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Review article

The global epidemiology of anabolic-androgenic steroid use: a meta-analysis and meta-regression analysis

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A B S T R A C T

Purpose: To estimate the global lifetime prevalence rate of anabolic-androgenic steroid (AAS) use and investigate moderators of the prevalence rate.
Methods: A meta-analysis and meta-regression analysis was performed using studies gathered from searches in PsycINFO, PubMed, ISI Web of Science, and Google Scholar among others. Included were 187 studies that provided original data on 271 lifetime prevalence rates. Studies were coded for publication year, region, sample type, age range, sample size, assessment method, and sampling method. Heterogeneity was assessed by the I^2 index and the Q-statistic. Random effect-size modeling was used. Subgroup comparisons were conducted using Bonferroni correction.
Results: The global lifetime prevalence rate obtained was 3.3% (95% confidence interval [CI], 2.8–3.8; $I^2 = 99.7$, $P < .001$). The prevalence rate for males, 6.4% (95% CI, 5.3–7.7, $I^2 = 99.2$, $P < .001$), was significantly higher ($Q_{bet} = 100.1$, $P < .001$) than the rate for females, 1.6% (95% CI, 1.3–1.9, $I^2 = 96.8$, $P < .001$). Sample type (athletes), assessment method (interviews only and interviews and questionnaires), sampling method, and male sample percentage were significant predictors of AAS use prevalence. There was no indication of publication bias.
Conclusion: Nonmedical AAS use is a serious widespread public health problem.

Introduction

Anabolic-androgenic steroids (AAS) are a group of hormones that include the natural male hormone, testosterone, together with a set of synthetic testosterone used clinically to treat several conditions such as reproductive system dysfunction, breast cancer, and anemia. AAS have, however, been used by some healthy men and more rarely by women, to gain muscle and lose body fat [1]. Nonmedical AAS use was primarily confined to elite athletes and bodybuilders in the 1960s who used it as a means to enhance performance [2]. In the last three decades, however, AAS use has spread into the general population [3]. Presently, AAS are been used worldwide by millions of men, many of whom having no athletic ambitions, wishing to increase and improve their physical strength and appearance [4–6]. Indeed, it has been suggested that elite athletes comprise the smallest group of AAS users [7] with higher levels of use occurring among such groups as recreational sportspeople [8] and those who use AAS for either occupational or aesthetic purposes [7,9].

In the short-term, AAS use seems to have few serious medical consequences, but in the long-term, it has generally been associated with several debilitating physical and psychological symptoms and increased mortality [3,7,10–14]. Before 1990, most prevalence studies of AAS use were conducted in North America [6]. However, more recent studies of the AAS epidemiology have been conducted outside North America [11,15–21].

In spite of this, the worldwide prevalence of AAS use is poorly documented, and geographical distribution of studies concerning AAS use is mostly limited to the USA, Canada, Brazil, and some European countries [15]. In addition, although literature abounds on AAS use, no quantitative meta-analysis has been conducted on the global prevalence rate of AAS use. An analysis of this type is important because it can also be used to identify moderators of the prevalence rate. Against this backdrop, we conducted a meta-analysis on the global lifetime prevalence of AAS use. In addition to calculating an overall prevalence figure, we compared prevalence rates across sample type, gender, age, region, assessment method,

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sampling method, and publication year. Furthermore, we conducted a meta-regression analysis to investigate the predictive effect of the above study characteristics on the overall lifetime prevalence rate of AAS use.

Methods

Search strategy and inclusion criteria

A systematic and comprehensive literature search was conducted in PsycINFO, PubMed, ISI Web of Science, and Google Scholar for articles published between 1970 and July 2013. The following keywords: "anabol*," "steroid*," and "doping" were each used in combination with "preval*," "epidem*," and "incidence" for the search.

From an initial pool of 16,626 hits, 311 full-text articles were retrieved for further evaluation. After screening the 311 full-text articles for eligibility, 162 studies met the following key criteria for inclusion: (a) studies were published between 1970 and July 2013 (b) studies presented original data on the lifetime prevalence rate of AAS use, and (c) studies were published in English. Also, a manual check of the references of identified studies was conducted in search of potential unidentified studies. Searches were also conducted in online databases and Web sites for data on lifetime prevalence rates of AAS use in general population or household surveys, school surveys, government reports, and regional reports. Twenty-five new articles were identified through this grey literature search. Thus, a total of 187 articles were identified in the literature search.

Moreover, we were guided by the strategy of Calabria et al. [216, pg. 9] that "if data from a representative National study existed for a country, data from a study with a similar methodology and target age group were not included. In the United States, for example, the Monitoring the Future Continuing Study has provided extensive National survey results on American youth from 1975 to 2006. These National surveys cover the Global Burden of Disease target years, and therefore, studies that provided data for a similar population were not extracted. This decision was made to (a) avoid unnecessary duplicate year extractions and (b) address time restrictions." Hence, in the United States and related countries, we relied solely on the Monitoring the Future Surveys [181,182] as representative of similar National surveys of AAS use among adolescents and youth. For European adolescents, we relied on the European School Survey Project on Alcohol and Other Drugs (ESPAD), a cross-national survey (of about 35 countries) conducted every fourth year since 1995 [162–166]. The literature search strategy adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [33] and followed the recommendation of the Meta-analysis of Observational Studies in Epidemiology (MOOSE) group [34]. Figure 1 presents the process of the search and selection of relevant studies.

Description of studies

Of the 187 articles identified, 16 articles [21,75,88,104,133,146,168,171,173,174,176,181–183,199,200] presented prevalence rates of AAS use for 84 other original studies. Thus, a total of 271 separate studies were identified which provided data on lifetime prevalence rates of AAS use. The year of publication of the studies ranged from 1974 [217] to 2013 [23,24,37,76,167,169,172,181,182,207]. Most studies were conducted in Western countries: North America ($n = 126$), Europe ($n = 81$), and Oceania ($n = 38$), although 11 studies were conducted in Africa, seven in the Middle East, five in South America,

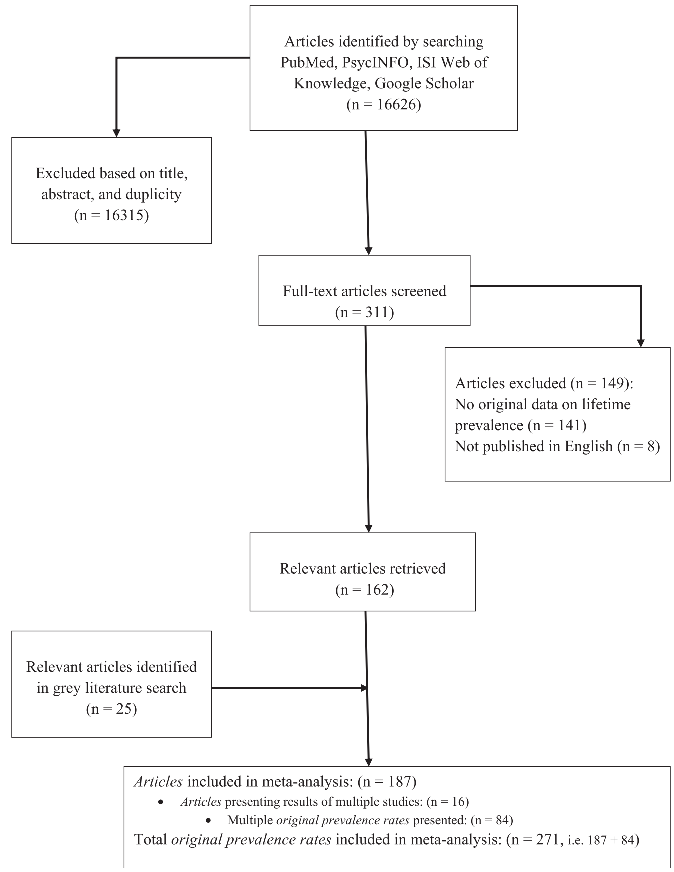

Fig. 1. Flow diagram of systematic literature search on lifetime prevalence of AAS use.

and one in Asia. Two studies were transregional [154,155]. The study characteristics are presented in Table 1.

Data extraction and publication bias

During the literature search, the first author independently scrutinized and selected studies based on their titles, abstracts, and subject matter. Using a standardized data extraction form, the first author and another reviewer independently extracted data from the identified studies and coded them for potential moderators. Data extracted and coded included author name and publication year, country, and region of research, type of sample (prisoners and arrestees, recreational sportspeople, athletes, drug users, non-athletes, and high school), assessment method (questionnaires, interview, or both), sampling method (random or nonrandom), sample size (total, male, and female), age of participants (range, mean, and standard deviation), response rate, and lifetime prevalence rate of AAS use reported (male, female, and overall). To determine consistency between the two reviewers, an interrater reliability analysis using the Kappa statistic was performed in SPSS, version 20. The inter-reviewer reliability for the reviewers was found to be kappa = 0.854 ($P < .001$) indicating an almost perfect agreement between the two reviewers [25]. Discrepant findings between the two reviewers were settled through discussion and further review of the article until consensus was reached.

A final table of all studies is presented in Table 1. Publication bias was assessed visually by funnel plot and statistically by the trim and fill procedure [26] in Comprehensive Meta-Analysis version 2.0 (Biostat, Inc.) [27]. Under the random effects model, the point estimate and 95% confidence interval for the combined studies was

Table 1
Characteristics of studies on the lifetime prevalence of AAS use

First author, year, reference	Country	Sample type	Assessment method	Sampling method	N	Sample size (male)	Sample size (female)	Age range (y)	Age mean	Age SD	Prevalence (male) %	Prevalence (female) %	Prevalence (overall) %	Response rate %
Africa														
Afolayan, 2012 [57]	Nigeria	Athletes	Q	R	220	135	85	—	—	—	—	—	5.45	—
Ama, 2003 [58]	Cameroon	Footballers	Q	R	1116	1037	79	—	21	1	0	0	0	74.4
Gradidge, 2011 [18]	South Africa	High-school athletes	Q	R	100	100	—	17–18[*]	—	—	4	—	4	81
Lambert, 1998 [56]	South Africa	High school	Q	R	2772	1396	1376	16–18	—	—	2.82	0.07	1.44	—
Makanjuola, 2007 [59]	Nigeria	Long distance vehicle drivers	I	NR	69	69	—	27–65	44	0.4	34.8	—	34.8	72.6
Molobe, 2012 [60]	Nigeria	Athletes	Q	R	345	208	137	21–30[*]	—	0.9	—	—	5.6	—
Ohaeri, 1993 [61]	Nigeria	Athletes	Q	R	250	181	69	17–40	24.6	4.9	—	—	1.2	83.3
Oshikoya, 2006 [62]	Nigeria	University	Q	R	807	427	374	19–30[*]	—	—	0	0	0	80.7
Rocha-Silva, 1996 [43]	South Africa	Youth	Q	R	1376	—	—	10–21	—	—	—	—	2	—
Sagoe, in press [37]	Ghana	High school	Q	R	2597	1146	1412	11–35	17.2	1.4	4.9	3.1	3.8	96.8
Schwellnus, 1992 [63]	South Africa	High school	Q	R	1361	683	678	—	—	—	1.2	0	0.6	—
Asia														
Yang, 2009 [49] and Kanayama, 2012 [65]	China	University	Q	R	221	118	103	21–38	—	—	0	—	0	—
Europe														
Agathangelou, 2010 [218]	Cyprus	Gym users	Q	NR	100	100	—	18–30	—	—	18	—	18	—
Andersson, 2007 [162]	7 countries	High school	Q	R	19,206	8899	10,307	17–18	17.8	—	2.9	0.4	1.6	86
Anton, 2011 [71]	Spain, Portugal, Italy	University adolescents	Q	R	115	64	51	18–20	—	—	6.25	0	3.4	79.9
Baker, 2008 [8]	UK	Gym users	Q	R	146	136	10	15–72	33.6	6.7	—	—	70	69.5
Bolding, 2002 [72]	UK	Gay gym users	Q	NR	772	772	—	—	—	—	15.2	—	15.2	52
Goltsos, 2012 [73]	Greece	High-school athletes	Q	R	2535	1182	1353	—	—	—	9.6	3.7	6.65	97.5
Grace, 2001 [40]	UK	Gym users	Q	R	106	97	9	15–58[†]	32.4[†]	7.5[†]	58	0	53	63
Gårevik, 2010 [74]	Sweden	Arrested drug users	I	NR	56	—	—	—	30[†]	7.4[†]	—	—	81	—
Hakansson, 2012 [19]	Sweden	General	Q	R	21,211	14,160	7051	15–64	29	—	1.7	0.3	1.7	32
Hibell, 2012 [163]	36 countries	High school	Q	R	10,3076	50,178	52,898	15–16	15.8	—	2	1	1	93
Hibell, 2007 [164]	35 countries	High school	Q	R	104,828	51,249	53,579	15–16	15.8	—	2	1	1	87
Hibell, 2004 [165]	35 countries	High school	Q	R	102,946	50,192	52,754	15–16	15.8	—	2	1	1	87
Hibell, 2000 [166]	30 countries	High school	Q	R	91,773	42,511	49,262	15–16	—	—	2	1	1	88
Hope, 2013 [167]	England and Wales	Injecting drug users	I	NR	395	395	—	—	—	—	86	—	86	—
Keene, 1997 [168]	Wales	Prisoners	Q	NR	134	134	—	—	—	—	5	—	5	50
Keene, 1997 [168]	Wales	Ex-prisoners	Q	NR	119	119	—	—	—	—	12	—	12	70
Kindlundh, 1998 [32]	Sweden	High school	Q	R	2742	1353	1364	16–19	—	—	1.7	0.1	0.9	80.8
Klötz, 2010 [50]	Sweden	Prison	I	NR	59	59	—	21–52[†]	30.1[†]	6.5[†]	55.9	—	55.9	50
Kokkevi, 2008 [75]	Bulgaria	High school	Q	R	5391	—	—	16	—	—	4.0	0.7	2.2	—
Kokkevi, 2008 [75]	Cyprus	High school	Q	R	2095	—	—	16	—	—	4.5	0.5	2.3	—
Kokkevi, 2008 [75]	Greece	High school	Q	R	2259	—	—	16	—	—	3.2	1.2	2.0	—
Kokkevi, 2008 [75]	UK	High school	Q	R	2641	—	—	16	—	—	2.2	1.7	2.0	—
Kokkevi, 2008 [75]	Slovakia	High school	Q	R	2442	—	—	16	—	—	2.5	0.2	1.2	—
Kokkevi, 2008 [75]	Croatia	High school	Q	R	3602	—	—	16	—	—	4.4	2.4	3.5	—
Korkia, 1994 [76]	UK	Gym users	Q	NR	1659	1310	349	17–56	—	—	6	1.4	7.65	59
Korkia, 1997 [77]	UK	Gym users	Q	R	1667	1310	349	—	—	—	9.1	2.3	8	59
Korte, 1998 [78]	Finland	Prison	Q	R	354	354	—	18–76	32	10	9.6	—	9.6	82.5
Kyselovicova, 2008 [79]	Slovakia	Gym users	Q	R	64	64	—	—	21.6	3.4	21	—	21	80
Laure, 2004 [81]	France	High school	Q	R	1459	846	613	—	16.6	1.7	—	—	10	60
Laure, 2007 [80]	France	High school athletes	Q	R	3594	1912	1682	—	11.2	0.6	—	—	10.2	—
Leifman, 2011 [82]	Sweden	Gym users	Q	R	1752	1183	563	16–49[*]	33	—	3.9	0.2	2.05	91.1
Lindström, 1990 [83]	Sweden	Bodybuilders	Q	NR	171	138	33	15+	25	—	38.4	9.09	32.7	90
Lindqvist, 2013 [169]	Sweden	Former athletes	Q	NR	683	683	—	39–82	57	—	21	—	21	68.6

(*continued on next page*)

Table 1 (*continued*)

First author, year, reference	Country	Sample type	Assessment method	Sampling method	*N*	Sample size (male)	Sample size (female)	Age range (y)	Age mean	Age SD	Prevalence (male) %	Prevalence (female) %	Prevalence (overall) %	Response rate %
Ljungqvist, 1975 [22]	Sweden	Athletes	Q	NR	99	—	—	—	—	—	—	—	31	69
Lundholm, 2010 [84]	Sweden	Prison	I	NR	3597	3201	396	—	—	—	28.1	5	26	—
Mattila, 2009 [178]	Finland	Adolescents	Q	R	22519	—	—	12–18	—	—	0.5	0.2	0.3	—
Mattila, 2010 [85]	Finland	Military conscripts	Q	NR	10,396	10,396	—	18–29	—	—	0.9	—	0.9	96
McKillop, 1987 [86]	UK	Bodybuilders	I	NR	41	41	—	17–32	23	—	19.5	—	19.5	—
McVeigh, 2003 [170]	UK	Injecting drug users	I	NR	14,491	—	—	—	—	—	—	—	44	—
NACD, 2012 [171]	Northern Ireland	General	Q	R	2535	1163	1372	15–64	—	—	1.9	0.9	1.4	—
NACD, 2012 [171]	Northern Ireland	General	Q	R	2002	893	1109	15–64	—	—	0.9	1.0	1.0	—
NACD, 2012 [171]	Northern Ireland	General	Q	R	3516	1575	1941	15–64	—	—	0.7	0.8	0.7	—
Nilsson, 1995 [159]	Sweden	High school	Q	R	1383	688	695	14–19	—	—	5.8	1.0	3.4	96
Nilsson, 2001 [87]	Sweden	Adolescents	Q	R	5827	—	—	16–17	—	—	2.9	0	1.4	95
Nilsson, 2001 [88]	Sweden	Adolescents	Q	R	345	345	—	16–17	—	—	8.7	—	8.7	96
Nilsson, 2001 [88]	Sweden	Adolescents	Q	R	451	451	—	16–17	—		5.76	—	5.76	—
Nilsson, 2005 [89]	Sweden	High school	Q	R	4049	4049	—	14–18	—	—	1.2	—	1.2	92.7
Nøkleby, 2013 [76]	Norway	Drug users	Q	NR	109	79	30	17–50	—	—	40.5	20	35	
Pallesen, 2006 [11]	Norway	High school	Q	R	1351	703	642	—	17.5	2.2	3.6	0.6	2.1	69.8
Perry, 1992 [91]	UK	Gym users	Q	NR	160	—	—	≤39*	—	—	—	—	38.8	53.3
Posiadala, 2010 [92]	Poland	Recreational sportspeople	I	NR	50	50	—	21–45	—	—	36	—	36	—
Rachoń, 2006 [20]	Poland	Adolescent and youth athletes	Q	NR	3233	—	—	13–37*	—	—	6.2	2.9	4.6	87.7
Sagoe [172]	Norway	Adolescents	Q	R	2055	963	1088	17	17	0	0.52	0.09	0.30	70.4
Sas-Nowosielski, 2006 [93]	Poland	High school	Q	R	1175	597	578	15–22	16.75	1.43	9.38	2.08	5.79	—
Scottish Government, 2012 [173]	Scotland	General	I and Q	R	10,999	4737	6262	16+	—	—	—	—	0.3	85
Scottish Government, 2012 [173]	Scotland	General	I and Q	R	10,974	4813	6161	16+	—	—	—	—	0.5	69
Scottish Government, 2012 [173]	Scotland	General	I and Q	R	13,418	5913	7506	16+	—	—	—	—	0.4	84
Singhammer, 2013 [23]	Denmark	Recreational sportspeople	Q	R	5010	2006	3004	15–60	—	—	—	—	1.8	—
Smith, 2011 [174]	England and Wales	General	Q	R	27,327	—	—	16–59	—	—	—	—	0.6	—
Smith, 2011 [174]	England and Wales	General	Q	R	26,199	—	—	16–59	—	—	—	—	0.7	—
Smith, 2011 [174]	England and Wales	General	Q	R	28,407	—	—	16–59	—	—	—	—	0.6	—
Smith, 2011 [174]	England and Wales	General	Q	R	28,500	—	—	16–59	—	—	—	—	0.6	—
Smith, 2011 [174]	England and Wales	General	Q	R	28,975	—	—	16–59	—	—	—	—	0.6	—
Smith, 2011 [174]	England and Wales	General	Q	R	29,748	—	—	16–59	—	—	—	—	0.6	—
Smith, 2011 [174]	England and Wales	General	Q	R	28,330	—	—	16–59	—	—	—	—	0.5	—
Smith, 2011 [174]	England and Wales	General	Q	R	24,296	—	—	16–59	—	—	—	—	0.6	—
Smith, 2011 [174]	England and Wales	General	Q	R	23,331	—	—	16–59	—	—	—	—	0.5	—
Smith, 2011 [174]	England and Wales	General	Q	R	20,051	—	—	16–59	—	—	—	—	0.6	—
Smith, 2011 [174]	England and Wales	General	Q	R	12,852	—	—	16–59	—	—	—	—	1.0	—
Smith, 2011 [174]	England and Wales	General	Q	R	9884	—	—	16–59	—	—	—	—	1.1	—
Smith, 2011 [174]	England and Wales	General	Q	R	10,813	—	—	16–59	—	—	—	—	1.1	—
Solberg [217]	Norway	Weightlifters	Q	NR	25	25	—	—	—	—	24	—	24	
Striegel, 2006 [41]	Germany	Gym users	Q	R	621	390	231	—	33.7	10.6	19.2	3.9	13.5	34.5
Thorlindsson, 2010 [94]	Iceland	High school	Q	R	10,918	5195	5585	15–24	17.7	1.84	1.6	0.2	0.9	—
Wanjek, 2007 [34]	Germany	High school	Q	R	2313	1071	1229	>12	15.8	2.2	0.5	0.9	0.7	76
Wichstrøm, 2001 [96]	Norway	Adolescents	Q	R	8508	3931	4577	14–25	17.33	2.18	1.2	0.6	0.8	78
Wichstrøm, 2006 [95]	Norway	High school	Q	R	2924	1277	1647	15–24	22.1	1.9	—	—	1.9	68
Williamson, 1993 [160]	UK	College	Q	R	687	—	—	≤19*	—	—	4.4	1.0	2.8	92
Wright, 2000 [97]	UK	Bodybuilders	Q	R	135	119	16	18–68	32.97	9.97	48	13	44	2.7
Özdemir, 2005 [90]	Turkey	Athletes	Q	R	883	691	192	15–34	21.8	3.7	—	—	60.5	—
Middle East														
Al-Falasi, 2008 [66]	UAE	Gym users	Q	R	154	144	10	21–39*	—	—	23.6	0	22.1	44

Angoorani, 2012 [67]	Iran	Gym users	Q	R	843	843	—	16–40	25.2	5.9	19.6	—	19.6	90.6
Habeeb, 2012 [68]	Iraq	Bodybuilders	Q	NR	172	172	—	20–24[*]	—	—	44.8	—	44.8	86
Jalilian, 2011 [69]	Iran	Gym users	Q	R	120	—	120	15–43	23.68	4.46	37.5	—	37.5	46.15
Sepehri, 2009 [70]	Iran	Bodybuilders	Q	R	202	—	—	—	24.4[†]	5[†]	—	—	18.8	—
Tahtamouni, 2008 [21]	Jordan	College athletes	Q	R	503	—	—	18–29[†]	19.9[†]	0.3[†]	—	—	4.2	100[†]
Tahtamouni, 2008 [21]	Jordan	Bodybuilders	Q	R	154	—	—	18–45[†]	28.1[†]	1.0[†]	—	—	26	100[†]
North America														
Adlaf, 2004 [175]	Canada	General	Q	R	13,909	—	—	15+	—	—	—	—	0.3	75.6
Adlaf, 1992 [103]	Canada	High school	Q	R	3892	—	—	—	—	—	—	—	1.1	81
Anderson, 1991 [104]	USA	College athletes	Q	R	2282	1552	730	—	—	—	—	—	5	70
Anderson, 1991 [104]	USA	College athletes	Q	R	2039	1407	632	—	—	—	—	—	4	—
Baumert, 1998 [176]	USA	Adolescent athletes	Q	R	4036	2340	1696	—	—	—	—	—	5	—
Baumert, 1998 [176]	USA	Adolescent non-athletes	Q	R	2183	985	1198	—	—	—	—	—	3	—
Beauvais, 1992 [177]	USA	High school	Q	R	51,097	25,262	25,416	<19	—	—	3.1	0.1	2.1	—
Beaver, 2008 [105]	USA	High school	Q	R	6823	—	—	—	—	—	2.6	0.9	1.75	—
Berning, 2008 [106]	USA	College	Q	R	485	219	266	19–26	—	—	7.63	1.03	8.7	—
Blouin, 1995 [107]	Canada	Bodybuilders	Q	NR	139	139	—	—	42.7[†]	2.3[†]	14.4	—	14.4	27.8
Bosworth, 1987 [108]	USA	Athletes			190	—	—	—	—	—	1.1	—	1.1	—
Brower, 1994 [109]	USA	Weightlifters	Q	R	404	404	—	—	24.4[†]	5.7[†]	12.13	—	12.13	—
Buckley, 1988 [110]	USA	High school	Q	R	3403	3403	—	17–19[*]	—	—	6.64	—	6.64	50.3
Cafri, 2006 [156]	USA	Adolescents	Q	R	266	266	—	13–18	14.64	1.03	2.6	—	2.6	100
Corbin, 1994 [111]	USA	High school	Q	R	1690	1013	677	—	—	—	2.4	1.1	1.9	—
Corder, 1975 [179]	USA	High school	Q	R	1393	—	—	—	—	—	—	—	0.7	—
Dezelsky, 1985 [112]	USA	Athletes	Q	R	4171	—	—	—	—	—	—	—	12	—
DuRant, 1993 [115]	USA	High school	Q	R	1881	962	919	—	14.9	1	6.5	1.9	4.2	—
DuRant, 1995 [114]	USA	High school	Q	R	12,267	5984	6283	≤18[*]	—	—	4.08	1.2	3.9	90.4
Elliot, 2004 [117]	USA	High school athletes	Q	R	928	—	928	—	15.4	1.2	—	0.3	0.3	—
Elliot, 2007 [116]	USA	High school	Q	R	7447	—	7447	—	—	—	—	5.3	5.3	83
Faigenbaum, 1998 [93]	USA	High school	Q	R	965	466	499	9–13	11.4	0.9	2.6	2.8	2.7	82
Ferenchick, 1996 [118]	USA	Weightlifters	I and Q	NR	48	48	—	—	—	—	52.08		52.08	
Field, 2005 [119]	USA	High school	Q	R	10,449	4237	6212	12–18	15	—	0.7	0.2	0.45	—
Fisher, 1996 [121]	USA	High school gym users	Q	R	838	377	461	—	16	—	11	4	7	—
Frankle, 1984 [180]	USA	Weightlifters	Q	NR	250	—	—	—	—	—	—	—	44	—
Gaa, 1994 [122]	USA	High school	Q	R	3047	1477	1562	—	—	—	3	0.9	1.9	81
Goldfield, 2009 [123]	Canada	Female bodybuilders and trainers	Q	NR	45	—	45	—	—	—	—	17.8	17.8	—
Gruber, 1999 [124]	USA	Female athletes	I	NR	75	—	75	18–65	32.3[†]	7.9[†]	—	33	33	—
Hoffman, 2007 [157]	USA	Adolescents	Q	R	3248	1559	1689	—	—	—	2.4	0.8	1.6	98.3
Horn, 2009 [125]	USA	Retired professional footballers	Q	NR	2552	—	—	—	53.8	13.4	—	—	9.1	69.3
Irving, 2002 [126]	USA	Middle and high school	Q	R	4344	2170	2174	11–18	14.9	—	5.4	2.9	4.15	81.5
Johnson, 1989 [31]	USA	High school	Q	R	1767	853	914	—	—	—	11.1	0.5	5.8	—
Johnston, 2013 [181]	USA	High school	Q	R	45,400	—	—	<19	—	—	—	—	1.4	—
Johnston, 2013 [181]	USA	High school	Q	R	46,700	—	—	<19	—	—	—	—	1.5	—
Johnston, 2013 [181]	USA	High school	Q	R	46,500	—	—	<19	—	—	—	—	1.5	—
Johnston, 2013 [181]	USA	High school	Q	R	46,000	—	—	<19	—	—	—	—	1.5	—
Johnston, 2013 [181]	USA	High school	Q	R	46,000	—	—	<19	—	—	—	—	1.6	—
Johnston, 2013 [181]	USA	High school	Q	R	48,000	—	—	<19	—	—	—	—	1.8	—
Johnston, 2013 [181]	USA	High school	Q	R	48,500	—	—	<19	—	—	—	—	2.0	—
Johnston, 2013 [181]	USA	High school	Q	R	49,300	—	—	<19	—	—	—	—	2.1	—
Johnston, 2013 [181]	USA	High school	Q	R	49,500	—	—	<19	—	—	—	—	2.5	—
Johnston, 2013 [181]	USA	High school	Q	R	48,500	—	—	<19	—	—	—	—	3.0	—
Johnston, 2013 [181]	USA	High school	Q	R	43,700	—	—	<19	—	—	—	—	3.3	—
Johnston, 2013 [181]	USA	High school	Q	R	44300	—	—	<19	—	—	—	—	3.3	—
Johnston, 2013 [181]	USA	High school	Q	R	45,000	—	—	<19	—	—	—	—	3.0	—

(continued on next page)

Table 1 (*continued*)

First author, year, reference	Country	Sample type	Assessment method	Sampling method	*N*	Sample size (male)	Sample size (female)	Age range (y)	Age mean	Age SD	Prevalence (male) %	Prevalence (female) %	Prevalence (overall) %	Response rate %
Johnston, 2013 [181]	USA	High school	Q	R	45,000	—	—	<19	—	—	—	—	2.8	—
Johnston, 2013 [181]	USA	High school	Q	R	49,866	—	—	<19	—	—	—	—	2.3	—
Johnston, 2013 [181]	USA	High school	Q	R	50,807	—	—	<19	—	—	—	—	2.1	—
Johnston, 2013 [181]	USA	High school	Q	R	49,065	—	—	<19	—	—	—	—	1.8	—
Johnston, 2013 [181]	USA	High school	Q	R	51090	—	—	<19	—	—	—	—	2.1	—
Johnston, 2013 [181]	USA	High school	Q	R	49,717	—	—	<19	—	—	—	—	2.1	—
Johnston, 2013 [181]	USA	High school	Q	R	51,099	—	—	<19	—	—	—	—	1.8	—
Johnston, 2013 [181]	USA	High school	Q	R	50,263	—	—	<19	—	—	—	—	1.8	—
Johnston, 2013 [181]	USA	High school	Q	R	48,323	—	—	<19	—	—	—	—	1.9	—
Johnston, 2013 [181]	USA	High school	Q	R	15,200	—	—	<19	—	—	—	—	2.9	—
Johnston, 2013 [181]	USA	High school	Q	R	16,700	—	—	<19	—	—	—	—	3.0	—
Johnston, 2013 [182]	USA	College	Q	R	1150	—	—	19–50	—	—	—	—	0.4	—
Johnston, 2013 [182]	USA	College	Q	R	1230	—	—	19–50	—	—	—	—	1.1	—
Johnston, 2013 [182]	USA	College	Q	R	1260	—	—	19–50	—	—	—	—	0.7	—
Johnston, 2013 [182]	USA	College	Q	R	1320	—	—	19–50	—	—	—	—	1.3	—
Johnston, 2013 [182]	USA	College	Q	R	1270	—	—	19–50	—	—	—	—	1.6	—
Johnston, 2013 [182]	USA	College	Q	R	1250	—	—	19–50	—	—	—	—	0.6	—
Johnston, 2013 [182]	USA	College	Q	R	1280	—	—	19–50	—	—	—	—	1.9	—
Johnston, 2013 [182]	USA	College	Q	R	1360	—	—	19–50	—	—	—	—	1.0	—
Johnston, 2013 [182]	USA	College	Q	R	1400	—	—	19–50	—	—	—	—	1.6	—
Johnston, 2013 [182]	USA	College	Q	R	1270	—	—	19–50	—	—	—	—	1.2	—
Johnston, 2013 [182]	USA	College	Q	R	1260	—	—	19–50	—	—	—	—	1.2	—
Johnston, 2013 [182]	USA	College	Q	R	1340	—	—	19–50	—	—	—	—	1.5	—
Johnston, 2013 [182]	USA	College	Q	R	1350	—	—	19–50	—	—	—	—	0.6	—
Johnston, 2013 [182]	USA	College	Q	R	1440	—	—	19–50	—	—	—	—	1.3	—
Johnston, 2013 [182]	USA	College	Q	R	1440	—	—	19–50	—	—	—	—	0.9	—
Johnston, 2013 [182]	USA	College	Q	R	1480	—	—	19–50	—	—	—	—	1.6	—
Johnston, 2013 [182]	USA	College	Q	R	1450	—	—	19–50	—	—	—	—	0.6	—
Johnston, 2013 [182]	USA	College	Q	R	1450	—	—	19–50	—	—	—	—	0.8	—
Johnston, 2013 [182]	USA	College	Q	R	1410	—	—	19–50	—	—	—	—	0.5	—
Johnston, 2013 [182]	USA	College	Q	R	1490	—	—	19–50	—	—	—	—	1.9	—
Johnston, 2013 [182]	USA	College	Q	R	1490	—	—	19–50	—	—	—	—	1.7	—
Johnston, 2013 [182]	USA	College	Q	R	1410	—	—	19–50	—	—	—	—	1.4	—
Johnston, 2013 [182]	USA	College	Q	R	1400	—	—	19–50	—	—	—	—	1.5	86
Johnston, 2013 [182]	USA	College	Q	R	1300	—	—	19–50	—	—	—	—	0.4	86
Kanayama, 2001 [127]	USA	Gym users	Q	R	511	334	177	14–70	—	—	5	—	3.33	50
Kanayama, 2003 [46]	USA	Drug users in treatment	I	NR	223	223	—	—	—	—	13	—	13	60.1
Kersey, 1996 [128]	USA	College athletes	Q	R	1185	833	352	17–39	19.6	2.2	4.2	1.2	3.3	—
Komoroski, 1992 [129]	USA	High school	Q	R	1492	672	806	—	16.9†	—	7.6	1.5	4.4	93.2
Krowchuk, 1989 [130]	USA	High school athletes	Q	R	295	—	—	13–18	15.6	—	—	—	1.4	99
Lippe, 2008 [183]	Puerto Rico	High school	Q	R	2640	1257	1383	<19	—	—	4.4	0.9	2.6	77
Lorang, 2011 [42]	USA	High school	Q	R	4231	2128	2103	—	15.91	1.23	1.7	1.1	1.4	98.5
Luetkemeier, 1995 [131]	USA	High school	Q	R	1907	1325	582	—	—	—	4	1.4	3.3	87
MacNeil, 1997 [186]	Canada	General	I	R	12,155	—	—	15+	—	—	—	—	0.3	75.6
Malone, 1995 [132]	USA	Gym users	I, Q, and UT	NR	164	147	17	—	—	—	43.3	3.7	47	—
McCabe, 2007 [133]	USA	College	Q	R	15,282	—	—	—	—	—	1.52	0.25	0.86	70
McCabe, 2007 [133]	USA	College	Q	R	14,428	—	—	—	—	—	1.75	0.21	0.95	59
McCabe, 2007 [133]	USA	College	Q	R	13,953	—	—	—	—	—	1.80	0.25	0.97	59
McCabe, 2007 [133]	USA	College	Q	R	10,904	—	—	—	—	—	1.99	0.25	1.05	52
Melia, 1996 [134]	Canada	High school	Q	R	16,169	—	—	11–18	—	—	—	—	2.8	—
Middleman, 1995 [135]	USA	High school	Q	R	3054	1501	1549	—	16	1.2	5.7	1.7	3.7	—
Miller, 2002 [136]	USA	High school	Q	R	16,262	8841	7340	—	15.7†	—	4.1	2	3.1	69
Miller, 2005 [44]	USA	High school	Q	R	16,183	—	—	14–18	—	—	4.1	2	3	87.2
Naylor, 2001 [43]	USA	High school	Q	R	1515	773	742	—	—	—	—	—	2.8	—
Newman, 1987 [184]	USA	Athletes	Q	R	271	—	271	—	—	—	—	3	3	59

Nutter, 1997 [137]	USA	High school	Q	R	265	135	130	12–16	13.3	0.8	5.3	1.5	3.4	—
Perry, 2005 [161]	USA	Weightlifters	Q	NR	260	—	—	16–51†	27.2†	7.2†	—	—	79.6	—
Pope, 1988 [138]	USA	College	Q	R	1010	1010	—	21–23*	—	—	2	—	2	30.8
Pope, 1994 [139]	USA	Weightlifters	I	NR	156	—	—	—	25.5†	7†	—	—	56	—
Pope, 1996 [140]	USA	Prison	I	NR	133	133	—	17–57	30.7	7.6	7	—	7	—
Pope, 2012 [12]	USA	Weightlifters	I and Q	NR	233	233	—	18–40	29.9†	6.1†	44	—	44	—
Radakovich, 1993 [141]	USA	High school	Q	R	782	—	—	12–15*	—	—	4.7	3.2	3.8	48
SAMHSA, 1996 [185]	USA	General	I and Q	R	17,809	7950	9859	12+	—	—	—	—	0.68	85.3
Scott, 1996 [142]	USA	High school	Q	R	4722	2136	2522	—	—	—	4.5	0.8	2.5	—
Stilger, 1999 [143]	USA	High school footballers	Q	R	873		—	—	—	—		—	6.3	66
Street, 2000 [144]	USA	Gym users	Q	R	516	366	150	18–87	30†	6.8†	—	—	11	100
Tanner, 1995 [6]	USA	High school	Q	R	6930	3438	3492	8–17	—	—	4	1.3	2.7	96.6
Taylor, 1987 [145]	USA	Athletes	Q	R	114	—	—	—	25.1†	6.1†	—	—	90	—
Terney, 1990 [146]	USA	High school	Q	R	2113	—	—	—	—	—	6.5	2.5	4.4	69
Terney, 1990 [146]	USA	Athletes	Q	R	1436	—	—	—	—	—	—	—	5.5	—
Terney, 1990 [146]	USA	High school	Q	R	636	—	—	—	—	—	—	—	2.4	—
Tricker, 1989 [147]	USA	Bodybuilders	Q	R	176	108	68	—	—	—	54.6	10.3	37.5	46
van den Berg, 2007 [148]	USA	Adolescents	Q	R	2516	1130	1386	—	—	—	1.7	1.4	1.5	—
Whitehead, 1992 [149]	USA	High school	Q	R	3900	3900	—	—	—	—	5.3	—	5.3	—
Windsor, 1989 [150]	USA	High school	Q	R	901	462	439	13–21	—	—	5	1.4	2.8	89.2
Wroble, 2002 [151]	USA	Adolescent sportspeople	Q	R	1553	1087	466	10–15	—	—	0.9	0.2	0.7	76
Yesalis, 1988 [153]	USA	Weightlifters	I and Q	NR	65	—	—	20–39†	27†	—	—	—	40	—
Yesalis, 1990 [187]	USA	NFL players	I	NR	120	120	—	—	—	—	28	—	28	7.5
Yesalis, 1993 [152]	USA	General	Q	R	32,594	—	—	12+	—	—	0.9	0.1	0.5	84.2
Young, 2011 [188]	Canada	High school	Q	R	40,630	—	—	—	—	—	—	—	1.4	—
Oceania														
Adhikari, 2000 [189]	Australia	General	I and Q	R	10,030	—	—	14+	—	—	—	—	0.8	56
AIHW, 2002 [190]	Australia	General	I and Q	R	26,744	—	—	14+	—	—	—	—	0.2	—
AIHW, 2005 [191]	Australia	General	I and Q	R	30,000	—	—	12+	—	—	—	—	0.3	46
AIHW, 2011 [192]	Australia	General	I and Q	R	26,000	—	—	12+	—	—	—	—	0.4	50.6
Cormack, 1998 [193]	Australia	Injecting drug users	I	NR	119	73	46	—	—	—	—	—	4	—
Dunn, 2010 [194]	Australia	General	I and Q	R	23356	—	—	—	—	—	—	—	0.3	49.3
Dunn, 2011 [17]	Australia	High school	Q	R	21,905	10,295	11,610	12–17	14.5	—	3.1	1.7	2.4	76
Gridley, 1994 [98]	Australia	Gym users	Q	R	42	42	—	25–30	—	—	51	—	51	34.1
Handelsman, 1997 [99]	Australia	High school	Q	R	13,121	6710	6411	—	—	—	3.2	1.2	2.2	89
Hando, 1997 [195]	Australia	Injecting drug users	I	NR	152	83	69	—	—	—	—	—	0.7	—
Hando, 1998 [196]	Australia	Injecting drug users	Q	NR	308	170	138	17–52	—	—	—	—	3.5	—
Kirwan, 2012 [197]	Australia	Injecting drug users	I	NR	150	113	37	—	37	7.6	—	—	8	—
Letcher, 1999 [198]	Australia	High school	Q	R	29,700	14,444	15,256	12–17	—	—	2.7	0.8	1.8	—
Lippe, 2008 [183]	NMI	High school	Q	R	2371	1209	1162	<19	—	—	5.9	2.8	4.4	85
Lippe, 2008 [183]	NMI	Middle school	Q	R	1556	808	748	<19	—	—	4.7	2.7	3.7	86
Lippe, 2008 [183]	Palau	High school	Q	R	600	282	318	<19	—	—	8.9	4.7	6.7	95
Lippe, 2008 [183]	Palau	Middle school	Q	R	739	377	362	<19	—	—	8.9	5.2	7.1	86
Lippe, 2008 [199]	NMI	High school	Q	R	2292	1171	1121	<19	—	—	6.1	3.3	4.9	81
Lippe, 2008 [199]	American Samoa	High school	Q	R	3625	1852	1800	<19	—	—	9.4	3.8	6.5	87
Lippe, 2008 [199]	Palau	High school	Q	R	732	369	363	<19	—	—	6.0	4.6	5.3	90
Lippe, 2008 [199]	Guam	High school	Q	R	1716	803	913	<19	—	—	5.5	3.5	4.8	78
Makkai, 1998 [200]	Australia	General	I and Q	NR	3500	—	—	14–60+	—	—	—	—	0.3	—
Makkai, 1998 [200]	Australia	Injecting drug users	I and Q	NR	3850	—	—	14–60+	—	—	—	—	0.6	—
McIlwraith, 2012 [201]	Australia	Injecting drug users	I	NR	102	80	22	18–60	38	—	—	—	13	—
Ministry of Health, 2010 [202]	New Zealand	General	Q	R	6784	—	—	16–64	—	—	—	—	0.1	60
Phillips, 2012 [203]	Australia	Injecting drug users	I	NR	150	98	52	21–58	40	—	—	—	9	

(continued on next page)

Table 1 (*continued*)

First author, year, reference	Country	Sample type	Assessment method	Sampling method	*N*	Sample size (male)	Sample size (female)	Age range (y)	Age mean	Age SD	Prevalence (male) %	Prevalence (female) %	Prevalence (overall) %	Response rate %
Rumbold, 1998 [204]	Australia	Injecting drug users	I	NR	254	163	91	16–52	29	—	—	—	8	—
Rysavy, 2011 [205]	Australia	Injecting drug users	I	NR	98	69	21	18–63	42	—	—	—	13	—
Stafford, 2011 [206]	Australia	Injecting drug users	I	NR	902	586	316	18–64	38	—	—	—	7.2	—
Stafford, 2013 [207]	Australia	Injecting drug users	I	NR	924	610	314	17–71	39	—	—	—	6	—
Sutherland, 2012 [208]	Australia	Injecting drug users	I	NR	100	59	41	21–57	—	—	—	—	9	—
Topp, 2001 [209]	Australia	Injecting drug users	I	NR	910	618	292	14–64	28.8	8.0	—	—	1.1	—
White, 2001 [210]	Australia	High school	Q	R	25,486	12,544	12,942	12–17	—	—	3.7	1.7	2.7	—
White, 2004 [211]	Australia	High school	Q	R	23,417	11,646	11,771	12–17	—	—	3.6	2.2	2.9	—
White, 2006 [212]	Australia	High school	Q	R	21,805	10,162	11,643	12–17	—	—	3.4	1.8	2.6	—
White, 2009 [213]	Australia	High school	Q	R	24,408	11,491	12,917	12–17	—	—	3.1	1.7	2.4	—
White, 2012 [214]	Australia	High school	Q	R	24,854	11,741	13,113	12–17	—	—	2.4	1.5	2.0	—
Wilkins, 2008 [215]	New Zealand	Drug users	I	NR	324	224	100	16–58	30	—	—	—	1	—
South America														
Abrahin, 2013 [24]	Brazil	Physical education teachers and students	Q	R	117	—	—	>18	28	6.3	—	—	31.6	—
De Andrade, 2012 [16]	Brazil	College	Q	R	12,711	5720	6991	18–24*	—	—	8.1	0.4	3.8	72.1
De Micheli, 2004 [100]	Brazil	Elementary and high school	Q	R	6417	3016	3401	<18	—	—	—	—	0.1	100
Maharaj, 2000 [101]	Trinidad	Gym users	Q	R	1062	502	560	20–29*	—	—	—	—	2.9	92.8
Santos, 2011 [102]	Brazil	Bodybuilders	Q	R	123	123	—	18–50	—	—	33.3	—	33.3	—
Trans-Region														
Ip, 2012 [154]	Not specified	Weightlifters	Q	NR	1519	—	—	18–57	29.6†	0.8†	33.3	0.8	34.1	—
Papadopoulos, 2006 [155]	Finland, France, Germany, Greece, Israel, Italy	University recreational athletes	Q	R	2173	—	—	—	—	—	—	—	0.8	79

AIHW = Australian Institute of Health and Welfare; I = interview; NACD = National Advisory Committee on Drugs; NMI = Northern Mariana Islands; NR = non-random sampling; Q = questionnaire; R = random sampling; SAMHSA = Substance Abuse and Mental Health Services Administration; UT = urine testing.

* Majority of participants.

† AAS users.

3.3% (95% CI, 2.8–3.8). Applying the trim and fill function, these values were unchanged indicating the absence of publication bias. In addition, inspection of the funnel plot showed a symmetrical distribution of studies in terms of prevalences, confirming the absence of publication bias.

Statistical analysis

We performed a meta-analysis to estimate the global lifetime prevalence rate of AAS use. A random-effects model was used in the calculation of prevalence rates and 95% CIs. A random effects model is preferred because it is the most realistic assumption when the studies to be meta-analyzed cannot be reasonably considered as representative of the population of potential studies that have been conducted or can be conducted in the future about the research topic. Moreover, the random effects model allows a higher generalization of the results than the fixed effects model [27]. To assess the heterogeneity of the prevalences, the *Q*-statistic and the I^2 index were used. The *Q*-statistic is calculated by adding the squared deviations between the effect size of each study and the overall effect size weighted by the inverse variance for each study. The I^2 index on the other hand can be interpreted as the percentage of the total variability in a set of effect sizes due to true heterogeneity rather than chance [28].

We also performed subgroup analyses for all moderator variables separately based on the *Q*-statistic to assess the statistical significance of differences in prevalence rates between the subgroups using a random-effects model [29]. To reduce the probability of committing a type I error due to the high number of subgroup comparisons, Bonferroni correction was used. The meta-analysis was conducted using Comprehensive Meta-Analysis, version 2.0 [27].

Moreover, to discover relevant moderator variables that could account for the variance in the overall prevalence rate, we performed a meta-regression analysis assuming a random effects model. The following moderator variables were included in the meta-regression analysis: publication year (1970–1979, 1980–1989, 1990–1999, 2000–2013), region (Africa, Asia, Europe, Middle East, North America, Oceania, South America, and Trans-Region), sample type (athletes, high school, drug users, non-athletes, prisoners and arrestees, recreational sportspeople), age range (≤19 years and >19 years), and studies with overlapping range of ages (trans-age range), sampling method (random and nonrandom), assessment method (interviews, questionnaires, or both) and the percentage of males in the sample (percentage of males in the sample >75%, percentage of males in the sample ≤50%, percentage of males in the sample >50% to ≤75%, and the percentage of males not provided). Because our independent variables were categorical, we dummy coded categories independently so that each level of the variable provided the basis for a dummy coded variable as 0 or 1. For each moderator variable, the category with the highest number of studies was used as a contrast. The meta-regression analysis was conducted in SPSS, version 20 (IBM Corp.). For the meta-regression analysis, we used SPSS macros provided by Wilson [30] as the meta-regression module in Comprehensive Meta-Analysis 2.0 cannot handle categorical moderator variables.

Results

Overall prevalence rates and heterogeneity testing

Table 2 presents the total number of studies, the prevalence rates and confidence limits, and the heterogeneity statistics (Q and I^2) for the overall population, males, and females.

Table 2
Prevalence rates, CIs, and heterogeneity statistics for the overall population, males, and females

	N	*p*%	95% CI	*Q*	df (*Q*)	I^2
Overall	271	3.3	2.8–3.8	86828.2*	270	99.7
Male	112	6.4	5.3–7.7	13626.6*	110	99.2
Female†	83	1.6	1.3–1.9	2525.1*	82	96.8

df (Q) = Q's degrees of freedom; I^2 = heterogeneity index; *N* = number of studies; *p* % = prevalence (%); *Q* = heterogeneity statistic.
* $P < .001$.
† *p*% is significantly lower than *p*% for males ($P < .001$).

From Table 2, the overall prevalence rate obtained from 271 studies was 3.3% (95% CI, 2.8–3.8%, $I^2 = 99.7$, $P < .001$). In addition, the prevalence rate for males, 6.4%, was significantly higher ($Q_{bet} = 100.1$, df = 1, $P < .001$) than the prevalence rate for females, 1.6%.

Regional prevalence rates and heterogeneity testing

Table 3 presents the total number of studies, the prevalence rates, and the confidence interval for the various geographical regions. Also presented are their respective heterogeneity statistics.

From Table 3, the region with the highest overall prevalence rate of AAS use is the Middle East: 21.7%, followed by South America: 4.8%, Europe: 3.8%, North America: 3.0%, Oceania: 2.6%, Africa: 2.4%, and Asia: 0.2%. Moreover, overall prevalence rate for Trans-Regional studies was 6.0%. In addition, apart from Asia, the heterogeneity statistic (*Q*) for the overall prevalence rates, reached statistical significance ($P < .001$). Furthermore, we found from the subgroup comparisons that the prevalence rates in North America, Oceania, and Africa are significantly lower than the prevalence rate in the Middle East ($Q_{NA} = 65.1$, $Q_{Oc} = 58.0$, $Q_{Afr} = 25.3$, df = 1, $P < .001$).

Prevalence rates for sample type and heterogeneity testing

Table 4 presents the total number of studies, the prevalence rates and confidence limits, and the heterogeneity statistics in an order of hierarchy for the various sample types.

From Table 4, recreational sportspeople had the highest overall prevalence rate: 18.4%, followed by athletes: 13.4%, prisoners and arrestees: 12.4%, and drug users: 8.0%. Moreover, prevalence rate for high-school students was 2.3%, whereas nonathletes had the lowest prevalence rate of 1.0%. In addition, the heterogeneity statistic (*Q*) for the overall prevalence rates for all sample types reached statistical significance ($P < .001$). From the subgroup comparisons, we found prevalence rates for high-school students and nonathletes to be significantly lower than prevalence rates among recreational sportspeople ($Q_{HS} = 301.3$, $Q_{N\text{-}A} = 87.4$, df = 1,

Table 3
Regional prevalence rates, 95% CIs, and heterogeneity statistics

	N	*p*%	95% CI	*Q*	df (*Q*)	I^2
Middle East	7	21.7	13.5–32.9	138.8*	6	95.7
Trans-Region	2	6.0	0.1–79.5	281.4*	1	99.6
South America	5	4.8	1.2–16.7	397.0*	4	99.0
Europe	81	3.8	2.4–5.8	60009.6*	80	99.9
North America†	126	3.0	2.7–3.4	14752.7*	125	99.2
Oceania†	38	2.6	2.1–3.3	2705.0*	37	98.6
Africa†	11	2.4	1.2–4.8	208.7*	10	95.2
Asia	1	0.2	0–3.5	0^{ns}	0	0

df (Q) = Q's degrees of freedom; I^2 = heterogeneity index; *N* = number of studies; *ns* = not significant; *p*% = prevalence (%); *Q* = heterogeneity statistic.
* $P < .001$.
† *p*% is significantly lower than *p*% in the Middle East ($P < .05$).

Table 4
Prevalence rates, 95% CIs, and heterogeneity statistics for sample type

	N	p%	95% CI	Q	df (Q)	I^2
Recreational sportspeople	18	18.4	11.2–28.6	1125.0*	17	98.5
Athletes	48	13.4	9.7–18.2	4484.7*	47	99.0
Prisoners and arrestees	6	12.4	5.8–24.7	114.7*	5	95.6
Drug users	20	8.0	3.6–16.8	2417.2*	19	99.2
High school†	109	2.3	2.1–2.5	7930.1*	108	98.6
Non-athletes‡	70	1.0	0.7–1.3	9818.0*	69	99.3

df (Q) = Q's degrees of freedom; I^2 = heterogeneity index; N = number of studies; p% = prevalence (%); Q = heterogeneity statistic.
* $P < .001$.
† p% is significantly lower than p% in recreational sportspeople ($P < .001$); p% is significantly lower than p% in athletes ($P < .001$); p% is significantly lower than p% in prisoners and arrestees ($P < .001$); p% is significantly lower than p% in drug users.
‡ p% is significantly lower than p% in high school ($P < .001$).

$P < .001$), athletes ($Q_{HS} = 397.6$, $Q_{N\text{-}A} = 131.3$, df = 1, $P < .001$), prisoners and arrestees ($Q_{HS} = 80.4$, $Q_{N\text{-}A} = 21.4$, df = 1, $P < .001$), and drug users ($Q_{HS} = 114.3$, $Q_{N\text{-}A} = 40.6$, df = 1, $P < .001$). Furthermore, the prevalence rate for nonathletes was significantly lower ($Q_{bet} = 65.6$, df = 1, $P < .001$) than the prevalence rate for high-school students.

Prevalence rates for age range and heterogeneity testing

Table 5 presents the total number of studies, the prevalence rates and confidence limits, and the heterogeneity statistics in an order of hierarchy for the age ranges.

From Table 5, it can be seen that adolescents aged 19 years and younger have a higher overall prevalence rate: 2.5% than people aged older than 19 years: 1.9%. The prevalence rate for studies with a mix of participants in terms of ages (trans-age range) was 4.6%. Moreover, the heterogeneity statistic for the prevalence rates for all three groups, Q, reached statistical significance ($P < .001$). In addition, from the subgroup contrasts, the prevalence for adolescents aged 19 years and younger was significantly lower than that among the trans-age range group ($Q_{bet} = 20.9$, df = 1, $P < .001$).

Prevalence rates for assessment method and heterogeneity testing

Table 6 presents the total number of studies, the prevalence rates and confidence limits, and the heterogeneity statistics in an order of hierarchy for the assessment methods used in the research selected for this meta-analysis.

From Table 6, it can be seen that studies that used only interviews had the highest overall prevalence rate: 11.1%, followed by studies that used only questionnaires: 3.0%, and studies that used both interviews and questionnaires: 1.8%. Moreover, the heterogeneity statistic for the overall prevalence rates of all assessment methods, Q, reached statistical significance ($P < .001$). From the subgroup comparisons, we found prevalence rates for studies that used only questionnaires or both interviews and questionnaires to be significantly lower than those for studies that used interviews only ($Q_Q = 27.3$, $Q_{IQ} = 9.4$, df = 1, $P < .001$).

Table 5
Prevalence rates, 95% CIs, and heterogeneity statistics for age range

	N	p%	95% CI	Q	df (Q)	I^2
Trans-age range	142	4.6	3.4–6.3	59969.6*	141	99.8
≤19 y†	98	2.5	2.2–2.7	8679.8*	97	98.9
>19y	31	1.9	1.1–3.2	1242.9*	30	97.6

df (Q) = Q's degrees of freedom; I^2 = heterogeneity index; Q = heterogeneity statistic; N = number of studies; p% = prevalence (%).
* $P < .001$.
† p% is significantly lower than p% for trans-age range ($P < .001$).

Table 6
Prevalence rates, 95% CIs, and heterogeneity statistics for assessment method

	N	p%	95% CI	Q	df (Q)	I^2
Interview	24	11.1	5.8–20.2	1765.5*	23	98.7
Questionnaire†	231	3.0	2.6–3.6	76009.8*	230	99.7
Interview and questionnaire†	16	1.8	0.7–4.7	3314.9*	15	99.5

I^2 = heterogeneity index; df (Q) = Q's degrees of freedom; N = number of studies; p% = prevalence (%); Q = heterogeneity statistic.
* $P < .001$.
† p% is significantly lower than p% for interviews only ($P < .01$).

Prevalence rates for sampling method and heterogeneity testing

Table 7 presents the total number of studies, the prevalence rates and confidence limits, and the heterogeneity statistics for sampling methods used in the various studies selected for this meta-analysis.

From Table 7, studies that used nonrandom sampling methods had a significantly higher ($Q_{bet} = 63.8$, df = 1, $P < .001$) overall prevalence rate, 11.4%, than studies that used random sampling methods, 2.4%.

Prevalence rates for publication year and heterogeneity testing

Table 8 presents the total number of studies, the prevalence rates and confidence limits, and the heterogeneity statistics in an order of hierarchy for the publication years of the research selected for this meta-analysis.

From Table 8, publication years 1970–1979 had the highest overall prevalence rate: 9.2%, followed by 1980–1989: 7.8%. Moreover, publication years 2000–2013 had a slightly higher prevalence rate, 3.2%, than 1990–1999: 2.9%. In addition, the heterogeneity statistic for the prevalence rates, Q, reached statistical significance ($P < .001$) for all publication years. Furthermore, from the subgroup comparisons, the prevalence rate for publication years 1990–1999 was significantly lower than prevalence rate for publication years 1970–1979 ($Q_{bet} = 8.7$, df = 1, $P < .001$).

Meta-regression analysis

The large heterogeneity found in the overall AAS use prevalence rate suggests the existence of study characteristics influencing this variance. Consequently, we performed a meta-regression analysis to assess the predictive effect of publication year, region, sample type, assessment method (interview, questionnaire, or both), age range, sampling method (random and nonrandom), and the percentage of males in the sample on the overall prevalence rate of AAS use. Of these variables, sample type (athletes), assessment through only interview or both interview and questionnaire, sampling method (nonrandom), and percentage of males in the sample

Table 7
Prevalence rates, 95% CIs, and heterogeneity statistics for sampling method

	N	p%	95% CI	Q	df (Q)	I^2
Non-random	54	11.4	7.0–18.0	18393.6*	53	99.7
Random†	217	2.4	2.2–2.7	33076.5*	216	99.3

df (Q) = Q's degrees of freedom; I^2 = heterogeneity index; N = number of studies; p% = prevalence (%); Q = heterogeneity statistic.
* $P < .001$.
† p% is significantly lower than p% for non-random sampling ($P < .001$).

Table 8
Prevalence rates, 95% CIs, and heterogeneity statistics for publication year

	N	p%	95% CI	Q	df (Q)	I^2
1970–1979	3	9.2	0.6–62.2	119.9*	2	98.3
1980–1989	16	7.8	3.9–15.2	2646.9*	15	99.4
2000–2013	174	3.2	2.6–3.9	76017.8*	173	99.8
1990–1999†	78	2.9	2.6–3.4	5406.3*	77	98.6

df (Q) = Q's degrees of freedom; I^2 = heterogeneity index; N = number of studies; p% = prevalence (%); Q = heterogeneity statistic.
* $P < .001$.
† p% is significantly lower than p% in the 1970s ($P < .008$).

(between 25% and 75%) were significantly related to the heterogeneity in the overall AAS use prevalence rate (Table 9).

Discussion

This article presents the very first meta-analysis of the global lifetime prevalence rate of AAS use. The overall lifetime prevalence rate across all studies was 3.3%. Moreover, from the subgroup comparisons, the overall lifetime prevalence rate for males, 6.4%, was significantly higher than the overall lifetime prevalence rate for females, 1.6%. This result corroborates the generally accepted position in the field [11,16,19,31,32]. In further support of this finding, the percentage of males in samples was significantly related to prevalence in the meta-regression analysis.

Table 9
Meta-regression analysis of the predictors of AAS use prevalence

	B	SE	β
Publication year			
2000–2013*			
1970–1979	−3.1364	8.0045	−0.0200
1980–1989	4.5273	4.2902	0.0568
1990–1999	−0.7842	2.2176	−0.0201
Region			
North America*			
Middle East	4.4691	5.9360	0.0432
Trans-Region	−3.9778	9.8073	−0.0208
South America	7.7709	6.6569	0.0638
Europe	2.9280	2.3427	0.0814
Oceania	2.1938	3.2091	0.0464
Africa	−3.2329	4.5408	−0.0388
Asia	4.5852	13.7958	0.0168
Sample type			
High school*			
Recreational sportspeople	8.1083	4.5524	0.1528
Athletes	8.4656	3.6468	0.1751†
Prisoners and arrestees	−6.1756	7.1070	−0.0554
Drug users	−8.6720	5.9928	−0.1350
Nonathletes	−6.8909	3.8314	−0.1870
Assessment method			
Questionnaire*			
Interview	9.9419	4.2865	0.1754†
Interview and questionnaire	12.2500	4.2905	0.1654†
Age range			
Trans-age range*			
≤19 y	−5.1381	3.2635	−0.1515
>19 y	−0.3335	3.6583	−0.0062
Sampling method			
Random samples*			
Nonrandom samples	7.8789	3.3084	0.1848†
Percentage of males in sample			
% of males not provided*			
>75%	4.0971	2.9257	0.0945
>50%–75%	−6.5656	2.7194	−0.1540†
≤50%	−5.1873	2.5560	−0.1217†

R^2 = 41.1.
* Reference category.
† $P < .05$.

With reference to sample type, our finding that AAS use is most prevalent among recreational sportspeople and athletes surpassing prevalence rates among prisoners and arrestees, drug users, high-school students, and nonathletes is consistent with available evidence [8,39–41]. This result is also consistent with evidence suggesting that the odds of AAS use increases by about 91% with participation in at least one sport [42,113]. Indeed, we confirmed the association of athletic involvement with AAS use in our meta-regression analysis with sample type (athletes) significantly predicting AAS prevalence. Our finding with regards to prisoners and arrestees and drug users corroborates available evidence connecting AAS use to polydrug use in studies of prisoners and arrestees [35,38,84] and also general populations [36].

In contrast to available evidence that most AAS users begin use in their 20s, leading to a significant increase in AAS use prevalence rate after the teenage years [44–46], we found that AAS use is more prevalent among teenagers than those older than 19 year. This finding may reflect a cohort effect.

Our finding that the regions with the highest overall rates of AAS use are the Middle East and South America is surprising but perhaps can be explained by the fact that most studies in these regions relied on self-reports from athletes and recreational athletes, a group among whom AAS use has been found to be highly prevalent [8,40]. Again, our finding that Europe, North America, and Oceania have higher rates of AAS use than Africa and Asia is perhaps attributable to the fixation on “muscularity” as a definition of “masculinity” in Western cultures [14,47–49,64]. Still, in the meta-regression analysis, region was insignificant suggesting that other factors better explained the variance in prevalence.

The meta-analysis showed that studies using nonrandom sampling methods reported a higher prevalence rate than studies based on random sampling methods is also explicable. This finding seems to be related to the fact that the predominance of nonrandomly selected samples comprised recreational sportspeople, athletes, prisoners, arrestees, and drug users among whom AAS use prevalence is relatively higher compared with high-school students and nonathletes, as previously found [8,38–40,50]. In further support of this finding, sampling method was significantly associated with prevalence in the meta-regression.

With reference to the assessment method, we found that studies using interviews reported a higher prevalence rate than studies using only questionnaires or both interviews and questionnaires. This finding is in part due to the fact that studies using interviews did not randomly select participants. More importantly, most respondents in these “interview studies” were prisoners, arrestees, recreational sportspeople, and athletes who, as indicated above, are notorious AAS users. Moreover, assessment method was found to be significant in the meta-regression analysis when we controlled for the other moderators.

Our finding that AAS use was most prevalent in the 1970s is comprehensible because two [22,217] of the three studies conducted in the 1970s in this meta-analysis sampled elite athletes who were the predominant users of AAS in the 1970s [4]. Moreover, our finding that AAS use was most prevalent in the 1980s compared with the 1990s and 2000s supports the reports that AAS began to spread beyond the elite athletic community and into the general population in the 1980s [4,51]. The authors of these studies suggest that the increase in AAS use during this period is due in part to the proliferation of underground guides [52,53], which offered detailed guidance on AAS use coupled with the fact that AAS were still readily available as prescription drugs with minimal federal enforcement until 1991 [54].

Moreover, our finding that the prevalence rate of AAS use is slightly higher in recent times (after 2000) than in the 1990s suggests that nonmedical use of AAS has steadily increased since the

1990s. The significant drop in the AAS use prevalence rate between 1990 and 1999 compared with the 1980s is perhaps attributable to concern over AAS use and the enactment of legislation against AAS use in the 1990s [55] such as the Anabolic Steroid Control Act of 1990 in the United States [54], the 1991 Act Prohibiting Certain Doping Substances in Sweden [219], and other similar legislation enacted in other countries since the 1990s. Moreover, when we controlled for other moderator variables in the meta-regression analysis, publication year was not a significant moderator variable.

This study, to our knowledge, is the first to have systematically examined the global lifetime prevalence rate of AAS use by a quantitative meta-analytic approach. Thus, the prevalence estimates in the present study constitute the best currently available basis for policymaking and planning. The global nature of this research, the large number of included studies and participants, and the advanced analysis of the data using both meta-analysis and meta-regression analysis are also notable assets of the present study.

The present meta-analysis, however, has limitations worth noting when interpreting our results. First is the validity of prevalence rates reported in the studies included in our meta-analysis and its potential to overestimate or underestimate our final prevalence rates. Kanayama et al. [158] contend that prevalence rates of AAS use are sometimes exaggerated due to false-positive responses to poorly worded questions regarding "steroids" on anonymous questionnaires. They argue that some respondents, especially high-school students, answer that they have used "steroids" when in fact they have used some over-the-counter substance that they thought was a steroid. Indeed, with the explosion of the supplement market in the 1990s [119, 120], it has become more difficult to determine whether a person is using AAS, an AAS derivative, or some other substance marketed to work like AAS [158].

Moreover, the present study concerned the lifetime prevalence of AAS use. Lifetime prevalences will naturally be higher than current prevalence. It should be noted that lifetime prevalence estimates by their retrospective nature are more susceptible to recall bias than current prevalences [220]. Lifetime prevalences also cover a wider range of use (from days to many years) in contrast to current prevalence that addresses "here and now" use. Again, in contrast to current prevalences, lifetime prevalence estimates cannot be validated against objective measures (e.g., urine samples) [221]. Our final prevalence estimates should, therefore, be considered in the light of this limitation. Another limitation is the paucity of studies on AAS use prevalence in many world regions, particularly in Africa, Asia, the Middle East, and South America. Although nonmedical AAS use is a global problem [14,56], the preponderance of epidemiologic research is limited to North America and Europe. Moreover, although some studies have been carried out in a few countries in these regions, generalization to a large number of other countries in the same region may be problematic, especially when the only available studies have small sample sizes and are of poor methodological quality.

The results of our study have important consequences for policymakers, health care professionals, and researchers. Nonmedical AAS use is a major global public health problem that requires the attention of policymakers and researchers. Thus, efforts need to be made in all regions, especially in Africa, Asia, the Middle East, and South America, not only to avert this disparity but also to monitor trends in the incidence and prevalence of AAS use. This research provides a strong starting point that can be improved as new evidence emerges especially from currently underrepresented regions. In addition, self-report measures of AAS use varied across studies and researchers are encouraged to move toward a common standard for assessing AAS use in future studies. In this regard, researchers must endeavor to formulate questions that explain carefully to respondents that AAS does not refer corticosteroids or over-the-counter nutritional supplements. Researchers must also require respondents to name the AAS that they have used. Thus, false-positive responses could be minimized and more accurate rates of AAS prevalence can be estimated.

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