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Article *in* Journal of Sports Sciences · March 2024

DOI: 10.1080/02640414.2024.2334483

Journal of Sports Sciences

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/rjsp20

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To cite this article: Eduard Bezuglov, Georgiy Malyakin, Danila Telyshev, Ryland Morgans, Artemii Lazarev, Elizaveta Kapralova, Olga Sadkovaya & Oleg Talibov (26 Mar 2024): The effects of anti-doping measures on sports performance in weightlifting, Journal of Sports Sciences, DOI: 10.1080/02640414.2024.2334483

To link to this article: https://doi.org/10.1080/02640414.2024.2334483

Published online: 26 Mar 2024.

JOURNAL OF SPORTS SCIENCES
https://doi.org/10.1080/02640414.2024.2334483

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SPORTS PERFORMANCE

The effects of anti-doping measures on sports performance in weightlifting

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ABSTRACT

Background: Evaluating anti-doping measures is essential to optimise their effectiveness. Comparing sporting results that have a higher doping prevalence, such as weightlifting, before and after the implementation of anti-doping measures may serve as an effectiveness indicator.
Methods: The results of the most successful weightlifters of both sexes in two time periods, 2009–2015 and 2016–2022 were analysed. The Sinclair Total (ST) to compare the relative strength of weightlifters from different weight categories was calculated.
Results: A significant decrease in the ST during 2016–2022 ($p < 0.001$) in athletes of all ages and both sexes overall was reported. When analysed by age, there was a decrease in ST in juniors and seniors of both sexes ($p = 0.010$ and $p < 0.001$, respectively), but not in youth. There was a decrease in the ST in senior men ($p < 0.001$), junior women ($p < 0.001$) and senior women ($p < 0.001$).
Conclusion: In elite weightlifting, adult athletic results declined during 2016–2022, which may partly be explained by the implementation of new methods to detect long-term anabolic androgenic steroid metabolites as well as other policies. This may highlight the effectiveness of these methods both in the prevention and detection of anti-doping rule violations.

ARTICLE HISTORY
Received 10 July 2023
Accepted 18 March 2024

KEYWORDS
Anabolic androgenic steroid; Olympic weightlifting; doping in sports; weightlifting; long-term metabolites

Introduction

Doping is one of the most pressing and prevalent issues in the sports world. Some athletes employ various doping methods to improve performance results, while the World Anti-Doping Agency (WADA) constantly increases their efforts to combat doping use. These efforts include increasing the total number of doping samples, conducting targeted testing, storing samples for ten years for further analysis, forming testing pools, and developing and introducing new methods of direct and indirect determination of prohibited substances (Anti-Doping Testing Figures Report, 2023). Moreover, WADA implemented anti-doping education as one of their strategic priorities in both the 2015–2019 and 2020–2024 strategic plans (World Anti-Doping Agency Strategic plan, 2015–2019; World Anti-Doping Agency Strategic, 2024). Additionally, WADA has increased the severity of punishment for anabolic androgenic steroids (AAS) use since 2015, extending disqualification periods from 2 to 4 years (World Anti-Doping Code, 2024). However, there remains a discrepancy between the number of prohibited substances and the metabolites found in samples and actual use. The number of samples containing prohibited substances in athletes does not exceed 2%, although, Ulrich et al. demonstrated that the actual athlete use can be much higher and reach 43–57% (Ulrich et al., 2018). This existing discrepancy indicates that WADA and other leading sports organisations, need to further develop to achieve maximum effectiveness in the fight against doping.

To optimise anti-doping measures, their effectiveness must be evaluated. One way to accomplish this is to compare performance results in sports with a high doping prevalence before and after the implementation of anti-doping measures. This approach has been previously utilised to assess the influence of the implementation of the Athlete Biological Passport (ABP) in elite female runners and the introduction of new methods to detect AAS in female athletics (Bezuglov et al., 2023; Iljukov et al., 2020). These athletes have historically had a high prevalence of doping and less subjective scoring of competition results, thus highlighting them suitable candidates for such examinations.

Weightlifting is another sport with a high doping prevalence. It is conducted indoors, with minimal influence from environmental factors, and the final result is based on the sum of the best attempts in snatch and clean and jerk with no significant rule changes in recent decades. Weightlifting as a sport has recently gained notoriety for doping prevalence to the extent that its exclusion from the Olympics was considered (LA28 Initial Sports Programme to be put forward to the IOC Session, 2023). Adverse analytical findings in weightlifting over the last decade account for 1.28% to 3.36% (one of the highest percentages among Olympic sports) of cases with AAS being

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the most common cause (Anti-Doping Testing Figures Report, 2023). According to Kolliari-Turner et al., there were 565 anti-doping sanctions in weightlifting between 2008 and 2019, with 82% related to AAS (Kolliari-Turner, Oliver, et al., 2021). This widespread violation related to AAS usage should not be surprising. The positive effect of AAS on muscle hypertrophy and strength has been previously proven, explaining the main reason for its inclusion on the World Anti-Doping Agency Prohibited List (Handelsman et al., 2018).

Tighter doping control can be achieved by increasing the number of doping samples and introducing new AAS detection methods, leading to increased detection and subsequent decreased AAS use, which may potentially result in decreased performance. Examples of such methods include the identification of long-term AAS metabolites and the use of highly sensitive chromatographic/mass spectrometric techniques, which enable AAS detection for a longer period and at lower concentrations of the substance in the sample (Iljukov et al., 2020; Kolliari-Turner, Lima, et al., 2021). Additionally, the implementation of the ABP steroidal module enables AAS detection even after the drug has been eliminated from the body (Geyer et al., 2014; Saugy et al., 2014; Vernec, 2014).

Thus, the aim of this study was to compare performance results in weightlifting prior to and following the implementation of anti-doping measures and an increased sample collection. The study hypothesis was that a decrease in performance results would be evident. Furthermore, based on exisiting literature, the most significant decrease would occur in adult weightlifters, as age group analysis of 565 weightlifter disqualifications from 2009 to 2022 showed that 69.6% (396 people) were adult, 20.04% (114 people) were junior and only 9.67% (55 people) were youth (Anti-doping sanctions list, 2023).

Methods

Using competition protocols obtained from the official website of the International Weightlifting Federation (IWF), an analysis of the results achieved by the most successful male and female weightlifters from various age groups during two distinct time periods, 2009–2015 and 2016–2022 was conducted (IWF events results, 2023). The 2017 World Senior Championship was excluded from the analysis as athletes from China, Kazakhstan, Russia, Armenia, Azerbaijan, Moldova, Turkey, Ukraine and Belarus did not compete due to numerous anti-doping rule violations (IWF Executive Board upholds decision related to Member Federations which have produced three or more retesting cases, 2023).

For the purposes of this study, "most successful athletes" are defined as those that achieved a place in the top 10 in the largest international competitions of their respective age groups, which included the World Weightlifting Championships for youth (age 13–17), juniors (age 15–20) and seniors (older than 15 years old), as well as the Olympics for seniors (Weightlifting age groups, 2023). The final analysis included the results obtained from a total of 10 World Youth Championships, 13 World Junior Championships, 10 World Senior Championships and 3 Olympic Games held between 2009 and 2022. The athletes belonged to the age and weight class in which they were at the time of a particular competition.

In Olympic weightlifting, the comparison of athletes from different weight categories is often carried out using the Sinclair coefficient, where Sinclair coefficient is multiplied by the athlete's actual total to produce the Sinclair Total (ST). The Sinclair coefficient allows for the standardisation of athlete's results and is calculated based on the world record holder's bodyweight in the heaviest weight class and their corresponding result. The Sinclair coefficient is updated for each Olympic Cycle to account for the most recent records and is calculated using the following formula $10^{A\left(\log_{10}\left(\frac{x}{b}\right)\right)^2}$, where x is the lifter's bodyweight, b is the absolute world record holder's body weight and A is the coefficient for the given Olympic Cycle (IWF, Sinclair Coefficient, 2023; Sinclair, 1985). In the present study, the ST for all athletes was calculated using the coefficient from the 2017–2020 Olympic Cycle. While this coefficient is based on the most recent records, it still allows for a reasonable comparison of athlete's results from previous years. In addition, since the Sinclair coefficient is based on the record in the absolute category, it allows to draw out the comparison before and after the introduction of new weight categories in 2018 (New Bodyweight Categories Approved by the IWF Executive Board, 2023). As a result, the use of ST as relative strength indicator is the best available option to be used in the study.

The mean ST was compared between weight groups, as per the classification previously described by Gottwald et al. and adjusted to the new weight categories implemented by the IWF in 2018 (Gottwald et al., 2021) (Table 1).

Table 1. Breakdown of weight groups and categories.

		Weight group (kg)		
Sex and time period	Age group	Lightweight	Middleweight	Heavyweight
Female 1998–2017	Youth	44, 48	53, 58, 63	69, 69+
	Junior and Senior	48, 53, 58	63, 69	75, 75+
Female 2018-present	Youth	40, 45, 49	55, 59, 64	71, 76, 81, 81+
	Junior and Senior	45, 49, 55	59, 64, 71	76, 81, 87, 87+
Male 1998–2017	Youth	50, 56	62, 69, 77	85, 85+
	Junior and Senior	56, 62	69, 77, 85, 94	105, 105+
Male 2018-present	Youth	49, 55	61, 67, 73, 81, 89, 96	102, 102+
	Junior and Senior	55, 61	67, 73, 81, 89, 96	102, 109, 109+

The number of doping samples collected across weightlifting between 2009 and 2021 was reported in the WADA Anti-Doping Testing Figures Report (Anti-Doping Testing Figures Report, 2023).

Statistical analysis

For statistical analysis, Jamovi 2.2.5 software, which is an internationally developed open-source project was used. The ST using mean, standard deviation, minimum and maximum values in a normal distribution were described. The normality of data distribution using the Shapiro–Wilk test was checked. Student's T-test to compare differences between two groups with normal distribution of ST was used. Age categories were analysed separately, and the T-test was applied in these categories for independent variables (Sinclair Total and number of samples). If significant, Cohen mean difference and effect size were reported. For non-normal distribution, Mann-Whitney tests were used, and the mean difference and rank biserial correlation if significant were reported. Finally, ANOVA was used to compare three or more groups, followed by Tukey's pairwise analysis. The results were considered statistically significant at $p < 0.05$.

Results

A total of 5703 performance results from 3014 weightlifters (including both sexes, youth, juniors and adults) were analysed from 2009 to 2022. The first period accounted for 2823 results of 1619 weightlifters, while the second period accounted for 2880 results of 1395 weightlifters.

Change in the ST among weightlifters from both sexes

A significant decrease in ST was found between 2016–2022 and 2009–2015 (average difference: −8.8 (4.9–12.7), effect size: 0.12 (0.06–0.17), $p < 0.001$). Sub-dividing all participants from both sexes by age group showed a statistically significant decrease in juniors and seniors ($p = 0.010$ and $p < 0.001$, respectively), but not in youth ($p = 0.39$) athletes from both sexes.

Change in the ST in male and female weightlifters with and without weight consideration

The analysis of overall ST for all age groups revealed a decrease in 2016–2022 compared to 2009–2015 for both men and women ($p = 0.015$ and $p < 0.001$, respectively) (Figure 1). Furthermore, there was a decrease in ST in senior men ($p < 0.001$), junior women ($p < 0.001$) and senior women ($p < 0.001$) when analysed separately.

Change in the ST in male and female youth weightlifters

There was no significant difference in the ST in youth male ($p = 0.33$, $p = 0.54$, $p = 0.97$ in light, middle and heavyweight groups respectively) and female ($p = 0.91$, $p = 0.99$, $p = 0.65$ for the same groups) weightlifters at the analysed time periods.

Change in the ST in male and female junior weightlifters

The ST decreased among male junior weightlifters from the lightweight category ($p = 0.010$, mean difference −7.3), and female middleweight ($p = 0.037$, mean difference 5.3, rank biserial correlation 0.14) and heavyweight ($p = 0.049$, mean difference 6.0, rank biserial correlation 0.13) groups. However, there was no ST decrease observed in other junior weightlifting groups (Figures 2 and 3).

Change in the ST in male and female senior weightlifters

When analysing male senior weightlifters, a decrease in ST was found in light and middleweight groups ($p = 0.018$, mean

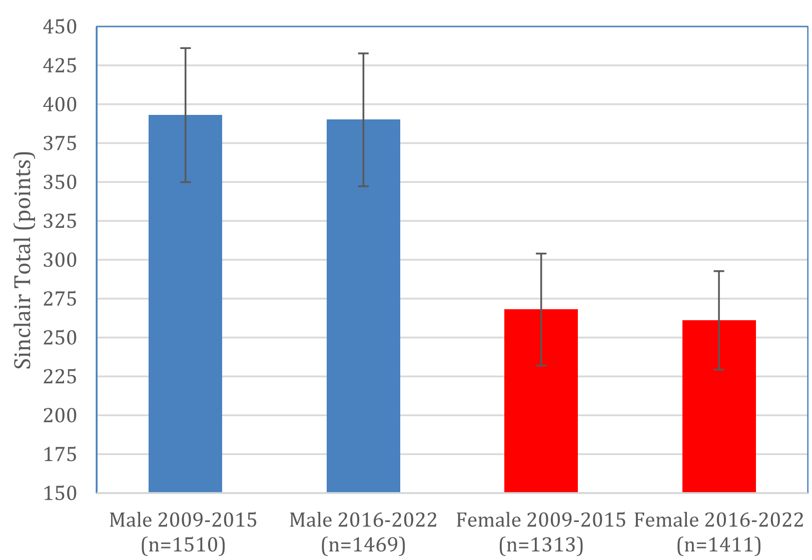

Figure 1. Change in the ST in male and female weightlifters during respective time periods.

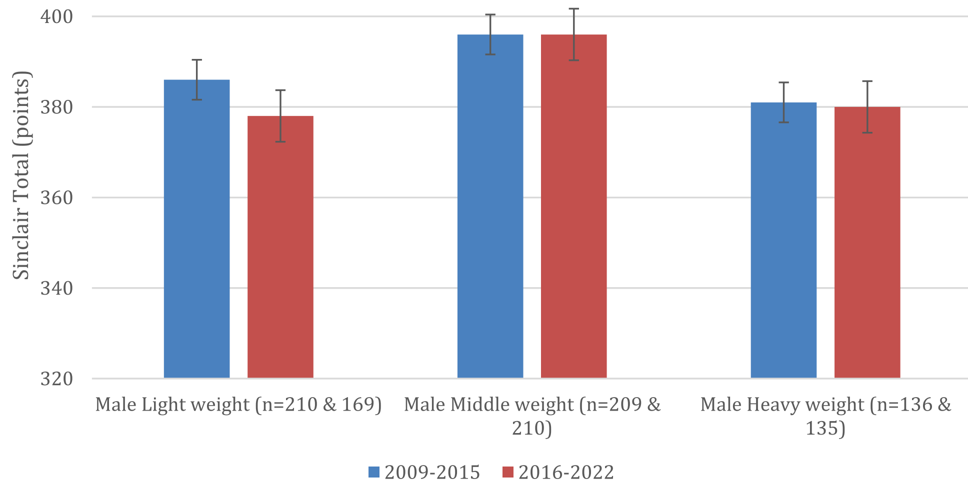

Figure 2. The ST comparison in male junior weightlifters.

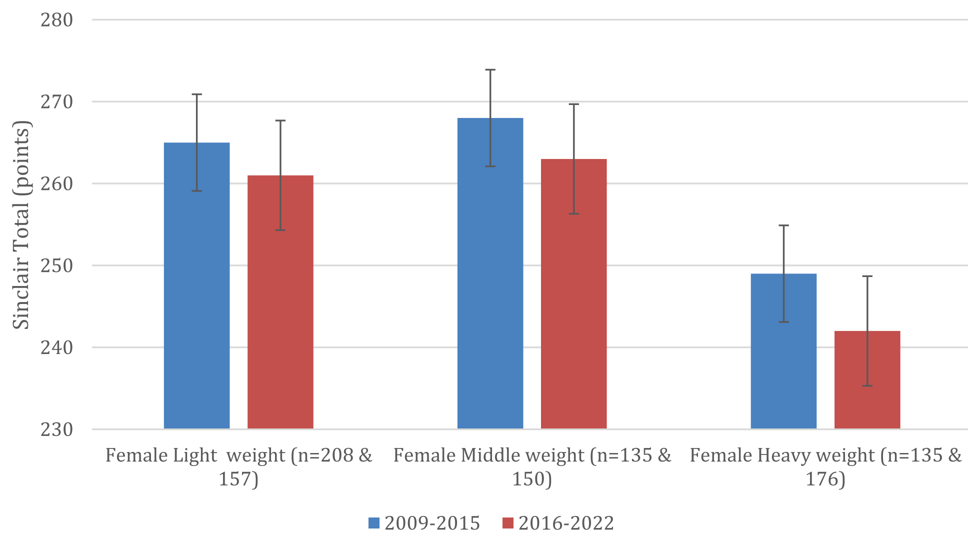

Figure 3. The ST comparison in female junior weightlifters.

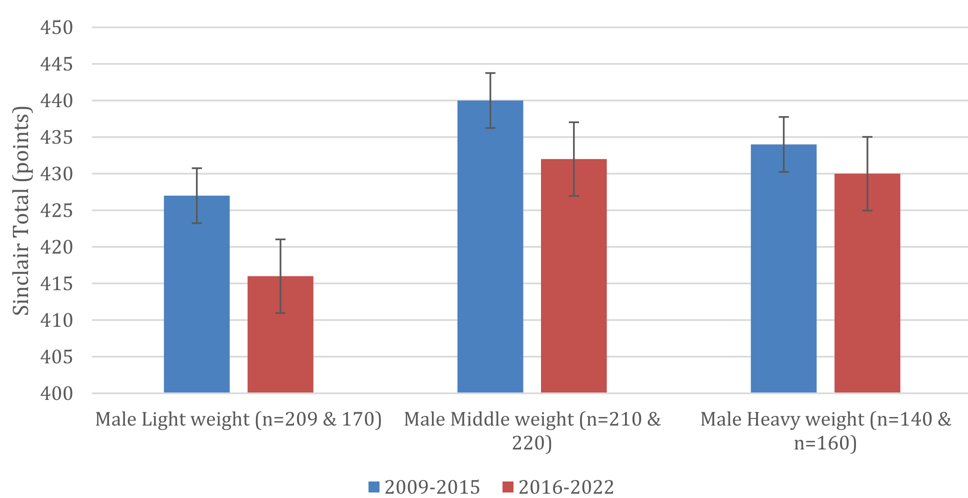

Figure 4. The ST comparison in male senior weightlifters.

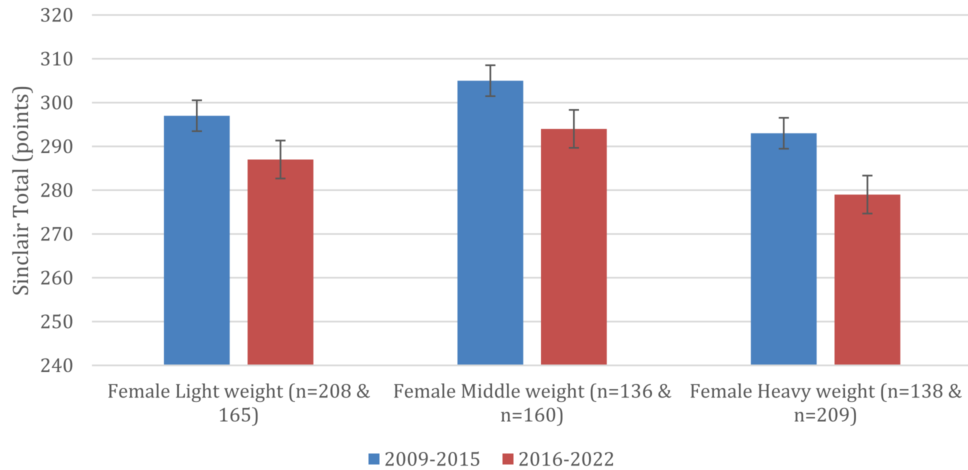

Figure 5. The ST comparison in female senior weightlifters.

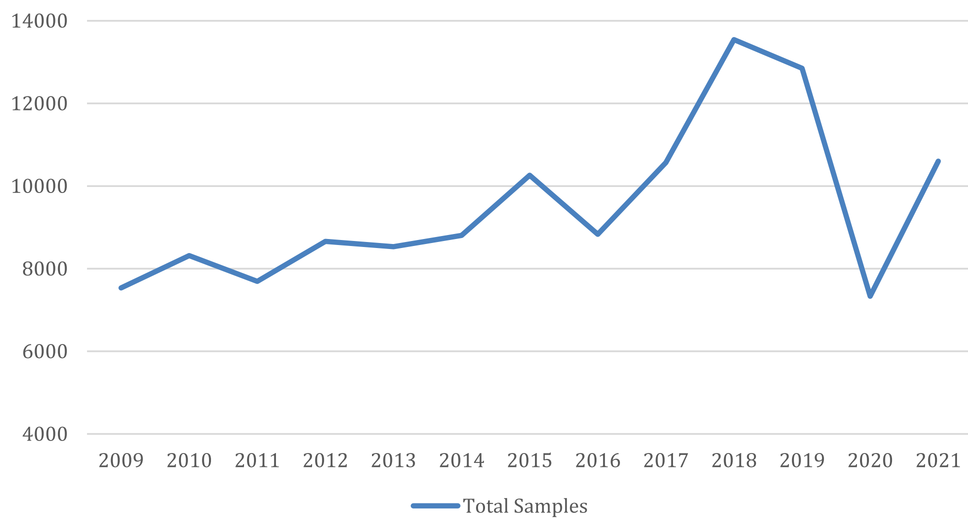

Figure 6. Number of doping samples collected in weightlifting between 2009 and 2021.

difference: 11.0, effect size: 0.69 and $p < 0.001$, mean difference: 6.8, rank biserial correlation 0.25, respectively), but not in the heavyweight group (Figure 4). In female senior weightlifters, a decrease in ST was found in the light ($p < 0.001$, mean difference: 10.8, effect size: 0.53), middle ($p < 0.001$, mean difference: 12.5, biserial rank correlation 0.37) and heavyweight groups ($p < 0.001$, mean difference: 11.7, rank biserial correlation 0.27) (Figure 5).

An analysis of WADA anti-doping testing figures reports shows a statistically significant increase in the total number of doping samples collected in weightlifting in recent years, with an average of 8,543 samples collected between 2009 and 2015 and 10,622 samples collected between 2016 and 2021, despite a decrease in samples collected in 2020 due to the COVID-19 pandemic ($p = 0.026$) (Figure 6) (Anti-Doping Testing Figures Report, 2023).

Discussion

Our analysis showed a significant decrease in the indicator of relative strength among weightlifters from various groups during 2016–2022 compared to 2009–2015. This decrease was observed in both male and female weightlifters. Further analysis by weight category and gender revealed a decrease in relative strength in five of the six weight groups in senior weightlifters. Among juniors, the decrease of results during 2016–2022 occurred among male juniors from the lightweight group and female juniors from the middle and heavyweight groups (i.e., from three categories out of six). Results of youth athletes showed no significant decrease. Therefore, our findings demonstrate a decline in the relative strength of weightlifters, especially among senior athletes.

The beginning of the first time period (2009) was selected as it coincided with the First World Youth Weightlifting Championship. Publications that described in detail new methods for detecting long-term metabolites of anabolic steroids and endogenous testosterone derivatives appeared in 2014 (Geyer et al., 2014). The start of the second time period (2016) was selected due to the time lag in obtaining information from advanced scientific research to most coaches and athletes. Thus, it can be assumed that 2015 may be the last year when the use of anabolic steroids and endogenous testosterone derivatives in sports was widespread. It should also be noted that the Olympic Games were held in 2016, before and during which the number of samples is traditionally higher than in other periods, while the samples are stored for up to 10 years to preserve the possibility of further analysis. This may also contribute to the lower use of the most banned substances in weightlifting than in previous years.

Previous studies have investigated the relationship between performance results analysis and anti-doping measures (Seiler et al., 2007). Iljukov et al. conducted a dedicated review of the influence of novel anti-doping measures on performance results, focusing on the implementation of the ABP in elite female runners from a country with a known high prevalence of doping. The study showed a clear decrease in the performance results of female runners in multiple distances associated with the use of ABP (Iljukov et al., 2020).

Our study is the first of its kind to focus on weightlifters. Doping, particularly the use of AAS, has been prevalent in weightlifting, potentially leading to exclusion from the Summer Olympics (LA28 Initial Sports Programme to be put forward to the IOC Session, 2023). The countries whose athletes were most often disqualified for doping were not allowed to participate in the World Weightlifting Championships (for example, Russia, Kazakhstan, Armenia, China and Egypt) (IWF Executive Board upholds decision related to Member Federations which have produced three or more retesting cases, 2023; Weightlifting - Doping positives need not be a negative, says top official, 2023). Thus, the widespread use of AAS in weightlifting, primarily exogenous anabolic steroids and endogenous testosterone derivation should come as no surprise. The positive effect of these substances on the hypertrophy of muscle fibres and the growth of strength indicators has been convincingly proven in several studies conducted both with the participation of humans and animals (Andrews et al., 2018; Skoupá et al., 2022).

In the present study, it may be reasonable to speculate that a combination of increased doping sample collection and implementation of novel methods led to a decrease in weightlifting performance. There is a statistically significant increase in the total number of doping samples collected in weightlifting in recent years as it showed in results section.

Another possible explanation for the observed decrease in performance results in our study is the implementation of novel anti-doping methods, such as long-term AAS metabolite identification, highly sensitive chromatographic/mass spectrometric techniques and ABP steroidal module implementation (Geyer et al., 2014; Saugy et al., 2014; Vernec, 2014). As previously mentioned, these methods have enabled anti-doping authorities to identify usage at lower concentrations for longer periods, or indirectly, even after elimination from the body. The existing scientific literature has previously described these methods, although it has shown that a certain amount of time is required for full implementation, including testing protocols, disciplinary actions and athlete behaviour change (Bezuglov et al., 2023; Geyer et al., 2014; Pitsiladis et al., 2017). The percentage decrease of AAS-positive ADRVs from 65% in 2009–2015 to 58% in 2016–2021 may support the notion of athletes changing their practices due to increased knowledge of new detection methods. The absence of a decline in performance results in the group of youth athletes may partly be explained by the low number of ADRV cases in this group (55 over 14 years), which may be due to the low prevalence of prohibited substance use (Anti-Doping Testing Figures Report, 2023).

It is important to note that the analysis of our results was conducted only using the official IWF website, without including the results of athletes who were disqualified for doping. Additionally, a significant number of disqualifications of athletes from major competitions occurred following a retrospective analysis of stored samples up to 10 years later. This was demonstrated by a study by Kolliari-Turner et al. that re-tested weightlifters' samples from the 2008 and 2012 Olympic Games and identified 94 positive samples, with AAS accounting for the majority of cases (Kolliari-Turner, Oliver, et al., 2021). Therefore, it is possible that some of the weightlifters included in the present study analysis may have their results cancelled, potentially contributing to an even greater decrease in the ST.

Furthermore, the number of doping tests required to obtain data for biological passports in the second analysed time period does not increase. In 2015, there were 495 samples (130 blood samples and 365 urine samples), while in 2020 and 2021 there were 281 such samples (41 blood samples and 240 urine samples) and 385 (86 blood samples and 299 urine samples), respectively (Anti-Doping Testing Figures Report, 2023). Thus, an increase in the number of samples used to compile biological passports cannot be regarded as a factor causing a decrease in sporting results. It is important to note that the total number of Athlete Biological Passport (ABP) samples in weightlifting is very low compared to other Olympic sports, at only 80 samples per year from 2010 to 2021 (Anti-Doping Testing Figures Report, 2023).

When analysing the possible reasons for the decline in the relative strength of weightlifters, it is important to consider other factors that may have contributed. These factors may include a decrease in the number of participants, restrictions and suspensions of leading weightlifting countries or the banning of certain techniques or technologies (known as technical doping). The official IWF website showed an increase in the number of participants in junior and senior categories but a decrease in the youth category, although there was no observed ST decrease in youth athletes in the present study (IWF events results, 2023). Secondly, restrictions were considered during the methodology planning phase, as the results of the 2017 World Weightlifting Championships were not included due to many previously successful athletes from nine different countries being banned from participating. No evidence was found regarding the prohibition of techniques or technologies, such as the clap skate in ice skating or racer swimsuits in swimming. Therefore, it may be assumed that the anti-doping measures were the main reason for the performance results decrease in weightlifting during the studied periods.

There are some limitations to our study that should be noted. First, there were two Olympic Games held during the second period (2016 and 2021), while only one was held in the first period (2012). As more samples are traditionally collected before and during the Olympics, athletes may be less likely to use doping during these periods due to a greater risk of detection and the world media surrounding such a prestigious competition. Second, different age categories are tested disproportionately, favouring older and higher-tier athletes. This results in a higher number of ADRVs in these more elite athletes, who tend to be older. Therefore, this could create a sample bias and does not fully provide a solid basis for making claims about differences in doping use by age. Future studies should investigate the impact of anti-doping measures on performance in other sports.

Conclusion

Overall, the present study highlights the importance of ongoing monitoring and analysis of the impact of anti-doping measures on athletic performance to ensure fairness and integrity in sporting competitions. The decrease in results in elite weightlifting may be partly due to the introduction of new methods for detecting prohibited substances, as well as the tightening of athlete monitoring procedures and many other policies. The effectiveness of anti-doping measures may be assessed via the results comparison before and after their implementation.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

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Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Georgiy Malyakin, Danila Telyshev and Eduard Bezuglov. The first draft of the manuscript was written by Eduard Bezuglov and Georgiy Malyakin. Critical revision was done by Oleg Talibov, Artemii Lazarev, Elizaveta Kapralova, Olga Sadkovaya and Ryland Morgans. The figures were created by Elizaveta Kapralova and Olga Sadkovaya. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Data availability statement

The datasets generated during and/or analysed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Local ethics committee approval was not required since publicly available data was utilised. The study was conducted according to the Helsinki declaration. The data were obtained from open access sources, therefore no informed consent for study participation was necessary.

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