔCV	ΔHHI	HP
Athletics	26.64	37.92	9.26	0.343	1.31	47.41
Sprint/hurdles	42.22	73.33	31.11	0.696	12.32	69.17
Middle-distance running	51.89	52.78	1.39	0.332	0.19	76.85
Long-distance running	68.52	97.22	28.70	0.110	17.42	52.78
Jumping events	47.22	36.81	−10.42	−0.326	−2.59	56.25
Throwing events	65.97	66.67	0.70	0.491	2.05	61.11
Race walking	72.22	83.33	11.11	0.363	8.64	66.67
Relays	63.89	65.28	1.39	−0.061	0.48	35.42
Decathlon/heptathlon	83.33	75.00	−8.33	−0.08	−3.70	66.67

Table 4 reports on the changes in competitive balance in men's competition, differentiated for the nine different disciplines. The table shows CR4 values for 2000 and 2015 (columns two and three) and changes in the four competitive balance indicators between 2000 and 2015 based on top-8 MS scores. Results for race walk, relays and decathlon/heptathlon should be interpreted with caution. As these disciplines represent only one or two events, high CR4 scores can be erroneously interpreted as representing an unbalanced competition. For example, when four different countries take the top 4 positions in women's heptathlon, the CR4 equals 72.22% (26/36 top-8 points). However, this situation represents the most balanced competition (i.e. four different countries taking the first four positions). Even though the results for these disciplines are presented in Table 4, disciplines including only one event in the athletic competition were excluded from an inter-discipline comparison.

In men's competition, the CR4 increased by 3.71 to 36.81%. CR4 increases can be identified for middle-distance running (+17.59%), throwing events (+4.17%) and relays (+1.39%). The dominance of top-4 countries decreased for long-distance running (−12.97%) and jumping events (−12.50%). Changes in CV and HHI also

indicated a smaller dispersion of MS values for these two disciplines. According to CR4 values in 2015, middle- and long-distance running are the most dominated or unbalanced disciplines, while jumping and throwing events are the most balanced. Major changes in MSs between competitors, identified by the changes in HP score, were found for all disciplines. High HP scores refer to strong MS changes of countries between two moments in time. In men's competition, between 48.15% and 61.81% of the MS shifted between competitors. The greatest shifts in MS in men's competition were identified for throwing events (61.81%) and sprint/hurdles (56.94%).

The same figures are presented for women's competition in Table 5. According to ΔCR4, all disciplines except jumping events were more dominated in 2015 than they were in 2000. CR4 increased by 31.11% for sprint/hurdles to 73.44% in 2015, while CR4 in long-distance running increased from 68.52% to −97.22% (+28.70%). More than 97% of all top-8 points at the women's 5000 m, 10,000 m and the marathon were won by four countries: Kenya, Ethiopia, the USA and Burundi. An increase according to CV and HHI refers to a greater variation between MS scores. Women's jumping events became more balanced, as the CR4 level decreased from 47.22% to 36.81% in

2015. According to CR4 values in 2015, long-distance running and sprint/hurdles are the most dominated or unbalanced events, while jumping and middle-distance running are the most balanced in women's competition. HP changes are highest in middle-distance running and sprint/hurdles. About 77% of the top-8 MS shifted in the 800, 1500 and 3.000 m steeple chase. HP changes are the lowest for long-distance running, the event which is most dominated in women's competition. This indicates that market leaders (i.e. Kenya and Ethiopia) hold a strong competitive position in this discipline.

A comparison between men's and women's competition (Tables 4 and 5) indicates that divergent changes between 2000 and 2015 can be identified. According to all four indicators, sprint/hurdles and long-distance running became more balanced for men, but more imbalanced for women. Furthermore, as HP scores are higher in women's competitions, it can be stated that top-8 success in women's competition is more dynamic than success in men's competition. Given the divergent changes in men's and women's competition, trends in competitive balance will be analysed for men's and women's competition first together and second separately.

Trends in Competitive Balance in Athletics

To evaluate whether or not the market of elite athletics has systematically become more (un)balanced, Table 6 provides an overview of the three different indicators of competitive balance. The CR4, CV and HHI are applied both on the medal MS and top-8 MS. Additionally, the proportion of medal winning countries (PMW) and the proportion of countries obtaining a top-8 position (PT8), which were presented in Figure 1, are added in the first two columns. For each indicator, historic rankings are provided between brackets, whereby the most balanced competition is ranked first. For instance,

according to the proportion of medal winning countries (PMW), the 2007 world champions (rank = 1) was the most balanced edition, while the 2013 world championships (rank = 12) was the most unbalanced edition. Spearman rank correlations were calculated between these rankings and the ranking of time (2000 = 1; 2015 = 12).

Six of the indicators presented in Table 6 point at a significant correlation between time (2000–2015) and competitive balance. A positive correlation, given that competitions are ranked from the most balanced to the most imbalanced, refers to a decrease in competitive balance in international competition. All indicators except PT8 and the CV medal MS indicate a systematic reduction in competitive balance in athletics at the world championships and Olympic Games since 2000.[1]

According to the proportion of medal winning countries, competitive balance has significantly decreased between 2000 and 2015 ($r = .727^{**}$, $p = .00$).

Two indicators based on medal MS (CR4 and HHI) point at a significant decrease in competitive balance in athletics. According to these indicators, there is a systematic tendency that medal success is concentrated among a smaller number of countries. All indicators based on top-8 MS give evidence of a significant decrease in competitive balance ($.767 \leq r \leq .860$, $p = .00$). A comparable analysis has been made for different subcategories of the athletic competition: men versus women's competition and the eight different disciplines of the athletic competition. Three indicators of competitive balance are represented in this analysis: CR4, the CV and the HHI. Both top-8 MS and medal MS are used to evaluate trends in competitive balance.

Competitive balance based on top-8 points MS

All correlations of these three indicators of competitive balance with the passage of

Table 6. Trends in Competitive Balance between 2000 and 2015

Year	PMW	PT8	Medal MS			Top-8 MS		
			CR4	CV	HHI	CR4	CV	HHI
2000 (1)	22.28 (2)	28.50 (12)	31.52 (1)	1.045 (1)	0.045 (1)	31.27 (2)	1.138 (1)	0.044 (2)
2001 (2)	21.69 (4)	33.33 (2)	34.42 (2)	1.066 (2)	0.050 (2)	31.10 (1)	1.299 (2)	0.042 (1)
2003 (3)	21.72 (3)	31.82 (8)	40.22 (3)	1.329 (3)	0.061 (3)	32.07 (3)	1.395 (3)	0.046 (3)
2004 (4)	20.41 (7)	33.16 (4)	42.03 (5)	1.440 (8)	0.075 (8)	34.84 (4)	1.543 (5)	0.051 (5)
2005 (5)	20.94 (5)	31.94 (7)	47.52 (10)	1.616 (10)	0.085 (10)	36.47 (5)	1.548 (6)	0.055 (8.5)
2007 (6)	23.15 (1)	32.51 (6)	45.39 (7)	1.628 (11)	0.074 (7)	38.42 (9)	1.597 (8)	0.054 (7)
2008 (7)	20.00 (9)	31.00 (9)	46.10 (8)	1.432 (7)	0.068 (5)	38.36 (8)	1.558 (7)	0.049 (4)
2009 (8)	18.41 (11)	30.35 (10)	45.04 (6)	1.342 (4)	0.072 (6)	37.88 (7)	1.539 (4)	0.055 (8.5)
2011 (9)	20.60 (6)	33.17 (3)	52.84 (12)	1.704 (12)	0.089 (12)	42.43 (12)	1.774 (11)	0.061 (10)
2012 (10)	19.40 (10)	34.33 (1)	49.29 (11)	1.604 (9)	0.086 (11)	41.37 (10)	1.898 (12)	0.066 (12)
2013 (11)	16.99 (12)	28.64 (11)	46.81 (9)	1.368 (6)	0.076 (9)	41.61 (11)	1.716 (10)	0.065 (11)
2015 (12)	20.29 (8)	32.85 (5)	41.84 (4)	1.365 (5)	0.065 (4)	36.94 (6)	1.623 (9)	0.052 (6)
Correlation	0.727**	−0.133	0.615*	0.420	0.600*	0.797**	0.860**	0.767**
	$p = 0.00$	$p = 0.68$	$p = 0.03$	$p = 0.17$	$p = 0.04$	$p = 0.00$	$p = 0.00$	$p = 0.00$

Notes: PMW = proportion of medal winning countries. PT8 = proportion of top-8-level countries. Correlation with time (2000 = 1; 2015 = 12).
*Correlations significant at the 0.05 level (two-tailed).
**Correlations significant at the 0.01 level (two-tailed).

Table 7. Spearman Rank Correlations with the Passage of Time, Based on Top-8 MS

	Men			Women		
	CR4	**CV**	**HHI**	**CR4**	**CV**	**HHI**
Athletics	0.734**	0.594*	0.558	0.608*	0.378	0.568
Sprint/hurdles	0.277	−0.105	−0.042	0.685*	0.587*	0.727**
Middle-distance running	0.615*	0.462	0.401	0.308	0.476	0.224
Long-distance running	−0.190	−0.413	−0.448	0.689*	0.503	0.651*
Jumping events	−0.267	−0.070	−0.392	0.182	−0.077	−0.042
Throwing events	0.049	0.552	−0.081	0.261	0.378	0.308
Race walking	−0.246	0.154	−0.207	0.553	0.646*	0.681*
Relays	0.312	0.350	0.361	0.213	−0.126	0.091
Heptathlon/decathlon	0.078	−0.039	0.221	−0.358	−0.098	−0.387

Note: Correlation with time (2000 = 1; 2015 = 12).
*Correlations significant at the 0.05 level (two-tailed).
**Correlations significant at the 0.01 level (two-tailed).

time are listed in Table 7 for both men's and women's competition. Two indicators show a significant decrease in competitive balance in men's competition in athletics ($.594 \leq r \leq .734$, $p < .04$, CR4 and CV), whereas only the CR4 top-8 indicates a systematic reduction in competition balance in women's events ($r = .608^*$, $p < .04$). Other indicators show non-significant positive correlations.

In women's events, competitive balance decreased significantly for sprint/hurdles ($.587 \leq r \leq .727$, $p < .04$, demonstrated by all three indicators), long-distance running ($.651 \leq r \leq .689$, $p < .02$, demonstrated by the CR4 and HHI) and race walking ($.646 \leq r \leq .681$, $p < .03$, demonstrated by CV and HHI). Middle-distance running and throwing events showed positive correlations for all indicators, although they were insignificant.

In men's competition, only the CR4 indicates a systematic reduction in competitive balance in middle-distance running ($r = .615^*$, $p = .03$). No other significant changes in competitive balance were identified in men's competition. For sprint/hurdles and throwing events, both positive and negative correlations were identified with the three indicators of competitive balance.

Additionally, different negative correlations were identified, even though these correlations were insignificant. These were found for men's long-distance running (by all three indicators), men's jumping events (by all three indicators), women's jumping events (CV and HHI), heptathlon (CR4 top-8) and men's race walking (CR4 and HHI). These insignificant negative correlations refer to a trend towards a more balanced competition.

Competitive balance based on medal points MS

The analysis based on the medal MS (as shown in Table 8) provides comparable results in women's competition. Both in sprint/hurdles and long-distance running, two indicators (CR4 and HHI) identified a systematic decrease in competitive balance. The HHI significantly correlated with the passage of time for race walking. In men's competition, the CR4 identified a significant reduction in competitive balance for athletics ($r = .592^*$, $p = .04$). At the discipline-specific level, competitive balance improved for medal MS according to the CV in long-distance running ($r = -.767^{**}$, $p = .00$).

Table 8. Spearman Rank Correlations with the Passage of Time, Based on Medal MS

	Men			Women		
	CR4	CV	HHI	CR4	CV	HHI
Athletics	0.592*	0.329	0.286	0.424	0.203	0.299
Sprint/hurdles	0.477	−0.490	−0.014	0.685*	0.420	0.643*
Middle-distance running	0.144	0.371	0.256	−0.386	0.280	−0.140
Long-distance running	−0.296	−0.767**	−0.514	0.664*	0.510	0.581*
Jumping events	−0.288	−0.105	−0.406	0.025	−0.256	−0.126
Throwing events	0.112	0.347	0.081	−0.504	−0.105	−0.476
Race walking	−0.305	0.042	−0.232	−[a]	0.490	0.755**
Relays	0.468	−0.065	0.479	−0.028	0.459	0.170
Heptathlon/decathlon	−[a]	0.389	0.389	−[a]	−[a]	−[a]

Note: Correlation with time (2000 = 1; 2015 = 12).
*Correlations significant at the 0.05 level (two-tailed).
**Correlations significant at the 0.01 level (two-tailed).
[a]No correlation could have been calculated as indicator scores were constant.

Difference between the medal MS of countries in this event decreased.

Analysis by Event Type

In order to compare levels of competitive balance between the eight disciplines in athletics, these disciplines were ranked for every competition according to their CR4 top-8 for both men's (Table 9) and women's competition (Table 10). Race walking for women, decathlon and heptathlon, representing only one event, were excluded from a comparison between disciplines. Therefore, rankings between one and six were awarded to women's disciplines, and rankings from one to seven to men's disciplines.

Table 9. Competitive Balance by Discipline for Men, Based on the CR4 Top-8 MS

Men	Sprint/ hurdles	Middle-distance running	Long-distance Running	Jumping events	Throwing events	Relays	Race walking
2000	60.56 (4)	62.04 (5)	82.41 (7)	58.33 (3)	47.22 (1)	47.22 (1)	72.22 (6)
2001	41.67 (1)	75.93 (5)	88.89 (7)	54.86 (4)	50.69 (3)	44.44 (2)	77.78 (6)
2003	55.00 (5)	48.15 (3)	76.85 (7)	47.92 (2)	50.00 (4)	41.67 (1)	73.61 (6)
2004	65.56 (5)	63.89 (4)	62.04 (3)	58.33 (2)	38.19 (1)	68.06 (6)	72.22 (7)
2005	71.11 (6)	62.96 (5)	72.22 (7)	49.31 (1)	52.78 (2)	56.94 (3)	62.50 (4)
2007	68.89 (6)	62.96 (5)	69.44 (7)	43.75 (2)	43.06 (1)	62.50 (4)	52.78 (3)
2008	72.22 (6)	63.89 (4)	88.89 (7)	29.86 (1)	47.22 (3)	43.06 (2)	68.06 (5)
2009	71.11 (6)	70.37 (5)	82.41 (7)	49.31 (1)	50.69 (3)	50.00 (2)	54.17 (4)
2011	56.67 (4)	65.74 (5)	87.04 (7)	45.83 (2)	44.44 (1)	50.00 (3)	84.72 (6)
2012	65.56 (4)	72.22 (5)	75.00 (6)	59.03 (3)	38.89 (1)	58.33 (2)	80.56 (7)
2013	69.44 (5)	70.37 (6)	76.85 (7)	54.17 (2)	50.00 (1)	58.33 (3)	59.72 (4)
2015	58.89 (4)	79.63 (7)	69.44 (6)	45.83 (1)	51.39 (3)	48.61 (2)	59.72 (5)
Average rank	4.67	4.92	6.50	2.00	2.00	2.58	5.25

Table 10. Competitive Balance by Discipline for Women, Based on the CR4 Top-8 MS

Women	Sprint/ hurdles	Middle-Distance running	Long-Distance running	Jumping events	Throwing events	Relays
2000	42.22 (1)	51.39 (3)	68.52 (6)	47.22 (2)	65.97 (5)	63.89 (4)
2001	48.33 (2)	50.00 (3)	69.44 (6)	45.14 (1)	54.86 (4)	65.28 (5)
2003	56.11 (2)	66.67 (5)	71.30 (6)	52.78 (1)	56.25 (3)	62.50 (4)
2004	63.33 (4)	62.50 (3)	71.30 (6)	59.72 (2)	66.67 (5)	58.33 (1)
2005	72.22 (5)	62.04 (4)	87.04 (6)	54.17 (2)	56.25 (3)	50.00 (1)
2007	70.56 (6)	63.89 (1)	69.44 (4)	63.89 (1)	63.89 (1)	69.44 (4)
2008	83.33 (6)	73.15 (5)	67.59 (4)	56.94 (2)	56.94 (2)	52.78 (1)
2009	81.11 (5)	60.19 (3)	90.74 (6)	54.86 (1)	56.25 (2)	61.11 (4)
2011	75.00 (5)	59.26 (3)	90.74 (6)	50.69 (1)	58.33 (2)	63.89 (4)
2012	76.67 (6)	65.74 (4)	87.96 (6)	62.50 (1)	62.50 (1)	65.28 (3)
2013	66.11 (4)	80.56 (5)	84.26 (6)	59.03 (1)	61.11 (2)	63.89 (3)
2015	73.33 (5)	52.78 (2)	97.22 (6)	36.81 (1)	66.67 (4)	65.28 (3)
Median rank	4.17	3.42	5.67	1.33	2.83	3.08

Average scores were calculated based on the 12 rankings between 2000 and 2015. For example, according to Table 9, the average ranking for men's sprint/hurdles is 4.67. This means that between 2000 and 2015, four events have been more balanced (i.e. jumping events, throwing events and relays).

In men's competition, both jumping and throwing events were the most balanced between 2000 and 2015 (rank = 2.00), followed by relays (2.58). Sprint (4.67), middle-distance running (4.92) and race walking (5.25) have medium rankings. The least competitive discipline in men's competition between 2000 and 2015 was long-distance running (6.50). For 2015, middle-distance running was identified as the most unbalanced, and jumping as the most balanced competition.

In women's competition (Table 10), jumping events were identified as the most balanced (1.33) between 2000 and 2015, followed by throwing events (2.83), relays (3.08) and middle-distance running (3.42). Long-distance running (5.67) was women's most unbalanced competition between 2000

and 2015. In 2015, jumping events and middle-distance running were most balanced, while success in long-distance running was the most concentrated in women's competition. In all, 97.22% of the top-8 MS was won by four countries. A comparison between the CR4 levels for the disciplines in men's and women's competition suggests than men's competition is stronger or more balanced than women's competition.

Fluctuations in competitive balance between disciplines and through time, as represented in Tables 9 and 10, mark specific competitions when a discipline was most unbalanced/balanced compared to the overall timeframe and other disciplines. For example, in men's competition, the jumping events (CR4 = 29.86%) and long-distance running (CR4 = 88.89%) at the 2008 Beijing Olympics represented men's most balanced and most unbalanced disciplines.

In women's competition, the most balanced and unbalanced disciplines took place at the most recent world championships in Beijing (2015). In all, 97.22% of all
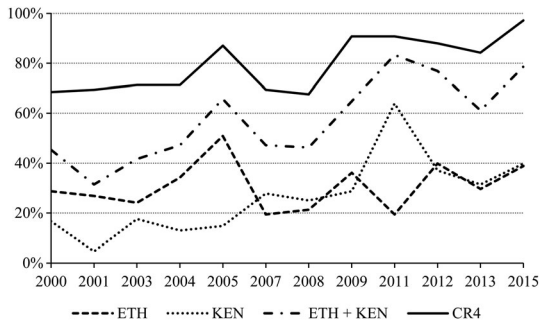
Fig. 2. CR4 Top-8 and MS for Ethiopia and Kenya in Women's Long-distance Running Between 2000 and 2015

top-8 points awarded in long-distance running (5000 m, 10,000 m and the marathon) were won by the top-4 countries. Competitive balance significantly decreased in this discipline by the growing level of success of Kenya and Ethiopia. This is illustrated in Figure 2 that compares the MS of these countries to the CR4 level. While the top 4 countries equalled a CR4 top-8 of 97.22% in 2015, Kenya and Ethiopia won 78.70% of the top-8 MS. Furthermore, since 2009, Kenya and Ethiopia won 87.78% of all medal points in five consecutive competitions (four world championships and one Olympic edition). In 2011, only two countries won medals in these three running events; Kenya won eight medals, Ethiopia one. Women's jumping competition in 2015 represented the most balanced competition since 2000. The top 4 performing countries won only 36.81% of all top-8 points awarded.

DISCUSSION AND CONCLUSION

This paper identified trends in competitive balance at world championships and Olympic Games. A longitudinal and cross-sectional analysis contrasted men's and women's competition and the eight different disciplines between 2000 and 2015. In summary, the analysis revealed four major conclusions.

First, evidence of static and dynamic changes in competitive balance was identified between 2000 and 2015. According to the CR4 top-8, both men's and women's competition were more dominated by the top-performing countries. At the level of specific disciplines, divergent trends in competitive balance were found. In 2015, men's competition was more dominated in middle-distance running, throwing events and relays, but more competitive in sprint/hurdles, long-distance running and jumping events. In women's competition, competitive balance decreased in all disciplines, except jumping events. The top-8 MS of the best four countries grew to 97.22% in long-distance running and 73.33% for sprint/hurdles.

Second, the subset of countries obtaining large MSs in these disciplines shifted. Compared to 2000, individual countries lost their MS (cfr. Belarus, Cuba & Romania) as new countries became more successful (cfr. Ethiopia, Kenya & China). For example, in 2015, 77% of the top-8 MS in women's middle-distance running and 69% of the MS in sprint/hurdles were won by countries which were not successful at the 2000 Olympics. This indicates that competition in athletics is dynamic and the market leaders changed between 2000 and 2015. Even though lower scores were found for the other disciplines in men's and women's competition, these competitions can still be described as highly competitive markets. In general, levels of dynamic changes in competitive balance were higher in women's competition than in men's competition.

Third, Spearman rank correlation based on three different indicators (CR4, CV and HHI) identified systematic changes in competitive balance for athletics between 2000 and 2015. All indicators, except the CV based on medal MS, indicated a significant decrease in competitive balance for athletics. The 2000 Olympic Games and 2001 world championships were identified as the most balanced, while the 2011 world

championships and the 2012 Olympics were the most unbalanced competitions.

According to CR4 and CV, competitive balance decreased significantly in men's competition, while only one indicator (CR4 top-8) showed a significant reduction in competitive balance among women's competition. An analysis of the different disciplines in men's and women's competition demonstrated a systematic decrease in competitive balance in sprint/hurdles, long-distance running and race walking for women and middle-distance running for men. Comparable results for women's competition were identified for indicators of competitive balance calculated based on medal MSs. According to CV, a significant trend towards a more balanced medal distribution was identified in men's long-distance running. No other significant changes were found in men's medal competition. Additionally, different negative correlations were identified for indicators based on both medal and top-8 MSs, but these correlations were not significant.

Finally, a cross-sectional analysis ranked the different disciplines for every competition to identify the most balanced discipline. Based on the averaged score between 2000 and 2015, long-distance running events were identified as the most unbalanced for men and women. The most balanced disciplines for women were the jumping events, while both jumping and throwing events were the most balanced in men's competition. Generally, men's competition has been identified as more balanced than women's competition.

Based on these results, this study concludes that the dynamic changes in market leaders in athletics combined with a reduction in competitive balance represent a market structure in which new countries which are more successful than their predecessors dominate the international competition. It can be stated that not only athletes improve their performances by achieving season's best or world record performances, but also elite sport systems of countries become more dominant in competition.

This market-based perspective on the environmental dynamics for one specific sport adds understanding to elite sport literature on how trends of competitive balance indicate prospects for success. While most elite sport studies focus on the relation between sport policies and success, this study creates insight on the market dynamics in athletics which influence opportunities for success. The identification of discipline-specific trends in competitive balance provides evidence to policy-makers and National Governing Bodies (NGBs) for athletics on current and historic trends of competitiveness. Knowledge on these trends can contribute to the decision-making process on the structural or priority support among these disciplines and adjust expectations on top-8 or medal success at the world level. For example, structural support in women's running events (sprint/hurdles, long-distance running and race walking) might be less efficient than investment in men's jumping or throwing events, as women's running events became more unbalanced and represent the highest level of dominance. In addition, dominance is the most stable in women's long-distance running, representing a low HP score compared to other disciplines. Jumping and throwing events represent lower levels of dominance and have witnessed a (non-significant) trend towards a more balanced competition.

Knowledge on market dynamics gains value if it can be applied to competitive strategy. According to Grant (2010) and Werner-felt (1984), strategy is based on countries' access to resources and the efficiency with which these resources are structured to match the opportunities in the external environment. Finally, this study contributed to the knowledge of current and historic dynamics in this competitive environment.

In previous research, Du Bois and Heyndels (2008) and De Bosscher et al. (2012) found not only evidence of an increasing internationalisation of athletics, but also 'barriers to entry' to technical events based on the long-term developing process to develop top-level athletes among these disciplines. In this study, dominance of top-performing countries in these events decreased and the medal competition became significantly more balanced according to the CV. In women's long-distance running, competitive balance significantly decreased and Kenya and Ethiopia obtained a duopoly in women's long-distance running, winning 79% of the top-8 MS in 2015.

In relation to barriers for countries to develop success in technical events, the results in this study identified high levels of change in top-8 success for women's sprint/hurdles (a 69% MS shift) and men's throwing events (a 61% MS shift). Current levels of sporting success in technical events like sprints and jumping events have been achieved by new countries and questions the predictability of success based on well-organised sport structures and macro-level factors. While Du Bois and Heyndels (2007) found evidence that African and Caribbean countries are systematically less successful in non-running events and race walking, recent examples show that performance patterns changed. At the 2015 world championships, Kenyan athletes Julius Yego and Nicholas Bett both won a gold medal. Yego became the first Kenyan to win a gold medal in a field event, while Bett obtained the first gold medal in the 400 m hurdles events. All other five gold medals were won in middle- and long-distance running. Additional research on the diverse trends in competitive balance is needed to evaluate the impact of strategy, innovation and macro-level factors on the long-term success of new entrants in technical events.

As international competition witnessed major changes over the past 15 years, the question remains how these findings on historic and contemporary trends in competitive balance can be translated to future dynamics and the strategy of countries. The fixed competition schedule, the stable number of contestable medals and the specific entry barriers do not change the market conditions. The countries themselves act as a driving force for changing the dynamics of the market. In order to do so, three different strategies for countries can be identified.

First, countries have to be aware of their structural strengths and weaknesses. In practical terms, this may relate to the tradition in success which may have generated an 'experiential advantage'. This may materialise in the presence of high-level coaches, facilities, etc. Alternatively, structural strengths may result from macro-level factors. A straightforward example may be the country's wealth which may be a proxy of its capacity to invest in technical events which tend to be more expensive. Based on this, the primary strategic focus of Western and (former) socialist countries should be on technical events, whereas African countries' focus may be on long-distance running.

Second, the observed dynamics in the competitions imply that – apart from the structural strengths discussed – opportunities are always present. This means that policy-makers should be vigilant so as to recognise opportunities for success. For example, Kenya became successful in technical events and the USA and Great Britain and Northern Ireland are successful in middle- and long-distance running events.

Third, a host effect on countries' success can be another way to strengthen a market position. Shibli et al. (2012) identified that during the last five Olympic Games, host countries won on average seven more gold medals compared to the previous edition. "A positive host nation effect is determined by the enhanced strategic investment in

elite sport and especially the right to contest more events, which increases the opportunity to win more medals" (Shibli et al., 2012, p. 281). If these results could be applied to athletics, we could expect Brazil (i.e. Rio is the host of the 2016 Summer Olympics) which is currently rather unsuccessful in athletics (i.e. Brazil obtained a 0.77% top-8 MS at the 2015 WCs), but especially the UK as future host of the 2017 World Championships as a dominant and successful country in international competition.

Still, at least two of these explanations point to strategic management action to strengthen policy and resource structures to improve sporting success and countries' market position. The capacity of countries to develop and perform will have a greater impact than the understanding of the market dynamics as such. However, the knowledge on historic and contemporary levels of competitive balance could support policy-makers and NGBs to apply dynamic strategies towards medal and diploma opportunities. Additionally, competition authorities should consider optimal levels of competitive balance and the dispersal of success among different competitors.

Future research may address some of the limitations of this study. First, athletic disciplines represent multiple events, varying from one event (i.e. women's race walking) to five events (women's sprint/hurdles). These differences have an influence on the CR4 level of dominant countries in competition. Erroneous interpretations on CR4 levels can be drawn in disciplines with less events. In this study, events representing only one event were removed from an inter-discipline comparison. Additional resource should take into account the number of events for each discipline to enable a comparison between all disciplines. Furthermore, continental championships have not been analysed to evaluate competitive balance in athletics. Additionally, a limitation of this study is the interference of doping to the development of success and the levels of competitive balance in athletics. Most recently, Russia has been banned from international competition by the IAAF as the World Anti-Doping Agency (2015) reported on systematic cheating by coaches, doctors and laboratory staff in Russia. In the last two decades, Russia has dominated the international athletics competition. These allegations obstruct the interpretation of contemporary and historic trends in competitive balance and countries' level of success in athletics. Even though medals can be redistributed, it is hard to reconstruct historic levels of competitive balance.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

NOTE

1. Appendix 2 shows the Spearman rank correlation of these indicators for the eight world championships and four Olympic Games separately. In both cases, positive correlations were found between competitive balance indicators and the passage of time, but only five are significant.

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Appendix 1. Overview of the Competitions Between 2000 and 2015 for Athletics

Year	Event	City (country)	Number of disciplines (men/women)
2000	Olympic Games	Sydney (Australia)	46 (24/22)
2001	World Championships	Edmonton (Canada)	46 (24/22)
2003	World Championships	Paris (France)	46 (24/22)
2004	Olympic Games	Athens (Greece)	46 (24/22)
2005	World Championships	Helsinki (Finland)	47 (24/23)
2007	World Championships	Osaka (Japan)	47 (24/23)
2008	Olympic Games	Beijing (China)	47 (24/23)
2009	World Championships	Berlin (Germany)	47 (24/23)
2011	World Championships	Daegu (South Korea)	47 (24/23)
2012	Olympic Games	London (Great Britain)	47 (24/23)
2013	World Championships	Moscow (Russia)	47 (24/23)
2015	World Championships	Beijing (China)	47 (24/23)

Appendix 2. Spearman Rank Correlations with the Passage of Time for Olympic Games and World Championships Separately

	Medal MS			T8 MS		
	CR4	**CV**	**HHI**	**CR4**	**CV**	**HHI**
Correlation Olympic Games with time (2000 = 1, 2012 = 4)	1.000**	0.800	0.800	1.000**	1.000**	0.800
Correlation world championships with time (2001 = 1, 2015 = 8)	0.429	0.452	0.429	0.714*	0.833*	0.619

*Correlations significant at the 0.05 level (two-tailed).
**Correlations significant at the 0.01 level (two-tailed).