Prevalence and correlates of androgen dependence: A meta-analysis, meta-regression analysis and qualitative synthesis

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ABSTRACT

Purpose of review

To investigate the prevalence and correlates of androgen dependence among users. A meta-analysis, meta-regression analysis, and qualitative synthesis were conducted based on a systematic literature search in Google Scholar, ISO Web of Science, PsycNET, and PubMed.

Recent findings

Twenty-six studies were included in the review and 18 studies (N = 1782) in the statistical analysis. The overall lifetime androgen dependence prevalence was 34.4% (95% CI: 27.8–41.7, Q = 113.1, I^2 = 85.0, p < .001). Although males (36.1%, p < .001) and females (37.0%, p = .188) did not differ (Q = 0.0, p = .930) in dependence prevalence, controlling for other study characteristics, higher study male sample proportion was related to higher dependence prevalence. Combined interview and questionnaire assessments showed higher prevalence compared to interviews only. Publications from 1990–1999 generated higher prevalence compared to 2000–2009 and 2010–2023 publications. Dependents were associated with a wide array of demographic inequalities, and biophysical, cognitive, emotional, and psychosocial problems.

Summary

About 1 of 3 persons who initiate androgen use experience dependence along with various serious disorders. Androgen use and dependence should be considered an important public health issue requiring targeted health interventions.

Keywords: anabolic-androgenic steroids, dependence, meta-analysis, steroid use disorder, prevalence

INTRODUCTION

In recent decades, it has become clear that using androgens, also known as anabolic-androgenic steroids (AAS), can lead to dependence [1▪]. Theoretical explanations of androgen dependence in humans include the body image [2, 3] and allostatic [4] models as well as problem behavior theory [5]. Considering the harms of long-term androgen use [6, 7] and the global prevalence of androgen use [8, 9], knowledge of androgen dependence prevalence is important. An androgen dependence prevalence of about 30% was estimated from the quantification of seven 1991–2005 publications [10]. A follow-up review by the authors pooled 1247 androgen users and estimated a 32.5% lifetime androgen dependence prevalence [11]. It is noteworthy that both literature reviews are vitiated by a lack of systematic literature search and selection process, and a dearth of evidence on the correlates of the estimated androgen dependence prevalence. We conducted a systematic literature review incorporating a meta-analysis, meta-regression analysis, and qualitative synthesis to investigate the prevalence as well as associated factors of androgen dependence. The questions guiding the present study were: (1) what are the characteristics of empirical studies on androgen dependence, (2) what is the pooled prevalence of androgen dependence, and what are the correlates of the (3) pooled androgen dependence prevalence and (4) androgen dependence?

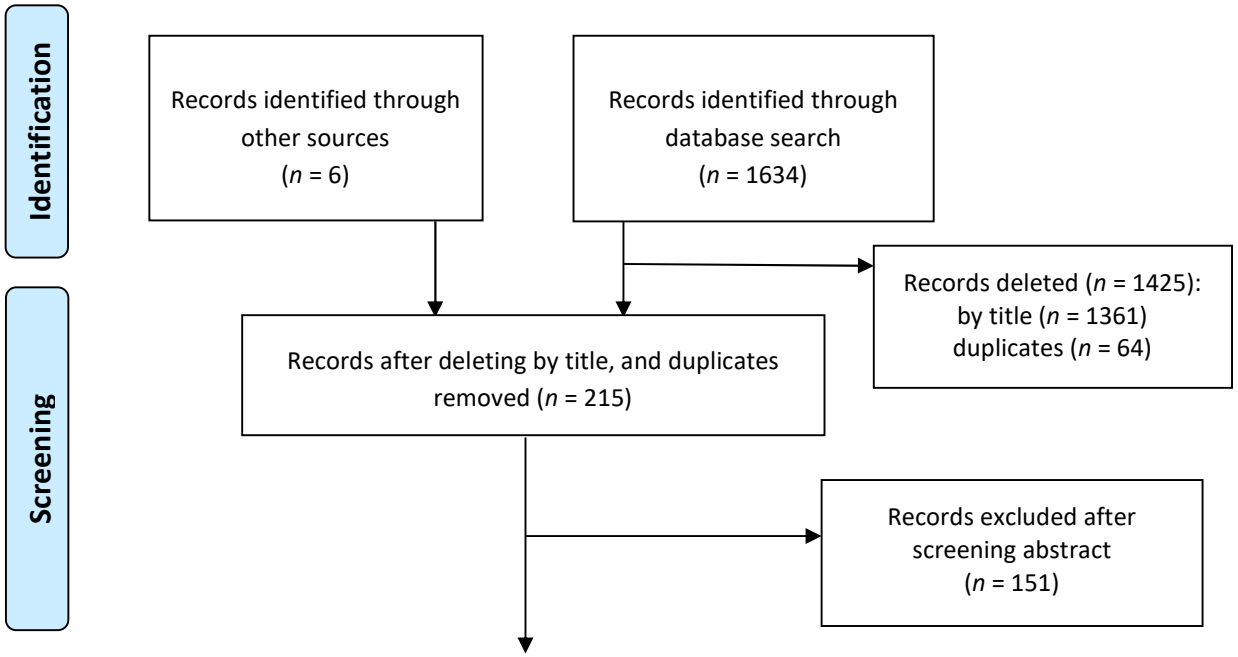
METHODS

Search strategy and inclusion criteria

A systematic and comprehensive literature search was conducted in Google Scholar, ISI Web of Science, PsycNET, and PubMed. The following keywords were used: “anabolic-androgenic steroid dependence” OR “anabolic steroid dependence” OR “anabolic-androgenic steroid use and

dependence" OR "anabolic steroid use and dependence". A total of 1634 hits were identified from the database search, and six records were identified through ad hoc searches. After deleting 1361 records by title and removing 64 duplicates, 215 records were available for screening. Of this pool, 151 records were removed after inspecting their abstracts. Thus, 64 full-text records were assessed for eligibility of which 26 were included in the review, and 18 in the meta-analysis.

The key inclusion criteria were that the record: (a) presented original data on the prevalence of androgen dependence, (b) as assessed with a valid measure (e.g., DSM-III-R), and (c) published in English. The search was conducted from 10th March, 2020 to 16th May, 2023. Selection was conducted in line with the PRISMA procedure [12], and the guidelines of the MOOSE group [13]. Figure 1 presents the literature search and selection process.



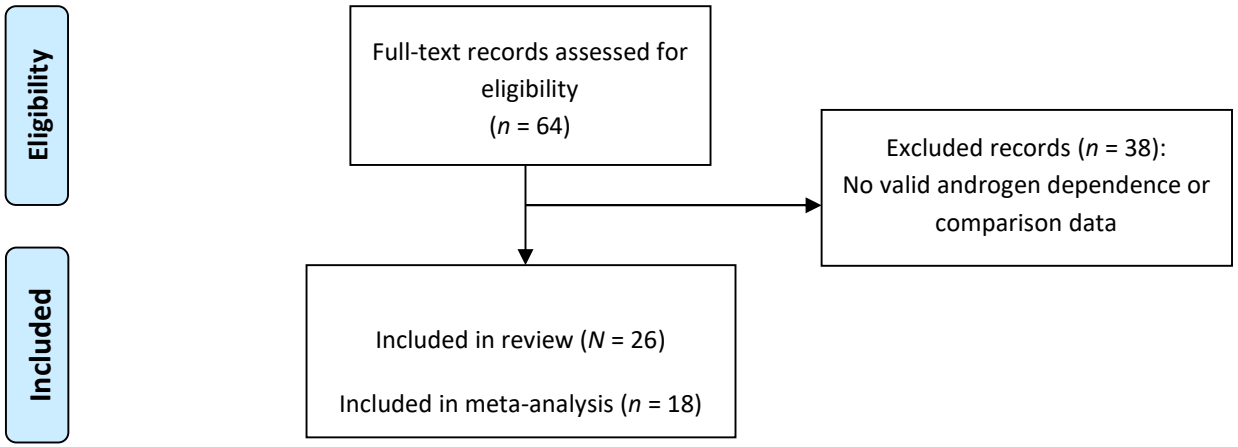


Figure 1. Flow diagram of systematic literature search on androgen dependence.

Data extraction and analysis

Using a standardized data extraction form, relevant data were extracted from the identified studies and coded (see Table 1). A meta-analysis was conducted to estimate the prevalence of androgen dependence. Heterogeneity was assessed using Cochran's Q and the I^2 statistic [14, 15]. Publication bias was investigated using Egger's test [16] and trim-and-fill [17], and study risk of bias using a checklist [18]. Two authors (JES, DS) independently conducted the risk of bias assessment and reached consensus on conflicting assessments through discussion. A random-effects model was used in the overall prevalence meta-analysis due to its propensity for higher external validity, whereas a fixed-effect model was used in the rest of the analyses due to the smaller number of studies [19, 20].

A meta-regression analysis was conducted to examine the correlates of the dependence prevalence. Here, dependence measure was not included due to multicollinearity feedback. Furthermore, using content analysis [21], evidence on the comparison/correlates of dependence were extracted and clustered under: demographic, biophysical, cognitive, emotional, and psychosocial. The interrater reliability was calculated using SPSS 28 (IBM Corp.), and publication bias, the meta-analysis and meta-regression analysis using CMA 4 (Biostat Inc.).

Table 1. Characteristics of studies on the prevalence and correlates of androgen dependence.

Study	Country	Sample	Assessment	Measure	*N*	M	F	Age range	Age *M*±*SD*	T Prev %	M Prev %	F Prev %	Correlates/comparison
Bjørnebekk 2016 [34]§	Norway	Weightlifters	I+Q	DSM-IV	82	82			33.0±8.2	53.7	53.7		AD < AND & ANU: Cerebral cortex, total gray matter, putamen. AD-OSD < AND & ANU: Cerebral cortex, total gray matter, putamen
Brennan 2011 [62]	USA	Weightlifters	I+Q	DSM-IV	100	100		18-40		31.0	31.0		
Brower 1991 [22]	USA	Weightlifters	Q	DSM-III-R	49	49			24.4±5.7	57.1	57.1		AD > AND: Cycles, maximum dose, feeling not big enough, aggression symptoms
Clancy 1992 [63]‡	USA	Weightlifters	Q	DSM-III-R	68	64	4			69.1			
Copeland 2000 [64]	Australia	Athletes and weightlifters	I+Q	DSM-IV	100	94	6	18-50	29.2±6.9	23.0	22.3	33.3	
de Zeeuw 2023 [23■■]	The Netherlands	Gym visitors	Q	DSM-V	103	103			31.2±9.3	24.3	24.3		AD > AND: training per week (mins), recreational athletes, androgen use (weeks), average androgen dose (mg/week), oral androgens (weeks), injectable androgen (weeks), past year

												nonmedical insulin and/or DNP use, side effects.
Ganson 2023 [24■■]	Canada	Adolescents and young adults	Q	DSM-V	44	36	8	16-30	26.4±3.4	23.1		
Goudy 1995 [65]	USA	Weightlifters	Q	DSM-III-R	3					66.7		
Gridley 1994 [29]	Australia	Gym exercisers	Q	DSM-III-R	21	21		25-30		57.1	57.1	AD > AND: Less knowledge of effects, polypharmacy, total number of cycles, use duration, weeks off cycle, weeks on cycle
Griffiths 2018 [38]	Australia	Exercisers and weightlifters	I	DSM-IV (SDS)	74	74						AD > AND: Social physique anxiety
Hauger 2019 [26]§	Norway	Weightlifters	I+Q	DSM-IV	83	83				54.2	54.2	AD > AND > ANU: antisocial personality. AD < AND: Fear recognition [unadjusted/adjusted for antisocial personality; anxiety; depression; IQ; OSD], IQ. AD > AND: ADHD, Anxiety, avoidant personality, depression, side effects (cognitive, physical, psychological), somatic problems, years of use. AD < ANU: Education, emotion recognition, fear recognition (unadjusted and adjusted for IQ), IQ AD > ANU: ADHD, anxiety, avoidant personality, depression, OSU, somatic problems, T/E ratio, weight (kg)
Hauger 2019 [35]§	Norway	Weightlifters	I+Q	DSM-IV	81	81				46.9	46.9	AD > AND: Aggression, anxiety, attention problems, blood pressure, depression, irritability, liver-related issues,

											memory problems, sexual dysfunction, side effects (cognitive, physical, psychological), sleep problems, total intra- and interpersonal problems, years of use.
Hauger 2020 [27■■]§	Norway	Weightlifters	I+Q	DSM-IV	96	96			60.4	60.4	AD < AND: acumbens, appetite, cortical thickness (unadjusted and excluding OSU), sex drive AD < AND & ANU: Education years, IQ. AD > AND: weekly dose, years of use. AD < ANU: [unadjusted: inhibition; adjusted for OSU: lower psychological distress, lower ADHD symptoms, problem-solving, working memory, mental flexibility, executive function]. AD < AND: [adjusted for OSU: executive function, lower psychological distress, lower ADHD symptoms]
Hildebrandt 2014 [36]	USA	Exercisers and weightlifters	I+Q	DSM-IV-TR	16	16	23-52	35.6±8.8			AD > AND: β-endorphin levels
Ip 2012 [30]	USA	Exercisers and weightlifters	Q	DSM-IV-TR	479				23.4		AD > AND: androgen types, Anxiety, depression, doses, duration of use, last 12 months' heroin use, married and not single, PEDs, psychiatric diagnosis, side effects, concern for side effects on long-term health

Kanayama 2003 [31]	USA	Substance users in treatment	I	DSM-IV	24	24			32.1±8.2	20.8	20.8		AD > AND: Duration of use. AD: androgen use is a gateway to opioid use
Kanayama 2009 [10]	USA	Weightlifters	I+Q	DSM-IV (AIM)	62	62		18-40		32.3			AD > AND & ANU: first degree relative with OSD, age, cocaine dependence, conduct disorder, more muscular, opioid abuse or dependence, OSD, AD < AND & ANU: Educational attainment AD > AND: Doses, duration of use, other PED use, single parent by age 13 AD > ANU: Body dysmorphic disorder
Malone 1995 [60]	USA	Weightlifters	I	DSM-III-R	77	71	6			14.3	14.1 †	16.7 †	
Midgley 1999 [66]	Scotland	Athletes, exercisers, and weightlifters	I+Q	DSM-III-R	50					26.0			
Perry 2005 [32]	USA	Athletes, exercisers, and weightlifters	Q	DSM-IV-TR	206				27.2±7.2	33.0			AD > AND: Stacking cycle length
Pope 2010 [33]	UK	Weightlifters	I	DSM-IV (AIM)	42	42		18-43	28.1±6.8	45.2	45.2		AD > AND: Age, doses, duration of use, hypothetical purchase of androgen, other PED use, perceived negative effects of androgen on mental health, sexual performance, and social life AD < AND: androgen initiation age
Pope 2014 [11]	USA	Weightlifters	I	DSM-IV (AIM)	102	102				36.3	36.3		

Scarth 2023 [25■■]§	Norway	Weightlifters	I+Q	DSM-IV (SCID-II)	153	153		35.78±9.95				Major dependence symptoms: continuing use despite physical and mental problems, longer use than planned, tolerance, work/life interference
Thiblin 1997 [67]	Sweden	Violent offenders	I	DSM-III-R	9				22.2			AD: Depression and suicide attempt upon withdrawal
Vaskinn 2020 [28■]§	Norway	Weightlifters	I+Q	DSM-IV	51	44	7		54.3	56.4	43.8	AD < AND & ANU: Education, IQ, OSU. AD < AND: Side effects (cognitive, physical, psychological), years of use. AD < ANU: affective ToM, cognitive ToM, overmentalizing/undermentalizing errors, total ToM
Westlye 2017 [37]§	Norway	Weightlifters	I+Q	DSM-IV	66	66			54.5	54.5		AD < AND & ANU: Brain connectivity in emotional and cognitive regulation (amygdala and default-mode network; dorsal attention network and frontal node)

AD: Androgen dependents. AD-OSD: Androgen dependents without other substance dependence. AIM: AAS Interview Module. AND: Androgen non-dependents. ANU: Androgen non-users. DNP: 2,4-dinitrophenol. DSM: Diagnostic and Statistical Manual of Mental Disorders. FPE: Forensic psychiatric evaluation. HGH: Human growth hormone. IGF-1: Insulin-like growth factor-1. I: Interview. I+Q: Interview and questionnaire. MASC: Movie for the Assessment of Social Cognition test. MDI: Muscle Dysmorphia Inventory. OSD: Other substance dependence. OSU: Other substance use. PED: Performance enhancing drugs. Prev: Prevalence. Q: Questionnaire. RR: Response rate. SCID: Structured Clinical Interview for DSM-IV. SDS: Severity of Dependence Scale. ToM: Theory of mind. §: Sample overlap. ‡in Brower et al. [22]. †In Kanayama et al. [61].

RESULTS

What are the characteristics of empirical studies on androgen dependence?

Description of studies

Of the 26 included studies, publication years range from 1991 [22] to 2023 [23▪▪–25▪▪]. Most studies were conducted in USA (*n* = 11), Norway (*n* = 7), and Australia (*n* = 3). Samples comprised predominantly weightlifters, exercisers, and athletes. Assessment methods comprised interviews and questionnaires (*n* = 12), interviews only (*n* = 6), and questionnaires only (*n* = 8). Androgen dependence was assessed using the DSM-III-R (*n* = 7), DSM-IV (*n* = 14), DSM-IV-TR (*n* = 2), and DSM-V (*n* = 2). The studies included a total of 1782 participants (range: 3 to 479, *M* = 89.10, *SD* = 23.36). Of this sample, 1011 were specified as males and 31 as females. Table 1 presents further characteristics of included studies.

Publication bias

There was no publication bias (Egger's *B*0 = 1.47, 95% CI: -1.38–4.33, *t* = 1.09, *p* (1-tailed) = .15). Similarly, the trim-and-fill procedure imputed no study and did not change the overall prevalence estimate.

Risk of bias

Table 2 presents results of the risk of bias assessment. All studies were evaluated as of moderate risk of bias. The inter-reviewer reliability kappa was 0.63 ($p < .001$) indicating substantial agreement between the two reviewers.

‡in Brower et al. [22]. †In Kanayama et al. [61].

Table 2. Risk of bias/methodological quality (Hoy et al., 2012) of included studies.

Study	1. *N* representativeness	2. *N* frame	3. Randomization	4. Non-response bias	5. Primary data	6. Operationalization	7. Instrument	8. Consistency	9. Period	10. Estimation	Total risk score	Risk category✓
Bjørnebekk 2016 [34]§	1	1	1	1	0	0	0	0	0	0	4	Moderate
Brennan 2011 [62]	1	1	1	1	0	0	0	0	1	0	5	Moderate
Brower 1991 [22]	1	1	1	1	0	0	0	0	1	0	5	Moderate
Clancy 1992 [63]‡	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copeland 2000 [64]	1	1	1	1	0	0	0	0	1	0	5	Moderate
de Zeeuw 2023 [23■■]	1	1	1	1	0	0	0	0	0	0	4	Moderate
Ganson 2023 [24■■]	0	0	1	1	0	1	0	0	1	0	4	Moderate
Goudy 1995 [65]	1	1	1	1	0	0	0	0	0	0	4	Moderate
Gridley 1994 [29]	1	1	1	1	0	0	0	0	1	0	5	Moderate
Griffiths 2018 [38]	1	1	1	1	0	0	0	0	1	1	6	Moderate
Hauger 2019 [26]§	1	1	1	1	0	0	0	0	0	0	4	Moderate
Hauger 2019 [35]§	1	1	1	1	0	0	0	0	0	0	4	Moderate
Hauger 2020 [27■■]§	1	1	1	1	0	0	0	0	0	0	4	Moderate
Hildebrandt 2014 [36]	1	1	1	1	0	0	0	0	1	1	6	Moderate
Ip 2012 [30]	1	1	1	1	0	0	0	0	1	0	5	Moderate
Kanayama 2003 [31]	1	1	1	0	0	0	0	0	1	0	4	Moderate
Kanayama 2009 [10]	1	1	1	1	0	0	0	0	1	0	5	Moderate
Malone 1995 [60]	1	1	1	1	0	0	0	0	0	0	4	Moderate
Midgley 1999 [66]	1	1	1	1	0	0	0	0	0	0	4	Moderate
Perry 2005 [32]	1	1	1	1	0	0	0	0	1	0	5	Moderate
Pope 2010 [33]	1	1	1	1	0	0	0	0	1	0	5	Moderate
Pope 2014 [11]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scarth 2023 [25■■]§	1	1	1	1	0	0	0	0	0	1	5	Moderate
Thiblin 1997 [67]	1	1	1	1	0	0	0	0	0	0	4	Moderate
Vaskinn 2020 [28■]§	1	1	1	1	0	0	0	0	0	0	4	Moderate
Westlye 2017 [37]§	1	1	1	1	0	0	0	0	0	0	4	Moderate

Item score: (0: low risk, 1: high risk). ✓Total quality/risk score: (range [0–10]: high quality/low risk [0–3], moderate quality/risk [4–6], poor quality/high risk [7–10]). ‡In Brower (2002). §: Sample overlap. NA: Not applicable. Primary document not available.

What is the prevalence of androgen dependence?

Table 3 presents the overall, sex, regional, assessment, measure, and publication year prevalence estimates, 95% confidence intervals, and heterogeneity statistics.

Table 3. Number of studies, prevalence rates, 95% confidence intervals, and heterogeneity statistics

	N	Prevalence (%)	95% CI	*Q*	I^2
Overall	18	34.4**	27.8–41.7§	113.1**	85.0
Sex					
Male	10	36.1**	32.3–40.1	54.9**	83.6
Female	3	37.0^{ns}	21.0–56.5	1.3^{ns}	0.0
Region					
Europe	5	36.9**	31.3–43.0	20.9**	80.9
North America	11	31.0**	28.4–33.8	79.5**	87.4
Oceania	2	29.5**	21.7–38.7	8.9*	88.8
Assessment					
Interview	5	30.9**	25.2–37.2	15.9*	74.8
Questionnaire	8	31.5**	28.5–34.6	75.9**	90.8
Interview and questionnaire	5	33.8**	29.1–38.8	20.5**	80.5
Measure					
DSM-III-R	7	$44.4^{ns\ abc}$	37.9–51.2	51.8**	88.4
DSM-IV	7	$35.5^{**\ ade}$	31.4–39.9	23.0*	73.8
DSM-IV-TR	2	$26.5^{**\ bd}$	23.3–29.9	6.8*	85.4
DSM-V	2	$23.8^{**\ ce}$	17.6–31.4	0.0^{ns}	0.0
Publication year					
1990–1999	7	$44.4^{ns\ fg}$	37.9–51.2	51.8**	88.4
2000–2009	4	$29.9^{**\ f}$	25.5–34.6	4.3^{ns}	30.0
2010–2023	7	$29.7^{**\ g}$	26.8–32.8	39.1**	84.7

** $p < .001$, * $p < .01$. *Q*: heterogeneity statistic. I^2: heterogeneity index.
§95% PI: 13.0–65.0.
Categories sharing a superscript are significantly different ($p < .05$).

Overall

The overall lifetime prevalence of androgen dependence from the 18 included studies was 34.4% (95% CI: 27.8–41.7, 95% PI: 13.0–65.0, $Q = 113.1$, $I^2 = 85.0$, $p < .001$). Figure 2 presents the forest plot of the overall lifetime prevalence.

Study name	Event rate	Lower limit	Upper limit	Z-Value	p-Value
Bjørnebekk 2016	0.537	0.429	0.641	0.662	0.508
Brennan 2011	0.310	0.227	0.407	-3.700	0.000
Brower 1991	0.571	0.431	0.701	0.997	0.319
Clancy 1992	0.691	0.572	0.789	3.069	0.002
Copeland 2000	0.230	0.158	0.322	-5.085	0.000
de Zeeuw 2023	0.243	0.170	0.335	-4.951	0.000
Ganson 2023	0.227	0.127	0.373	-3.402	0.001
Goudy 1995	0.667	0.154	0.957	0.566	0.571
Gridley 1994	0.571	0.360	0.760	0.652	0.514
Ip 2012	0.234	0.198	0.274	-10.994	0.000
Kanayama 2003	0.208	0.089	0.413	-2.656	0.008
Kanayama 2009	0.323	0.219	0.448	-2.731	0.006
Malone 1995	0.143	0.081	0.240	-5.502	0.000
Midgley 1999	0.260	0.157	0.398	-3.244	0.001
Perry 2005	0.330	0.269	0.397	-4.777	0.000
Pope 2010	0.452	0.310	0.603	-0.616	0.538
Pope 2014	0.363	0.275	0.460	-2.736	0.006
Thiblin 1997	0.222	0.056	0.579	-1.562	0.118
	0.344	0.278	0.417	-4.069	0.000

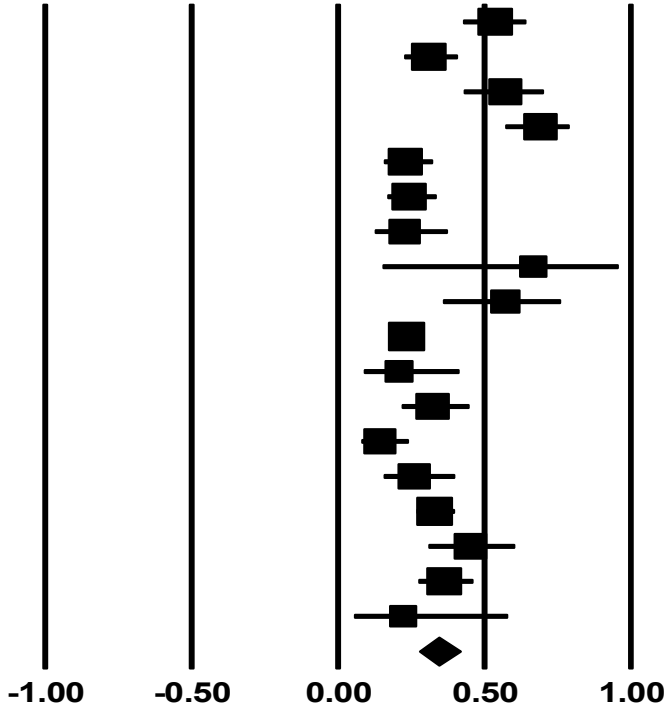


Figure 2. Forest plot of the lifetime prevalence (random-effects) of androgen dependence.

Sex

The dependence prevalence estimates for males (36.1%, $p < .001$) and females (37.0%, $p = .188$) were not different ($Q = 0.0$, $p = .930$).

Regions

From Table 3, Europe had a prevalence rate of 36.9%, North America had a prevalence rate of 31.0%, and Oceania had a prevalence rate of 29.5%. There were no significant differences in prevalence rates between the regions.

Assessment

Studies using interviews as a method of assessment had a prevalence of 30.9%, studies based on questionnaires had a prevalence of 31.5%, and studies applying both interviews and questionnaires had a prevalence of 33.8%. The three assessment methods did not significantly differ in prevalence rates.

Dependence measure

From Table 3, DSM-III-R as a measure had a prevalence of 44.4%, DSM-IV had a prevalence of 35.5%, DSM-IV-TR had a prevalence of 26.5%, and DSM-V had a prevalence of 23.8%. Subgroup comparisons showed higher DSM-III-R prevalence compared to DSM-IV ($Q = 5.0$, $p < .05$), DSM-IV-TR ($Q = 24.0$, $p < .001$), and DSM-V ($Q = 15.6$, $p < .001$) prevalences. Additionally, DSM-IV prevalence was higher than DSM-IV-TR ($Q = 10.9$, $p < .01$) and DSM-V ($Q = 6.9$, $p < .01$) prevalences.

Publication year

The estimated prevalence of androgen dependence across different time periods are listed in Table 3. Specifically, publications from 1990–1999 exhibited a prevalence of 44.4%, which was significantly higher than the estimated prevalence of 29.9% from 2000–2009 ($Q = 12.7$, $p < .001$), and of 29.7 % from 2010–2023 ($Q = 16.9$, $p < .001$).

What are the correlates of androgen dependence prevalence?

Table 4 presents results of the fixed effect meta-regression analysis of the correlates of androgen dependence prevalence. The model was significant ($Q = 35.28$, $df = 7$, $p < .001$). Higher study male sample proportion was related to higher dependence prevalence ($B = 0.11$, $p < .01$). Compared to interview-only dependence assessment, assessments that combined interviews and questionnaires were associated with higher dependence prevalence ($B = 0.45$, $p < .05$). Furthermore, 2000–2009 ($B = -1.45$, $p < .001$) and 2010–2023 ($B = -1.18$, $p < .01$) publications showed lower dependence prevalences in comparison to 1990–1999 publications.

Table 4. Meta-regression analysis (fixed effect) of the correlates of androgen dependence prevalence.

Predictor	*B*	SE	95% CI	*Z*	*p*
Male sample proportion (%)	0.11	0.04	0.03–0.18	2.6	.009
Region					
Europe§					
North America	-0.24	0.23	-0.68–0.21	-1.06	.291
Oceania	-0.17	0.36	-0.87–0.54	-0.46	.644
Assessment					
Interview§					
Questionnaire	0.14	0.26	-0.38–0.65	0.53	.597
Interview and questionnaire	0.45	0.21	0.04–0.86	2.17	.030
Publication year					
1990–1999§					
2000–2009	-1.45	0.35	-2.14–-0.75	-4.08	.000
2010–2023	-1.18	0.35	-1.86–-0.49	-3.36	.001

§: Reference category.

What are the correlates of androgen dependence?

Table 5 presents results of the comparison of androgen dependents to nonusers as well as nondependents.

Table 5. Summary of correlates/comparison of androgen dependence.

	Correlates/comparison		Correlates/comparison	
Domain	Dependents > nonusers	References	Dependents > nondependents	References
Demographic	Lower (age, educational attainment, education years, IQ), weight (kg) muscularity, weekly dose, years of use	[10, 24■■, 26–28■]	Androgen types used, age, cycles, doses, hypothetical androgen purchase, lower (androgen use initiation age, educational attainment, education years, IQ, knowledge of effects), married and not single, maximum dose, muscularity, recreational athletes, single parent by age 13, stacking cycle length, training per week (mins), use duration, weekly dose, weeks off cycle, weeks on cycle, years of use	[10, 22, 23■■, 26–33]
Biophysical	Lower (cerebral cortex, total gray matter, putamen), somatic problems, T/E ratio	[10, 26, 28■, 34]	β-endorphin levels, blood pressure, liver-related issues, lower (acumbens, appetite, brain connectivity [amygdala and default-mode network, dorsal attention network and frontal node], cerebral cortex, cortical thickness [unadjusted and excluding OSU], total gray matter, putamen), somatic problems, physical side effects, sex drive, sexual dysfunction	[10, 28■, 34–37]
Cognitive	Lower problem-solving, working memory, mental flexibility, executive function	[27■■, 28■, 37]	Attention problems, cognitive side effects, lower (affective ToM, cognitive regulation, executive function [adjusted for OSU], cognitive ToM, overmentalizing/undermentalizing errors, total ToM), memory problems	[26–28■, 35, 37]
Emotional	Lower emotional regulation, emotion recognition, fear recognition (unadjusted/adjusted for IQ)	[26, 37]	Lower fear recognition (unadjusted/adjusted for antisocial personality; anxiety; depression; IQ; OSD), lower emotional regulation, irritability	[26, 35, 37]
Psychosocial	ADHD symptoms (adjusted for OSU), antisocial personality, anxiety symptoms, body dysmorphic disorder, cocaine dependence, conduct disorder, depression symptoms, first degree	[10, 23■■, 24■■, 26–28■]	ADHD symptoms and psychological distress (adjusted for OSU), ADHD symptoms, aggression symptoms, antisocial personality, anxiety symptoms, avoidant personality, cocaine dependence, concern for side effects on long-term health, conduct	[10, 22, 23■■, 25■■–31, 33, 35, 38]

relative with OSD, lower inhibition, opioid abuse/dependence, OSD, OSU, psychological distress (adjusted for OSU), violent behavior	disorder, continuing use despite physical and mental problems, depression symptoms, feeling not big enough, first degree relative with OSD, intra- and interpersonal problems, past year heroin use, past year nonmedical insulin and/or DNP use, longer use than planned, lower inhibition, opioid abuse/dependence, other PED use, OSD, perceived negative effects of androgen use on mental health, sexual performance and social life, polypharmacy, psychiatric diagnosis, psychological side effects, sleep problems, social physique anxiety, tolerance, work/life interference

DNP: 2,4-dinitrophenol. OSD: Other substance dependence. OSU: Other substance use. PED: Performance enhancing drugs. ToM: Theory of mind.

Demographics

Compared to nonusers and nondependents, dependents were among others, older, more likely to have had a single parent by the age of 13, and to be recreational athletes, and had higher levels of fat-free muscle mass. They also had lower educational attainment and IQ, lower androgen initiation age, used higher doses and variety of androgens, had longer cycle durations, and had lower knowledge of androgen effects [10, 22–24▪▪, 26–33].

Biophysical

Compared to nonusers, dependents had lower brain volumes including the cerebral cortex, putamen, and total grey matter. They exhibited higher levels of somatic problems, and higher testosterone/epitestosterone (T/E) ratio [10, 26, 28▪, 34]. Compared to nondependents, dependents showed higher β-endorphin levels, blood pressure and liver-related issues. They also displayed lower levels of appetite, and lower brain connectivity (amygdala and default-mode network, dorsal attention network and frontal node). Additionally, dependents had thinner cortex in widespread regions specifically in pre-frontal areas, more somatic problems, physical side effects, increased sex drive and sexual dysfunction [10, 28▪, 34–37].

Cognitive

Dependents had, compared to nonusers, lower executive abilities including problem-solving skills, working memory, and mental flexibility [27▪▪, 28▪, 37]. Additionally, dependents self-reported more memory problems and scored higher (indicative of more impairments) on measures of executive function in everyday life. Furthermore, dependents showed impaired theory of mind on both affective and cognitive content [26–28▪, 35, 37].

Emotional

Compared to nonusers, dependents scored lower on emotional regulation, overall emotion recognition and fear recognition irrespective of IQ [26, 37]. Compared to nondependents, dependents were associated with lower level of fear recognition irrespective of antisocial personality, anxiety, depression, IQ, and other substance dependence, as well as lower levels of emotional regulation, and higher levels of irritability [26, 35, 37].

Psychosocial

Compared to nonusers and nondependents, dependents had higher prevalences of ADHD symptoms and psychological distress irrespective of other substance use. Dependents likewise had higher prevalences of aggression symptoms, antisocial personality disorder, symptoms of anxiety, avoidant personality disorder, and cocaine dependence. Dependents also showed higher conduct disorder, continuation of androgen use despite the experience of physical and mental problems, symptoms of depression, more feelings of not being big enough, and higher concern for side effects of androgens on their long-term health compared to nondependents. Additionally, dependents were more likely to have a first degree relative with other substance disorder, have intra- and interpersonal problems, have used heroin and insulin and/or DNP use in the past year, and have a longer androgen use than planned in comparison to nondependents. Moreover, dependents exhibited lower levels of inhibition, higher levels of opioid abuse or dependence and other performance-enhancing drug use, other substance disorder, and polypharmacy compared to nondependents. Furthermore, dependents reported more perceived negative effects of androgens on their mental health, sexual performance, and social life than nondependents [10, 22, 23■■, 25■■–31, 33, 35, 38].

DISCUSSION

Prevalence of androgen dependence

The overall lifetime prevalence of androgen dependence obtained from the meta-analysis (34.4%) is similar to the previously reported 32.5% estimate [11] despite limitations previously noted. In support of the overall prevalence estimate, no significant differences were observed in prevalence rates across sex, geographical regions, and assessment methods. The downtrend of the dependence prevalence rates by publication year is explainable by historical trends in androgen use and legislation. The 1970s and 1980s were characterized by the proliferation of magazines and underground guides on androgen use, the availability of androgens as prescription drugs, and loose regulation of androgens [3, 40–42]. Indeed, a global meta-analysis [9] found the 1970s (9.2%) as having a higher lifetime prevalence of androgen use compared to the 1990s (2.9%). It is therefore plausible that the higher dependence prevalence in 1990–1999 reflects the user group of the 1970s and 1980s who had a riskier user pattern in an environment characterized by higher levels of availability and less regulation of androgens by authorities [3, 42].

Relatedly, during the 1990s, concerns regarding androgen use led to legislation enactments such as the 1990 US Steroid Trafficking Act, and the 1991 Swedish Act Prohibiting Certain Doping Substances [42, 43]. It is reasonable to assume that these legislative actions, combined with increasing awareness of the potential harms associated with androgen use as evidenced by accumulating research [44, 45], contributed to a decrease in the availability of androgens and generated an apprehension regarding the legal and health risks associated with use. Consequently, this historical context, including legislation and growing apprehension, may explain the downtrend in the dependence prevalence rates observed in 2000–2009 and 2010–2023, and potentially the downtrend of the dependence prevalence rates by dependence measure considering the publication of the DSM-III-R in 1987, the DSM-IV in 1994, the DSM-IV-TR in 2000, and the DSM-V in 2013 [46–49]. Relatedly, it is noteworthy that in the most recent version of the DSM-V [49], there has been

a merger of “substance abuse” and “dependence” into “substance use disorder” with mild, moderate, and severe levels. In this regard, the call for clarity on the DSM-V criteria for androgen dependence assessment [50] is warranted.

Correlates of androgen dependence prevalence

Our finding that higher study male sample proportion is associated with higher dependence prevalence is in line with previous meta-regression results on androgen use prevalence [9] and the truism in the field. Additionally, the finding that combined interview and questionnaire dependence assessments generate higher dependence prevalence compared to dependence assessment using only interviews may be explained by the advantages of mixed-mode survey designs over unimode survey designs such as reduced nonresponse and error, and triangulation potential [51–53]. Furthermore, the association of publications from 2000–2009 and 2010–2023 with lower dependence prevalence relative to 1990–1999 publications is consistent with the results of our meta-analysis subgroup comparisons, and understandable from the previously explained historical and legal contexts [3, 42, 54].

Correlates of androgen dependence

The younger age of dependents compared to nonusers can be interpreted with meta-analytic results indicating higher prevalence among persons 19 years and younger (2.5%) compared to 1.9% for those older than 19 years [9], and meta-analytic evidence that about 80% of androgen users initiate use before age 30 [11]. Dependents’ lower educational attainment may also be explained by problem behavior theory and its proposed problem behavior syndrome [5]. Also, the finding that androgen dependents are heavier and more muscular may reflect the anabolic benefits of androgen use [55, 56].

The older age of dependents compared to nondependents can be explained by the criteria for meeting dependence diagnosis such as the duration of the dependent user pattern for at least 12 months [49, 57]. The older age of dependents also explains their higher

proportion of married and not single persons compared to the nondependents. The findings of younger androgen use initiation age, and lower educational attainment, education years, IQ, and knowledge of androgen effects can also be interpreted in light of problem behavior theory [5] as explained previously. Additionally, the higher proportion of recreational athletes in dependents compared to nondependents is in line with meta-analytic evidence [9] showing that recreational athletes constitute the largest subgroup of androgen users, which is understandable from an anti-doping perspective [58]. Also, the identified androgen use characteristics such as more types of androgens used and higher doses among dependents compared to nondependents is in line with the body image [2, 3] and allostatic [4] models of androgen dependence.

Altogether, the consistent higher association of dependents with a wide array of demographic inequalities and impaired functioning compared to nonusers and nondependents is explainable in light of problem behavior theory [5], the body image [2, 3], and allostatic [4] models of androgen dependence. For instance, from an allostatic paradigm [4], the long-term androgen use and exercise combination over time may lead to allostatic overload and related biophysical syndromes such as liver toxicity, reduced brain connectivity, and sexual dysfunction [4, 10, 35].

Implications, strengths and limitations

The high lifetime prevalence of androgen dependence found in our study is concerning and emphasizes the urgent need for targeted preventive, harm reduction and treatment interventions. Preventive efforts highlighting the substantial evidence of the high prevalence of androgen dependence and associated syndromes can be effective in deterring initiation. A recent qualitative study [59] identified barriers among androgen users (e.g., riskiness of disclosure) and healthcare professionals (e.g., lack of knowledge, guidelines, and resources) regarding healthcare access and provision for androgen users.

Addressing these factors can foster sustained clinical interaction between androgen users and healthcare professionals, leading to effective harm reduction and treatment.

The present study has several strengths such as the systematic literature search, risk of bias assessment, and multifaceted data analysis. However, some limitations of the study are noteworthy. The overrepresentation of males in the meta-analysis is noteworthy. Indeed, female dependence prevalence was reported in only two studies [28▪, 64] with personal communication dependence data [60] in a third study [61]. Similarly, we included only publications in English, and only studies from Europe, North America and Oceania were identified in the search. Additionally, all studies were assessed as of moderate risk of bias with notable limitations relating to the lack of nationally representative samples, non-random sample selection, reliance on self-reports, and lifetime prevalence estimation. Our findings may thus be subject to the above limitations associated with the included studies.

We were also unable to meta-analyse the correlates data due to sparsity and therefore used qualitative synthesis. Moreover, the included studies are cross-sectional which makes conclusions about causality and directionality of the findings difficult. Future research addressing the limitations noted above and incorporating longitudinal, qualitative, genetic, registry, family studies and other designs may be useful in further exploration of the topic. Furthermore, our use of "dependence" instead of "substance use disorder" as denoted in DSM-V [49] is for text fidelity. It is noteworthy that the call for examination of the DSM-V criteria is overdue [50] as a step towards clarification and scientific consensus on the assessment of this phenomenon.

CONCLUSIONS

Despite some limitations, the results of the present suggests that about 1 of 3 persons who initiate androgen use experience an androgen dependence syndrome. Dependents experience a wide array of demographic inequalities as well as impaired functioning. These reduce their

quality of life and have been implicated in premature mortality among this population. Thus, androgen use and dependence should be regarded an important public health issue. Targeted health interventions are required to prevent androgen use initiation, and to prevent, reduce, and treat dependence and associated disorders among androgen users.

KEY POINTS

- The estimated lifetime prevalence of androgen dependence for 1782 users is 34.4%.
- Although males and females do not differ in dependence prevalence, higher study male sample proportion predicts higher dependence prevalence.
- Combined interview and questionnaire assessments generate higher dependence prevalence compared to interviews only.
- Publications from 1990–1999 report higher dependence prevalence compared to 2000–2009 and 2010–2023 publications.
- Androgen dependence is associated with several demographic inequalities, and lower biophysical, cognitive, emotional, and psychosocial functioning.

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