Analysis of Anti-Doping Rule Violations that have impacted medal results at the Summer Olympic Games 1968 - 2012

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Abstract [250 limit]

Since 2004 the International Olympic Committee (IOC) store all samples collected at summer Olympic Games (OG) for retrospective re-analysis with more advanced analytical techniques to catch doping athletes. **Methods:** All announced Anti-Doping Rule Violations (ADRVs) from IOC re-tests of the 2004, 2008 and 2012 OG (via IOC, International Federations and Athletics Integrity Unit public data) and other ADRVs confirmed to impact OG results from 1968 - 2012 (via the list of Doping Irregularities on olympedia.org) were collated to investigate how many medals have been impacted by ADRVs, when the ADRV was identified relative to the OG in question and its cause. **Results:** 134 medals were impacted by ADRVs but only 26% of these ADRVs were identified at the time of the OG. Most ADRVs impacting medal results (74%) were identified retrospectively, either from events prior to the OG (17%) or via IOC re-tests of samples from 2004, 2008 and 2012 (57%). ADRVs impacting medal results from these re-tests took a mean of 6.8 ± 2.0 years to be announced relative to the end of the OG in which the medal was originally won. Exogenous Anabolic Androgenic Steroid metabolites were present in 90% of all athlete (n=142) samples from IOC re-tests with dehydrochloromethyltestosterone and stanozolol accounting for 79% of detected substances. Athletics (n=64) and weightlifting (n=62) were the most affected sports. **Conclusion:** This analysis shows the frequency of targeted pre-OG Out-of-Competition testing should increase. We advocate for long-term sample storage to continue and additionally incorporate novel and potentially complementary technologies/sample matrices.

Key Points

- Since 2004 all samples collected for an anti-doping purpose at summer Olympic Games (OG) are stored and since 2015 samples can be re-analysed with improved analytical techniques up-to 10 years after they were collected to catch doping athletes. In recent years, the detection window of exogenous Anabolic Androgenic Steroids (AAS) (e.g., dehydrochloromethyltestosterone and stanozolol) has greatly improved because of the discovery of their long-term metabolites excreted in urine.
- For the majority (74%) of summer Olympic medals impacted by doping violations (1968-2012), these doping violations have been identified retrospectively. International Olympic Committee (IOC) mandated re-testing of the 2004, 2008 & 2012 OG accounted for 57% of the total number of impacted medals. It took a mean of 6.8 ± 2.0 years for these IOC re-tests that impacted medal results to be announced relative to the end of the OG in which the medal was originally won. 90% of all positive IOC re-tested samples (n=142) contained metabolites of exogenous AAS with dehydrochloromethyltestosterone and stanozolol accounting for 79% of detected substances. Athletics (n=64) and weightlifting (n=62) were the most affected sports.
- This study shows the effectiveness of long-term sample storage in identifying Olympic doping medallists indicating that this practice should extend to other non-Olympic events (e.g., World Championships and Continental Games) and additionally incorporate novel technologies/matrices that may have future capabilities to complement doping detection. Additionally, the frequency of targeted out-of-competition testing prior to OG should be higher to increase the likelihood that doping athletes get caught prior to competing.

1 Introduction

In 1999 the International Olympic Committee (IOC) convened the World Conference of Doping in Sport in Lausanne and this conference served as the foundation of an international anti-doping initiative, which resulted in the formation of the World Anti-Doping Agency (WADA) in 2001 [1]. The immediate challenge for WADA was generating a set of universally accepted rules (the WADA Code) that contained international standards for laboratories, testing procedures, prohibited substances and mechanisms and rules for therapeutic exemptions as there were inconsistencies in this legislature across sports [1]. The IOC compelled the Olympic federations to adopt the Code and stated those who did not by the opening of the 2004 Athens Games, would not be allowed to have their sport on the Olympic program [2]. Consequently, all federations adopted the Code and it went into effect in January 2004 [2, 3]. In anticipation of anti-doping analytical techniques improving in the future and to deter doping, the IOC financed the shipment and long-term storage of all anti-doping samples collected during Olympic venues from 2004 onwards, with the initial statute of limitations for a retrospective Anti-Doping Rule Violation (ADRV) from sample re-analyses being set at 8 years and later extended to 10 years in the revised 2015 WADA Code [3, 4]. Anti-doping authorities can re-test samples at any point during this window of time as a function of the implementation of new methods or instruments in WADA accredited laboratories allowing the detection of prohibited substances or their metabolites at a much lower concentration or for a larger detection window [5].

During 2004 – 2008 WADA, the pharmaceutical industry and the Lausanne anti-doping laboratory put resources together to create an enzyme-linked immunosorbent assay (ELISA) for a third generation Erythropoietin (EPO) called CERA (Continuous EPO Receptor Activator) [4]. This test was made ready before CERA was available on the market due to the high likelihood of it being utilised as a doping substance [4, 6]. The first re-analysis of Olympic samples was conducted 6-months after the 2008 Beijing Olympic Games [7] in which all serum samples collected during these Games were re-tested with this new test for CERA [6]. Six athletes, including two medallists, tested positive [8]. Advances in the sensitivity of chromatographic/mass spectrometric techniques enabled improvements in the detection window of exogenous Anabolic Androgenic Steroids (AAS) [9] via the discovery of the long-term metabolites for compounds such as metandienone [10], oxandrolone [11], dehydrochloromethyltestosterone [12, 13] and stanozolol [14]. The IOC used these improved analytical methods to initiate the first targeted retrospective re-analysis of urine samples collected at the 2004 Athens Games in 2012 [4]. Prior to the Rio Olympic Games in 2016 the IOC initiated a re-analysis programme that utilised these improved analytical methods on samples collected during the Beijing 2008 and London 2012 Olympic Games and by March 2016, the targeted re-analysis of hundreds of samples was already underway [15]. The IOC has not disclosed the exact test distribution plan for the re-testing of these samples (e.g., exact numbers of which sports/nations were re-tested) as they regard this as "useful information for cheaters - the more unpredictable testing is, the more effective the deterrence"[16]. However, the IOC notes that the selection of samples for re-analysis was made in consultation with WADA and International Federations after a risk analysis and it focused on sports and groups of athletes with a higher risk of doping and who were successful [16]. Selection also depended on the number of samples collected, the number of athletes at the Games in each group and had the aim of preventing athletes who cheated in these Games from competing in Rio 2016 [16]. Additionally, after receiving the completed WADA Independent Person Report in December 2016 the IOC mandated the examination of all collected samples from Russian athletes during the London 2012 Games following findings of a systematic and centralised cover up and manipulation of the doping control process around this time [17]. Four-thousand eight hundred anti-doping tests were carried out during Beijing 2008 and after the conclusion of the 8-year statute of limitations 1,053 samples were selected for re-analysis [16]. Five-thousand anti-doping tests were carried out during London 2012 and by 2017 the IOC stated that 492 samples were selected for re-analysis.

Critics of reallocating Olympic medals via the retrospective re-analysis of samples, say this reduces live sport to “meaningless spectacles” as until the re-testing is concluded (which could be 10 years later) the initial results are provisional as neither the athletes nor spectators know who the real medal winners are [18]. The 8-year statute of limitations for sample re-analysis from London 2012 concluded in August 2020 finalising the IOC re-testing programme of samples collected during the 2004, 2008 and 2012 summer Olympic Games. This study investigated the effectiveness of identifying doping from long-term sample storage and re-analysis by collating all summer Olympic medal winning results impacted by doping, across 1968 – 2012, and classifying if the doping was identified retrospectively or not. At the time of writing the re-analysis of samples removed from the former Moscow laboratory by WADA’s Intelligence and Investigations team in December 2014 and April 2019 is still on-going and the associated “Operation Laboratory Information Management System (LIMS)” probe into institutionalized doping in Russia has not been concluded [19]. Due to this pending investigation which could involve samples collected at the winter Sochi Olympics 2014, this study only investigated the impact of doping on medal winning results of the summer Olympic Games and not winter Olympic Games.

2 Methods

2.1 Data entry and analysis

Data on athletes retrospectively identified to have committed an ADRV at the 2004, 2008 and 2012 Olympic Games, via the IOC's targeted re-analysis of samples, were obtained from publicly available data published by the IOC on April 28th 2020 [20], the Athletics Integrity Unit (AIU) list of Provisional Suspensions in Force [21] (last updated on 16th July 2020), the AIU Global List of Ineligible Persons [22] (last updated 28th July 2020) and the International Weightlifting Federation's Public Disclosures of 8th October 2019 [23], 10th and 20th January 2020 [24, 25] to include all known announced ADRVs from IOC re-testing. Data on other ADRVs that impacted the 1968 – 2012 summer Olympic Games was obtained from a publicly available list of Doping Irregularities at the Olympics curated by Olympic historians on olympedia.org [8] of which data entry ceased on 9th July 2020. News reports of press releases [26, 27] were used to confirm the timing of the identified cause of one sanction as it was not clear on olympedia.org. ADRVs that were overturned on appeal were excluded. If an athlete competed in a team sport this was counted as a single performance and as a single medal won (if applicable) and teammate medals that may have additionally been rescinded because of doping were not counted. Reasons for the ADRVs were classified as described in Table 1, with the classifications of substances defined by their location in the 2020 WADA Prohibited list [28] or their closest categorisation therein. ADRVs were classified if they occurred at the Olympic Games, prior to an Olympic Games and if they were identified retrospectively (either by IOC retests or by other investigations). Data analysis was conducted in Microsoft Excel and in R version 3.6.3 using the tidyverse [29], choroplethr [30] and choroplethrMaps [31] packages. The data files and R code used in this study have been made publicly available online [32].

3 Results

3.1 IOC Retests of Athens 2004, Beijing 2008, and London 2012

One-hundred and forty-two athletes were retrospectively identified to have committed ADRVs at the Athens 2004 (n=5), Beijing 2008 (n=65) and London 2012 (n=72) Olympic Games from the targeted re-analysis of samples by the IOC. In London 2012 one of these athletes was deceased when this retrospective ADRV was discovered and so no proceedings could be filed and two athletes in London 2012 were also retrospectively identified to have committed an additional ADRV prior to the Games. Metabolites of exogenous AAS were present in 90% of these samples with dehydrochloromethyltestosterone and stanozolol accounting for 79% of all detected substances (Table 2). Of the eight sports affected the highest number of athletes caught doping in these re-tests competed in athletics (n=64) and weightlifting (n=62) which combined accounted for 89% of the total (Table 3). Twenty-five nations were affected and the five nations with the highest number of affected athletes (Russia (n=41), Belarus (n=22), Ukraine (n=14), Kazakhstan (n=13) and Turkey (n=8)) accounted for 69% of the total (Figure 1).

3.2 Medals Impacted by Doping 1968 – 2012

From 1968 to 2012 one-hundred and thirty-four summer Olympic medal-winning performances (Gold 43, Silver 47, and Bronze 44) have been impacted by an ADRV. The Sydney 2000 (Gold 8, Silver 1, Bronze 5), Athens 2004 (Gold 8, Silver 2, Bronze 5), Beijing 2008 (Gold 9, Silver 22, Bronze 19) and London 2012 Games (Gold 12, Silver 17, Bronze 11) account for 89% of the total number of impacted medals (Table 4). For only thirty-five medals (26% of the total number of impacted medals) the associated doping violation was identified at the time of the Games (Table 4). Doping violations that have been identified retrospectively, either occurring prior to the Games in which the medal was won and then impacting the subsequent Olympic result (Gold 10, Silver 7, Bronze 6) or occurring during the 2004, 2008 or

2012 Games but identified retrospectively by IOC re-tests (Gold 18, Silver 31, Bronze 27 - including one Gold medal that involves both scenarios) account for the majority (74%) of impacted medal-winning results (Table 4). The seventy-six medals associated with ARDVs from IOC re-tests of the 2004, 2008 and 2012 Games account for 57% of the total number of impacted medals. For these seventy-six medals it took a mean of 6.8 ± 2.0 years for the announcement of these ADRVs relative to the end of their respective Games. Weightlifting (Gold 9, Silver 10, Bronze 16) and athletics (Gold 7, Silver 12, Bronze 10) were the most affected sports and accounted for 84% of medals associated with ADRVs from these IOC re-tests. The number of medals impacted by ADRVs that have been identified retrospectively *vs* those not classified as retrospective cases is greater in Sydney 2000 (8 *vs* 6), Beijing 2008 (46 *vs* 4) and London 2012 (38 *vs* 2) (Table 4). From 1968 – 2012 for all medal-winning results impacted by ADRVs the detection of AAS account for 67% of all ADRVs (Table 5). From 1968 – 2012 of the twelve sports with medal results impacted because of ADRVs, athletics (Gold 21, Silver 21, Bronze 16) and weightlifting (Gold 14, Silver 14, Bronze 19) have been the most affected and account for 78% of the total number of impacted medals.

4 Discussion

Athletes have been caught using prohibited substances at every summer Olympic Games in which testing has occurred except for at the 1980 Moscow Games. However, later unofficial research-based analysis suggested that ~20% of all athletes tested were likely doping with testosterone yet no test existed at the time [1] and there are reports from a retired KGB Lieutenant and a retired ex-Soviet Union medallist that urine swapping occurred at the 1980 Games "and that's how the samples were clean" [33]. This analysis from 1968 – 2012 shows that for the majority (74%) of Olympic medals that have been impacted by doping violations, these doping violations have been identified retrospectively. The IOC's targeted re-analysis of samples collected at the 2004, 2008 and 2012 Olympic Games accounted for 57% of all medals impacted by doping violations. It took a mean of 6.8 ± 2.0 years for these IOC re-tests that impacted medal results to be announced relative to the end of the Games in which the medal was originally won. Metabolites of exogenous AAS were present in 90% of the positive samples re-analysed by the IOC in 2004, 2008 and 2012 with dehydrochloromethyltestosterone and stanozolol accounting for 79% of all detected substances. The majority (89%) of the 142 athletes retrospectively charged with ADRVs from the IOC re-tests of the 2004, 2008 and 2012 Olympic Games competed in athletics (n=64) and weightlifting (n=62). Additionally, of twenty-five affected nations the five nations (Russia (n=41), Belarus (n=22), Ukraine (n=14), Kazakhstan (n=13) and Turkey (n=8)) with the highest number of affected athletes accounted for 69% of the total number of athletes. These two findings, in conjunction with high levels of detection for long term metabolites for exogenous AAS, suggest that the prevalence of Out-of-Competition (OOC) doping with AAS is higher in certain sports and regions than others. At the time of competition these athletes had timed the clearance of prohibited metabolites from their system so that the available detection science would not catch them. These athletes may have been caught doping in real time prior to the Games if subjected to sufficient levels of OOC testing.

It takes time to research and develop new reliable and effective drug tests. When the WADA Code was implemented in 2004 long-term sample storage and re-analysis was envisaged to act as a deterrent to doping [3]. This is because even if athletes managed to beat tests whilst competing, they still risk getting caught doping years later. However, considering that athletes knew since 2004 that sample re-analysis with improved technologies was possible and that 6-months after Beijing 2008 two Olympic medallists were caught via this practice, twenty-eight medallists still got caught doping retrospectively at London 2012. This had led to some authors to suggest that the deterrence effect of long-term sample storage is limited, otherwise we would not have seen so many retrospective doping incidents [18].

The IOC will only reallocate a medal once all remedies of appeal are exhausted and all proceedings are closed, which can take a considerable amount of time (in some cases years) after the retrospective ADRV is announced [34]. Dopers are requested by the IOC to return their medals so they can be given to the rightful winners, but they are not always so forthcoming and the IOC maintains a stock of blank medals for reallocations if the originals can't be acquired in time of the new planned medal ceremony [34]. Critics of the retrospective reallocation of Olympic medals years after the original event do acknowledge that it delivers sporting justice if enough athlete samples are stored and re-tested [18]. However, they also argue that any economic benefits from winning Olympic medals acquired from culprits in the years post victory are impossible to re-allocate and the athletes' experience of medal re-allocation years later can never replace a podium celebration after victory [18]. The IOC has improved their medal re-allocation protocols and in May 2018 approved six options for athletes to receive their medal(s): at the next edition of the Olympic Games; at the Youth Olympic Games; at the IOC headquarters or The Olympic Museum; at an event of their IF; at an event of their National Olympic Committee; or a private ceremony [35, 36]. Previously, there are reports of an athlete [37], nine years after the original event, being given his rightful Olympic gold medal in the food court of on airport by an official of their National Olympic Committee; a stark contrast to hearing their national anthem playing in a stadium filled with tens of thousands of people.

Start-up funding from the IOC in 2015 enabled the creation of the International Testing Agency (ITA) who's overarching goal is to make anti-doping testing independent from sports organisations to prevent conflicts of interest [38]. The ITA has planned the "most comprehensive pre-Games testing programme ever conducted" for Tokyo 2020 and $5 million, spread over 10 years, will be allocated to a comprehensive long-term storage programme of these pre-Games samples in addition to the regular long-term storage of samples collected during the Tokyo Games [39, 40]. This was announced prior to the coronavirus pandemic which has delayed the Tokyo Games to 2021 [41]. Globally, anti-doping testing has been greatly reduced during the coronavirus pandemic, (e.g. the United Kingdom Anti-Doping Agency between April and June 2020 carried out only 126 tests compared to 2,212 in the same quarter in 2019 [42]) making the long-term storage of pre-Games samples even more important for Tokyo as this lack of testing could have been an opportunity for a "doping-holiday" [43]. The IOC has also discussed the possibility of samples being collected in Tokyo for novel testing technologies/matrices, such as Dried Blood Spots (DBS) and gene expression ("omic") analysis, with the expectation that the long-term storage of samples with new methods will strengthen deterrence so that the cheats "never feel safe, anytime or anywhere" [38]. The collection of capillary blood on DBS cards [44] and the collection of venous blood in RNA preservative for gene expression ("omic") analysis [45] and other currently unknown advances in anti-doping science may be complementary matrices/methodologies for future drug detection.

This study has shown that for the summer Olympic Games 1968 – 2012, long-term sample storage and re-analysis with improved technologies has caught more doping medallists than the testing technology available at the time of sample collection. The disproportionate representation of athletes from certain sports and nations charged with ADRVs from the IOC re-testing of the 2004, 2008 and 2012 Olympic Games suggests that future levels of pre-Olympic OOC testing should increase in these areas. We therefore welcome the news [39] that the ITA is planning "the most comprehensive pre-Games testing programme ever conducted" for Tokyo 2021 that additionally includes the long-term storage of samples collected pre-Games. Educational programmes on anti-doping will also assist in changing this disproportionate presentation. Long-term storage is not standard across Continental Games, with International Federations having to fund the cost of long-term storage with WADA encouraging this practice to extend to Continental Games and other competitions [46]. Given these findings we encourage more International Federations to further their investment in long-term sample storage at Continental Games and other important international competitions to enhance future doping detection and to deliver sporting justice. Given these findings we also advocate for long-term sample storage to additionally incorporate the specific requirements of novel testing technologies/matrices even if at the time of collection these methodologies are not fully validated for doping detection. During the 10-year statute of limitations [3] in which sample re-analysis can happen, further research on these technologies will occur and once validated they could be applied to this biobank of samples and may complement doping detection.

5 Declarations

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Conflicts of interest/Competing interests (include appropriate disclosures)

The authors declare that they have no conflicts of interest that are directly relevant to the content of this manuscript.

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Not applicable

Consent to participate (include appropriate statements)

Not applicable

Consent for publication (include appropriate statements)

Not applicable

Availability of data and material (data transparency)

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Available on OSF [32].

Authors' contributions

Conceptualization: [Alexander Kolliari-Turner]; Data curation [Alexander Kolliari-Turner]; Investigation [Alexander Kolliari-Turner]; Formal analysis: [Alexander Kolliari-Turner]; Methodology: [Alexander Kolliari-Turner, Fergus M Guppy]; Project Administration [Yannis Pitsiladis, Fergus M Guppy]; Software [Alexander Kolliari-Turner]; Supervision: [Yannis Pitsiladis, Fergus M Guppy]; Visualization [Alexander Kolliari-Turner, Fergus M Guppy]; Writing – original draft preparation: [Alexander Kolliari-Turner]; Writing – review and editing: [Alexander Kolliari-Turner, Giscard Lima, Blair Hamilton, Yannis Pitsiladis, Fergus M Guppy].

6 Tables

Table 1 Classifications and examples of ADRVs within this study. Substance classifications were defined by their location in the 2020 WADA Prohibited list or their closest categorisation therein [28].

Classifications of ADRVs	Examples
AAS	AAF for the detection of AAS e.g., Testosterone, metandienone, nandrolone, oxandrolone, stanozolol, dehydrochloromethyltestosterone, metenolone
Stimulants	AAF for the detection of stimulants e.g., sibutramine, methylhexaneamine, ephedrine
Other substances	AAF for the detection of the following: Diuretics and masking agents (e.g. furosemide); Other anabolic agents (e.g. clenbuterol); Beta-blockers (e.g. propranolol); Substances used in equestrian doping (e.g. capsaicin); Ethanol; Hormone and metabolic modulators (e.g. tamoxifen); Peptide hormones, growth factors, related substances, and mimetics (e.g. Growth Hormone Releasing Peptides)
ABP Violations	A violation of the ABP due to abnormal athlete data
Other specific cases	Revelations of athlete involvement with an organised doping regime but specific substances used at the relevant Games are not fully elucidated (e.g. confessed or known involvement in the BALCO scandal); Confessions of doping; Refusal to submit urine or urine tampering; Doping identified retroactively at a prior Olympics causing result disqualification at a later Olympics; Combinations of these reasons and any of the previously mentioned classifications.

ADRV: Anti-Doping Rule Violation; AAS: Anabolic Androgenic Steroids; AAF: Adverse Analytical Finding; ABP: Athlete Biological Passport; BALCO: Bay Area Laboratory Co-operative

Table 2 Counts of detected prohibited substances (or their metabolites) from athletes (n=142) who generated an Anti-Doping Rule Violation from the IOC re-testing of samples from the 2004, 2008 and 2012 Olympic Games.

Games	**Count of Detected Prohibited Substances (or their metabolites) from the IOC re-tests of samples collected at the 2004 – 2012 summer Olympic Games**			
	DHCMT	Stanozolol	Other exogenous AAS*	Other substances**
2004 Athens	-	-	4	1
2008 Beijing	41	22	6	15
2012 London	59	28	11	4
Total	100	50	21	20

*denotes either: oxandrolone, metenolone, methandienone, drostanolone, 1-androsterone or clostebol. **denotes either: EPO; CERA, Growth Hormone-Releasing Peptide-2, acetazolamide, methylhexaneamine, tamoxifen, clenbuterol, ipamorelin, Athlete Biological Passport Violation or sibutramine. DHCMT: dehydrochloromethyltestosterone; AAS: Anabolic Androgenic Steroid; EPO erythropoietin; CERA (Continuous EPO Receptor Activator).

Table 3 The distribution of sports of athletes (n=142) who generated an Anti-Doping Rule Violation from IOC re-testing of samples from the 2004, 2008 and 2012 Olympic Games.

Sport	Olympic Games			
	2004 Athens	2008 Beijing	2012 London	**Total**
Athletics	4	31	29	64
Weightlifting	1	25	36	62
Freestyle wrestling	-	4	3	7
Cycling	-	2	1	3
Greco-Roman wrestling	-	3	-	3
Boxing	-	-	1	1
Canoe Sprint	-	-	1	1
Swimming	-	-	1	1

Table 4 For the Summer Olympic Games 1968 – 2012 all medals impacted by an Anti-Doping Rule Violation (ADRV) are shown, alongside when this ADRV occurred and when it was identified.

Games	**Olympic Medals Impacted by an ADRV**			
	ADRV occurred at the Games & identified during the Games	ADRV occurred at the Games & identified retrospectively by IOC re-tests	ADRV occurred prior to the Games & identified retrospectively	Combination*
1968 Mexico City	1	-	-	-
1972 Munich	4	-	-	-
1976 Montréal	3	-	-	-
1980 Moscow	-	-	-	-
1984 Los Angeles	2	-	-	-
1988 Seoul	5	-	-	-
1992 Barcelona	-	-	-	-
1996 Atlanta	-	-	-	-
2000 Sydney	6	-	8	-
2004 Athens	8	5	2	-
2008 Beijing	4	43	3	-
2012 London	2	27	10	1
Total	**35**	**75**	**23**	**1**

* denotes a combination of an ADRV occurring at the Games and being identified by retrospective IOC-retesting and an ADRV also occurring prior to the Games and being identified retrospectively by another testing initiative.

Table 5 Counts for the reason of Anti-Doping Rule Violations (ADRVs) that have impacted Olympic medal-winning results (n=134) for the summer Olympic Games 1968 – 2012.

Games	**Counts for the reasons of ADRVs that have Impacted Summer Olympic Medal Winning Results 1968 - 2012**				
	AAS	Stimulants	ABP Violation	Other Substances*	Other Specific Cases**
1968 Mexico City	-	-	-	1	-
1972 Munich	1	3	-	-	-
1976 Montréal	3	-	-	-	-
1980 Moscow	-	-	-	-	-
1984 Los Angeles	2	-	-	-	-
1988 Seoul	2	-	-	3	-
1992 Barcelona	-	-	-	-	-
1996 Atlanta	-	-	-	-	-
2000 Sydney	3	1	-	3	7
2004 Athens	7	1	-	4	5
2008 Beijing	53	2	-	12	-
2012 London	41	1	6	2	3
Total	**112**	**8**	**6**	**25**	**15**

*denotes either: diuretics and masking agents, other anabolic agents, beta-blockers, substances used in equestrian doping, ethanol, hormone and metabolic modulators, peptide hormones, growth factors, related substances and mimetics as defined, if applicable, by these substances locations in the 2020 Wada Prohibited list [28] and as defined in Table 1.** denotes either: revelations of athlete involvement with an organised doping regime but specific substances used at the relevant Games are not fully elucidated (e.g. confessed or known involvement in the Bay Area Laboratory Co-operative scandal), confessions of doping, refusal to submit urine or urine tampering, doping identified retroactively at a prior Olympics causing result disqualification at a later Olympics and combinations of these reasons and any of the previously mentioned classifications as defined in Table 1. AAS; Anabolic Androgenic Steroid. ABP; Athlete Biological Passport.

7 Figures

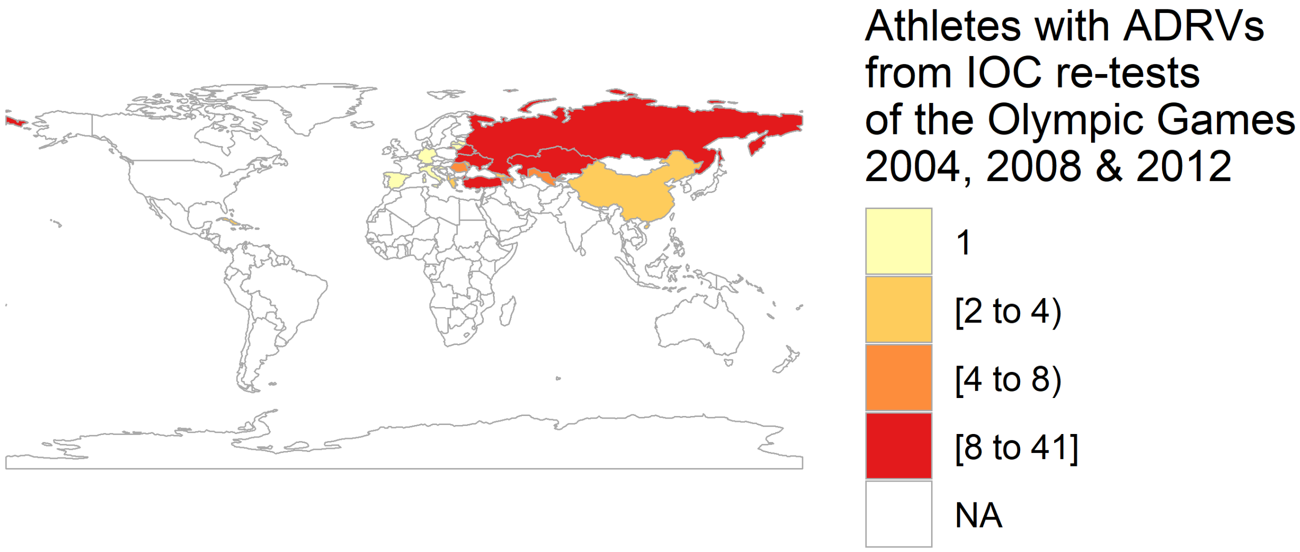

Figure 1: The athletes (n=142) from the twenty-five nations who generated Anti-Doping Rule Violations (ADRVs) from IOC re-tests of the 2004, 2008 and 2012 Olympic Games. NA indicates zero recorded ADRVs.

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