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Russian Doping in Sports

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Abstract

Statistical data from the Independent Commission and the World Anti-Doping Agency (WADA) indicate that Russia is the worst violator of anti-doping rules. Multivariate statistical models find evidence that Russia performed unexpectedly well at the London Games, that the cross-country pattern of outperformance correlates with the number of abnormal athlete biological passports and anti–doping rule violations, and that Russian outperformance was not limited to track and field but extended to sports such as wrestling, where WADA has documented a pattern of significant violations.

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Reporter's question: "What is your guess, what do you think: How many athletes from the national team in Russia are doping?"

Evgenia Pecherina, world-ranked discus thrower: "Most of them. The greater part of 99% and you get absolutely anything. Everything the athletes wants. [sic] And the shorter the period it can be detected, the more expensive the product."

Evgenia Pecherina (regarding Grigory Rodchenkov, director of the WADA-accredited Moscow laboratory): "He knows how long, which drugs need to disappear from the body. He knows about it and instructs. He is the most important specialist."

—Independent Commission Investigation Report (2015, 115)

Doping—which the International Olympic Committee defined in 1963 as "an illegal procedure used by certain athletes in the form of drugs; physical means and exceptional measures which are used by small groups in a sporting community in order to alter positively or negatively the physical or psychological capacity of a living creature, man or animal in competitive sport"—is "as old as competitive sport itself," in the words of the World Anti-Doping Agency (WADA). In the modern Olympic movement, the first recorded use of a performance-enhancing drug (PED) was at the 1904 St. Louis Games, when American marathoner Thomas Hicks consumed a concoction that included strychnine before his race. A focusing event occurred at the 1960 Rome Games, when Danish cyclist Knut Jensen died after suffering a heatstroke after overdosing on Ronicol, a peripheral vasodilator known to enhance blood circulation, that had been administered to him by a team trainer. Since Jensen's death, the Olympic movement has struggled with the medical, legal, and organizational complexities of dealing with doping.[1]

The low point of this endeavor was the confirmation, following German unification, of long-held suspicions regarding the comprehensive system of doping administered by East German authorities, who began exploring the potential impact of PEDs in the 1950s, building on the scientific knowledge and practices developed during the Nazi period. In the 1960s the doping program came under the direct control of the Stasi (secret police). In 1974 the East German sports authorities initiated a systematic program of administering PEDs to athletes in all sports except sailing and women's gymnastics. This effort, involving more than 10,000 athletes, has been documented from files that became available after

1. Dimeo (2007, 55) offers a dissenting view of Jensen's death, noting that "while the evidence of usage has never been proven, Jensen's posthumous reputation continues to be sullied by those eager to use his body as proof of the health risks of doping, and by those whose retrospective accounts neatly see his death as the catalyst for an international anti-doping movement." He argues that "anti-doping was about social power and was based on a very specific Eurocentric, pseudo-religious morality linked with a romantic idealism about the function of sport in society" (6). This broad critique may have merit but is beyond the scope of this paper.

the unification of Germany; the authenticity of the documents has been upheld in various court cases (Franke and Berendonk 1997, Hunt 2011, Ungerleider 2013).

The program began in earnest with female competitors before the 1968 Mexico City Games. From 1972 on, most East German medalists were on PEDs, including most gold medal winners in swimming events from the 1976 Montreal Games on and all gold medals in throwing events at the 1988 Seoul Games.

The distortive effect of this program appears to have been especially great in women's competitions. The East German share of women's medals rose from 7 percent in 1968 (in Mexico City) to 33 percent in 1976 (in Montreal) to 39 percent in 1980 (in the boycott-marred Moscow Games). The last two performances are the largest shares ever recorded, topping the shares achieved by the Soviet Union or the United States in any other post–World War II Games.

Using multivariate statistical analysis, Noland and Stahler (2015b) conclude that at its peak, the East German doping program was responsible for 17 percent of the medals awarded to female athletes, equivalent to the total women's medal share that the Soviet and American teams each earned in 1972, the last year the Summer Games were not marred by widespread doping.

The disproportional impact on women reflected the greater efficacy PEDs had on female athletes; the shallower depth of competition in women's events, which meant that the enhanced competitive edge more readily translated into medals; and perhaps the more subservient position of women in society, which made them especially vulnerable to abuse. The doping of women proved particularly pernicious, contributing not only to health problems for them but also to high rates of birth defects among their children.

In part because of this experience, as well as scandals at the Tour de France, in 1999 the International Olympic Committee convened the First World Conference on Doping in Sport, which led to the establishment of the World Anti-Doping Agency (WADA) later that year. In response to whistleblower allegations of state-sponsored doping within the All-Russia Athletics Federation (ARAF) broadcast in a German television documentary, including allegations of improprieties in the WADA-accredited Moscow laboratory, WADA commissioned a report by an Independent Commission (IC).

The first part of that study was submitted to WADA in November 2015. It documents a system of widespread abuse, including but not limited to athletes and coaches paying for PEDs and false (clean) test results and delaying notification to international authorities of positive tests; acceptance of such payments by the head of the Moscow lab; presence of Federal Security Bureau (FSB) personnel within the lab, creating a climate of intimidation for lab staff and signaling direct state involvement; nonconforming practices by ARAF; and attitudes and behaviors exhibited by Ministry of Sports officials that at best might be described as demonstrating a lack of institutional control (Independent Commission 2015). The report discusses the cases of specific athletes, including some who medaled at the 2012 London Games and at various world championships.

The second part of the Independent Commission's report, released in January 2016, goes farther. It alleges criminal misconduct by ARAF officials and officials of the International Association of Athletic Federations (IAAF), the governing body of athletics. Officials of the IAAF, including its one-time president Lamine Diack, have been arrested and criminally charged in France.

This paper summarizes statistical data from the IC investigation and the most recent WADA Anti–Doping Rule Violations annual report. The data indicate that Russia is the most prominent violator of anti-doping rules and that these violations are not limited to the athletics category (which encompasses track and field), the subject of the television documentary and the IC investigation, but extend to other disciplines. Then multivariate statistical models presented indicate that the Russian team outperformed at the London Games; that the cross-country pattern of outperformance is correlated with the number of abnormal athlete biological passports and anti–doping rule violations; and that Russian outperformance was not limited to the athletics category but extended to sports such as wrestling, where WADA has documented a pattern of significant violations.

EVIDENCE ON ANTI–DOPING RULE VIOLATIONS

No method of detecting doping is foolproof; athletics federations have used a variety of techniques to try to detect cheating. Starting in 2009, WADA adopted the athlete biological passports (ABP), a multi-marker assessment used to define an individual's hematological profile as a baseline indicator. Excessive changes in the ABP can lead to the sanctioning of athletes for violations of anti-doping rules. Russian athletes have accounted for 35 percent of PED positive results since WADA began tracking the data in 2010 (figure 1).

The anti–doping rules violations (ADRVs) comprise a more inclusive set of test results and nonconforming infractions. In 2013, the most recent year for which data are available and the year following the London Games, Russia had the largest number of ADRVs, accounting for 12 percent of all violations (figure 2). It had the second-highest number of ADRVs in athletics, after Turkey (figure 3). The WADA data reveal significant dispersion in ADRVs across athletic disciplines, with only Russia, Turkey, and France making the top five in both total ADRVs and ADRVs in athletics.

Table 1 presents ADRV data for Russia by sport for 2012.[2] The largest number of violations was in athletics (42), but other sports, such as powerlifting (35), wrestling (32), weightlifting (26), and cycling (19), are also well represented.

2. The categorization used in table 1 and the categorization used by the International Olympic Committee are not identical. In particular, table 1 includes data on non-Olympic sports.

WADA reports data on a subset of these ADRVs (urine-based tests) by gender. Male athletes account for more ADRVs than female athletes, because of the high rates of male ADRVs in powerlifting, weightlifting, and wrestling. In athletics, violations by women competitors predominate.

Russia is the main source of ADRVs. The violations are not limited to athletics, the topic of the IC investigation, but occur frequently in other sports as well. In athletics most of the documented cases involve female athletes, as revealed by both the WADA data and the case studies of individual athletes documented in the IC report.

It is impossible to comprehensively model the impact of doping on outcomes—by its very nature the practice is concealed. Noland and Stahler (2015b) examine East German doping by estimating a baseline model and then interpreting an East German dummy variable for peak doping years as an implicit indicator of the doping program.

Table 2 reports Tobit regressions on a country's shares of total and women's Summer Games medals (the Tobit estimator is used because of the presence of a significant number of zero-valued dependent variable observations). Two specifications are reported. The first is for 1960–2012, the longest sample period for which a reasonably complete panel could be constructed. The second is for 1992–2012, a shorter period for which an extended set of regressors could be constructed.[3]

Consistent with prior research, the regressions indicate that medal success is correlated with country size and per capita income; average years of schooling (in the case of the female-specific regression, female schooling); status as a host or immediately past host country; membership in the Communist bloc; participation in competitions marked by significant boycotts; the female labor force participation rate; and a variable that captures the East German doping program.[4] In table 2 a dummy for the Russian team at the 2012 London Games is added. It is estimated to be positive and significant in all four regressions, indicating that Russia garnered about 4–5 percent more medals overall than would have otherwise been expected and about 4–6 percent more in women's events. These figures mean that Russia won three to four additional medals at the London Games—a nontrivial number (especially for the clean competitors cheated out of medals they would otherwise have won) but nothing close to the scale of the East German program.

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3. The data used in this paper are posted on the Peterson Institute website (http://www.piie.com/). For a detailed description of the dataset, including data sources, assumptions, and limitations, see the appendix in Noland and Stahler (2014).

4. Researchers have investigated the determinants of success at the Olympic Games by modeling medal counts primarily as a function of country size and income, host and socialist country advantage, socioeconomic indicators, and the impact of boycotts on the quality of competition (see, for example, Balmer, Nevill, and Williams 2001, 2003; Tcha and Pershin 2003; Bernard and Busse 2004; Hoffmann, Lee, and Ramasamy 2004; Klein 2004; Johnson and Ali 2004; Pfau 2006; Lui and Suen 2008; Andreff 2013; Leeds and Leeds 2014; Lowen, Deaner, and Schmitt 2014; Otamendi and Doncel 2014; and Noland and Stahler 2015a, 2015b).

An alternative way of analyzing the data would be to regress medal counts on abnormal ABPs and ADRVs. Table 3 reports Tobit estimates for percent medal shares at the London Games.[5] Use of the ABP data reported by WADA is a bit problematic, because the violations run from 2010 through 2015, meaning that some of the violations may have occurred well after the London Games. The ADRV data refer to results reported by WADA-accredited labs in 2013.

ABP violations and ADRVs are estimated to have statistically significant positive coefficients when entered singly, and ABP violations are still significant when the two series are entered jointly. Unsurprisingly, the coefficients on the more numerous and broadly defined ADRVs are estimated to be much smaller than the coefficients on ABP violations. Evaluated at the sample mean, the estimated coefficients imply that at the London Games, a country might have expected to win 0.6–0.8 additional medals for each ABP violation, or 0.02–0.07 additional medals per ADRV.

Like many cross-sectional regressions, the impacts implied by these coefficients seem high. Accepting that not all the ADRVs in table 1 are in Olympic events, 225 violations would translate into 4–16 additional medals, depending on which estimated coefficient is applied. If the ABP violations were assumed to have occurred uniformly over the sample period, applying the estimates to an implied annual incidence of abnormal ABPs would imply roughly three to four additional medals at the London Games, similar in magnitude to the outcomes implied by the regressions in table 2.

Table 4 extends these aggregate estimates to specific competitions, reporting gender-specific estimations of negative binomial models for the seven disciplines that awarded more than 50 medals at the London Games (aquatics, athletics, boxing, cycling, gymnastics, judo, and wrestling). Insofar as this approach uses nonnegative-count dependent variables, the dependent variable changes from medal shares to total medals won.

East German doping appears to have been relatively effective in women's aquatics and athletics but less so in other disciplines. Boycotts appear to have had particularly strong effects on the more objectively judged aquatics and athletics and less of an impact on the more subjectively judged gymnastics.

The Russian London Games dummy variable is statistically significant with a positive coefficient in 7 of 14 cases. Perhaps not surprisingly, the single largest positive coefficient is in female athletics, but there are some anomalies. The Russia dummy is estimated with a significant negative coefficient in two cases (men's cycling and women's judo) and is estimated to be significant and positive in two cases (women's gymnastics and women's wrestling), where there is no evidence of ADRVs around the time of the London Games (though doping could have occurred during the rest of the sample period). These results suggest

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5. The controls are similar to the ones used in table 2. The Communist bloc dummy was dropped, because it was statistically insignificant. This result is not surprising, insofar as membership in the Communist bloc was radically different in 2012 than it was for 1960–2012 (see Noland and Stahler 2015a).

that the dummy variables may be picking up effects not generated by doping, that doping occurred earlier but declined in recent years, and/or that there is doping that has gone undetected.

Table 5 moves away from the implicit approach of using dummy variables, reporting cross-sectional estimates for the 2012 London Games, with data on ADRVs included directly. Insofar as some ADRVs are not reported by gender, regressions were estimated for men only, women only, and men and women combined (that is, the ADRV data entered into the combined regressions are not the sum of the data in the male and female regressions but also include cases where the gender of the violator was not reported).

In just under half the regressions reported in table 5, ADRVs are associated with unusually successful medaling performances. For men and women combined, the ADRV share is estimated with a positive and significant coefficient in three of seven cases (cycling, wrestling, and gymnastics, in declining order of magnitude) and is insignificant otherwise.

When the data for men and women are separated, by far the largest significant coefficient is for women's athletics. Other significant coefficients (in declining order of magnitude) are men's cycling, men's wrestling, women's gymnastics, women's cycling, and men's aquatics. The result for women's gymnastics is worth commenting on, because there was only a single ADRV (Italy, which medaled in women's gymnastics). There is one negative significant coefficient estimate, for women's judo.

In sum, there is some evidence that the Russian national team performed beyond expectations at the 2012 London Games, particularly in women's athletics. A variety of modeling approaches document a broad correlation between the pattern of outperformance across athletic disciplines and ADRVs, which suggests that the models may be picking up some doping effects beyond the results documented for athletics by the IC. It is also possible that the regressions may be attributing to ADRVs other unobservable correlated factors. The underlying statistical models are admittedly crude, and the results reported may well not be robust to changes in specification or sample frame. They should therefore be interpreted as supplementary or suggestive rather than dispositive.

CONCLUSION

The IC investigation into Russian athletics documented the most systematic state-supported doping program since the East German program of the 1970s and 1980s. As in the East German program, female athletes appear to be a particular focus of intervention. One can only hope that these women do not experience the sorts of reproductive health problems and birth defects that their East German counterparts did. The data suggest that the Russian program extends beyond athletics into other sports not investigated by the IC.

The multivariate regressions yield evidence of Russian outperformance at the London Games (though nothing on the scale of East Germany in the 1970s and 1980s), cross-country correlations between abnormal ABPs and ADRVs and medaling, and some correlation between event-specific medaling performance and documented ADRVs. The specific numerical results may be sensitive to changes in the specification or sample frame and should be interpreted as suggestive rather than dispositive.

In response to the IC investigation, Grigory Rodchenkov stepped down as head of the Moscow lab. The IAAF, the governing body of athletics, took the unprecedented action of suspending Russia from all IAAF-sanctioned competitions, potentially including the 2016 Rio Summer Olympic Games, until ARAF can demonstrate that its athletes are competing cleanly. The IAAF suspension of the head of Athletics Kenya, the Kenyan athletic governing body, and two of his senior colleagues show that the problem is not limited to Russia. The second IC report and subsequent arrests in France point to fundamental corruption at the highest levels of the IAAF. As the results reported in this paper indicate, these problems are not limited to athletics.

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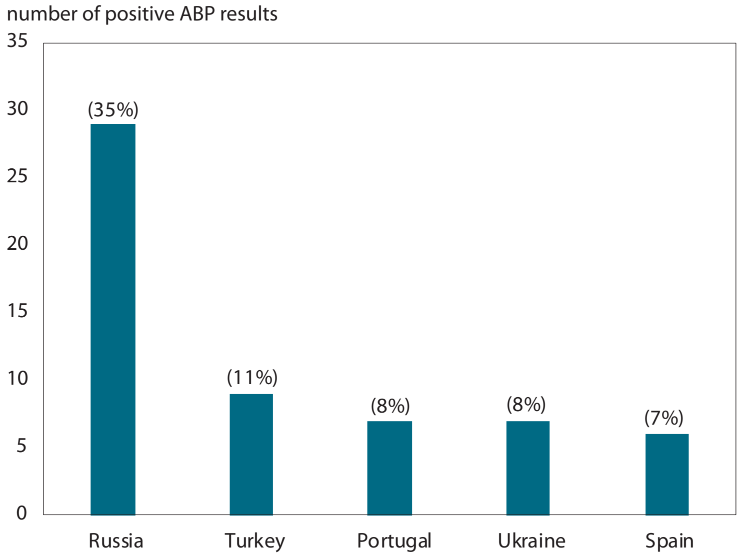
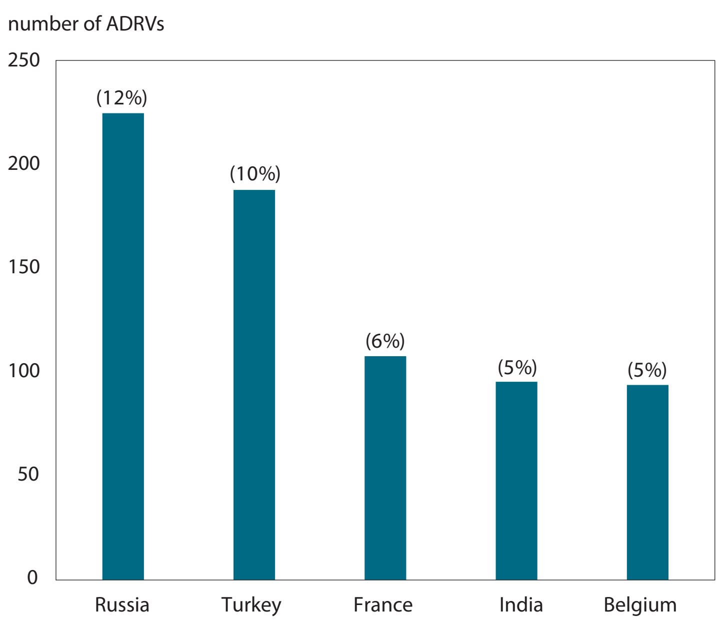
Figure 1 Positive athlete biological passport (ABP) results in top five countries since 2010



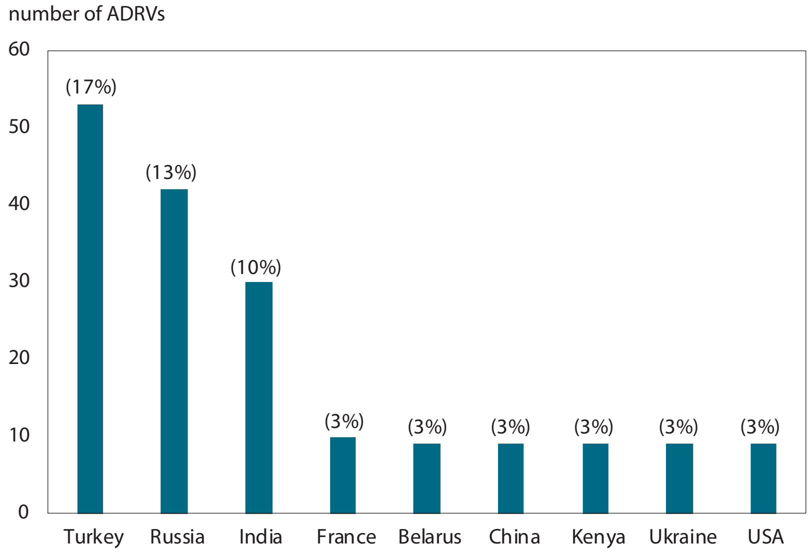
Note: Percent of total in parentheses.
Source: Independent Commission (2015).

Figure 2 Total number of anti–doping rule violations (ADRVs) in top five countries, 2013



Note: Percent of total in parentheses.
Source: WADA (2013, table 9).

Figure 3 Number of anti–doping rule violations (ADRVs) in athletics (track and field), 2013



Note: Percent of total in parentheses; six countries tie at 9 ADRVs.
Source: WADA (2013, table 9).

Table 1 Anti–doping rule violations (ADRVs) by Russia, by sport, 2012

Sport	Urine-based violations: Out of competition, Women	Out of competition, Men	In competition, Women	In competition, Men	Total ADRVs
Aquatics	1	1	5	6	14
Athletics	8	5	15	8	42
Biathlon				2	2
Boxing		1			1
Canoeing/kayaking			1	5	6
Cycling	2	3	3	10	19
Dance sport				1	1
Equestrian			1		1
Fencing			1		1
Ice hockey				3	3
Judo		1	1	3	5
Kettlebell lifting			2		2
Kickboxing		1	1		2
Kurash			1	4	5
Luge				1	1
Orienteering			1		1
Powerlifting	4	13	1	17	35
Rowing			1		1
Rugby					1
Sambo	1			3	4
Savate				1	1
Shooting			2	2	4
Skating				1	1
Skiing				1	2
Sport climbing			1		1
Tennis				1	1
Underwater sports			1	1	2
Weightlifting		5	8	13	26
Wrestling		6		23	32
Wushu			1	7	8
Total	16	36	47	113	225

Note: Gender-specific urine-based tests do not sum to total ADRVs because of unreported categories.

Source: WADA (2013, table 9).

Table 2 Tobit regressions on total and women's Olympic medal shares, 1960–2012 and 1992–2012

	Total Olympic medal share		Women's Olympic medal share	
Variable	**1960–2012**	**1992–2012**	**1960–2012**	**1992–2012**
Log of GDP per capita	0.451***	0.415***	0.490**	0.519***
	(0.105)	(0.0982)	(0.230)	(0.144)
Log of population	1.199***	0.868***	2.107***	1.334***
	(0.101)	(0.082)	(0.189)	(0.117)
Current host	5.029***	4.026***	5.199***	3.860***
	(1.688)	(0.8218)	(1.639)	(0.922)
Host of previous Olympics	1.789***	2.126**	1.125	2.268***
	(0.587)	(0.919)	(0.694)	(0.768)
Communist bloc	2.759***	1.214***	5.031***	2.141***
	(0.428)	(0.440)	(0.647)	(0.626)
Average total years schooling	0.646***	0.434***		
	(0.0676)	(0.0578)		
East Germany dummy	2.533		9.136	
	(2.352)		(5.839)	
Doping dummy	8.706***		17.41**	
	(2.653)		(6.801)	
Boycott dummy	2.151***		3.159***	
	(0.402)		(0.852)	
Russia 2012 dummy	4.249***	4.989***	4.453***	6.255***
	(0.362)	(0.321)	(0.612)	(0.426)
Labor ratio		0.0168***		0.0367***
		(0.00398)		(0.00827)
Average years schooling (girls)			1.272***	0.585***
			(0.142)	(0.0803)
Constant	–29.83***	–22.92***	–52.43***	–35.04***
	(2.321)	(1.970)	(4.620)	(2.971)
Number of observations	1,446	644	1,170	614

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Note: Robust standard errors in parentheses. Time controls are included.

Source: Author's calculations.

Table 3 Tobit regression results on anti-doping rule and athlete biological passport violations at 2012 London Games

	2012	2012	2012	2012
Independent variable	**(1)**	**(2)**	**(3)**	**(4)**
Log of GDP per capita	0.242	0.123	0.206	0.139
	(0.203)	(0.212)	(0.202)	(0.213)
Lop of population	0.625***	0.554***	0.592***	0.560***
	(0.183)	(0.199)	(0.197)	(0.188)
Current host	4.959***	5.158***	5.031***	5.046***
	(0.381)	(0.407)	(0.402)	(0.380)
Host of previous Olympics	6.276***	6.451***	6.370***	6.348***
	(0.727)	(0.764)	(0.759)	(0.722)
Athlete biological passport (ABP) violations	0.169***		0.138***	
	(0.0321)		(0.0455)	
Average total years schooling	0.486***	0.516***	0.488***	0.528***
	(0.137)	(0.142)	(0.137)	(0.142)
Anti–doping rule violations (ADRVs)		0.0154**	0.00439	
		(0.00728)	(0.00646)	
Share of total ADRV violations				0.276*
				(0.140)
Constant	–16.69***	–14.88***	–15.90***	–15.22***
	(4.590)	(4.845)	(4.877)	(4.567)

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Note: The dependent variable is total medal shares. ABP violations are violations that occurred in 2010–15. ADRVs are violations that occurred in 2013. The share of total ADRV violations is a percent of total violations. Robust standard errors in parentheses. The number of observations is 124.

S*ource:* Author's calculations.

Table 4 Determinants of success at the Summer Games, by sport, 1960–2012

Sport/gender	Log, GDP per capita	Log, population	Current host	Host of previous Olympics	Average years schooling	Communist bloc	East German doping dummy	Russia 2012 dummy	Boycott	Constant	Number of observations
Aquatics (men)	0.743***	0.825***	0.727*	0.519	0.458***	0.645***	0.800**	0.422	1.430***	–26.69***	939
Aquatics (women)	0.273	0.799***	0.743*	0.324	0.577***	0.898***	3.205***	0.217	1.568***	–22.92***	765
Athletics (men)	0.0529	0.460***	0.724***	0.453**	0.276***	0.392*	1.771***	–0.230	0.746*	–11.44***	1,309
Athletics (women)	–0.172	0.473***	0.968**	0.583	0.423***	1.241***	2.720***	2.132***	1.355***	–11.50***	1,020
Boxing (men)	–0.0118	0.330***	1.201***	0.739**	0.250***	1.560***	0.201	1.139***	0.864**	–8.775***	851
Boxing (women)	–0.617	0.563**	1.155*	0.338	0.342**	—	—	0.346	—	–8.506***	20
Cycling (men)	2.000***	0.512***	0.994**	0.667	0.0502	1.103***	1.542***	–22.27***	0.583	–29.43***	654
Cycling (women)	1.029***	0.487***	0.357	0.225	0.197**	0.826	1.428*	1.121***	–0.881	–21.23***	248
Gymnastics (men)	–0.509***	0.776***	0.927***	0.674	0.414***	0.247	2.167***	0.352	0.737	–14.03***	351
Gymnastics (women)	–1.810***	0.485***	1.141**	0.319	1.031***	3.127***	1.277**	1.572***	0.862	–3.732	380
Judo (men)	0.174	0.576***	–0.166	–0.581	0.320***	0.24	0.776	1.480***	1.511***	–16.03***	637
Judo (women)	0.891***	0.371***	–0.00206	–0.543	0.222***	3.144***	—	–17.02***	—	–17.94***	276
Wrestling (men)	–0.169	0.389***	0.583	0.242	0.279***	1.359***	–0.929***	1.747***	1.182***	–8.568***	643
Wrestling (women)	0.0905	0.379***	–0.138	–0.268	0.280**	0.610	—	0.863**	—	–11.31***	78

— = Omitted because results were undefined or perfectly collinear.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Note: Negative binominal models are estimated. Time controls are included. Gender-specific average years of schooling variables are used. For women's boxing, women's judo, and women's wrestling, the East German doping dummy and boycott dummy were omitted because these sports were introduced at the Olympics only recently. Women's boxing has the fewest observations, because it became an Olympic sport only in 2012. The women's boxing Communist bloc dummy was omitted because of collinearity with the previous host variable.

Source: Author's calculations.

Table 5 Determinants of success at the 2012 London Games, by sport

Sport/gender	Log, GDP per capita	Log, population	Current host	Host of previous Olympics	Average years of schooling	Share of ADRVs	Constant	Number of observations
Aquatics (men and women)	0.697	0.874***	0.799**	0.787	0.501***	0.034	–26.93***	115
Aquatics (men)	0.776*	0.834***	0.802*	0.19	0.357**	0.0419*	–26.14***	100
Aquatics (women)	1.341***	0.957***	0.149	1.246	0.524**	0.0221	–35.45***	97
Athletics (men and women)	–0.324	0.114	2.585***	1.502*	0.459**	0.316	–3.963	124
Athletics (men)	0.126	–0.0124	2.601***	1.507**	0.263	0.424	–4.636	122
Athletics (women)	–1.181**	0.478***	2.395***	1.564*	0.816***	0.153***	–6.619*	122
Boxing (men and women)	–0.627	0.535***	2.338***	0.655	0.624***	0.0519	–10.38**	86
Boxing (men)	–0.221	0.211	2.343**	0.386	0.531**	0.0476	–7.627	62
Boxing (women)	–0.802*	0.536**	1.373**	0.771	0.474**	0.00979	–7.714***	20
Cycling (men and women)	1.197***	0.323	2.750***	2.147	0.439*	0.107*	–22.48***	79
Cycling (men)	1.056**	0.0626	2.870***	–21.00***	0.267	0.0973*	–15.30**	58
Cycling (women)	1.715**	0.393**	2.127***	2.728	0.315	0.0453*	–28.03***	40
Gymnastics (men and women)	–1.459***	1.042***	3.945***	1.927***	1.128***	0.0576***	–17.38***	74
Gymnastics (men)	–0.477	0.759***	2.849***	1.057	0.509***	—	–15.18***	42
Gymnastics (women)	–3.192***	1.135***	4.405***	3.322**	1.629***	0.0493***	–9.068	44
Judo (men and women)	–0.404	0.867***	1.312*	–0.735	0.702***	–0.0396	–18.84***	103
Judo (men)	–0.887	0.763***	–18.19***	–21.15***	0.822***	–0.00572	–14.50*	78
Judo (women)	0.339	0.723***	0.656	0.411	0.207	–0.141*	–18.45**	49
Wrestling (men and women)	–0.297	0.455***	–19.22***	–0.312	0.512***	0.0700***	–10.92***	81
Wrestling (men)	–0.238	0.328*	—	–27.44***	0.417***	0.0600***	–8.377***	48
Wrestling (women)	–0.226	0.223	–21.24***	1.221	0.426**	–0.0186	–6.938	34

ADRVs = anti–doping rules violations

— = Omitted because results were undefined or perfectly collinear.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Note: Negative binominal models are estimated. Time controls are included. The "share of ADRVs" variable uses separate variables for the share of ADRVs for each gender and sport. Gender-specific average years schooling variables were used. Men's gymnastics had just one ADRV, by Belarus, which fielded no athletes in the London Games. The host (Britain) fielded no athletes in men's wrestling.

Source: Author's calculations.