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Economic and equity evaluation of age restrictions on over-the-counter diet pills and muscle-building supplements

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Abstract

Over-the-counter diet pills and muscle-building supplements are linked to increased eating disorder diagnoses, especially among youth. With limited regulatory oversight, minors may unknowingly consume harmful substances leading to other adverse effects. Massachusetts has proposed restricting sales to individuals under 18 years. However, concerns about health equity and unintended consequences arise when proposing new policies. We conducted a cost-effectiveness analysis of the proposed age-restriction policy compared to the status quo, focusing on 2 closed cohorts of males and females aged 0-17 years in Massachusetts over a 30-year time horizon. We evaluated the impact from both societal and health systems' perspectives and further assessed equity implications by modeling 3 racial/ethnic subgroups. The policy is projected to prevent 57 034 eating disorder cases and over 46 000 additional adverse medical events (eg, liver injuries). It would yield 51 749 quality-adjusted life years and generate healthcare savings of $14 million and societal savings of $30 million annually. The Latine subpopulation would see the highest per capita health benefits followed by Black and White residents, respectively. Restricting the sale of these supplements to minors offers both health and economic benefits. These findings underscore the policy's effectiveness, fiscal responsibility, and positive equity impacts, providing confidence for policymakers and the public.

Lay summary

Over-the-counter diet pills and muscle-building supplements are linked to increased eating disorder diagnoses, especially among youth, as well as other harms such as liver and kidney injury. In part that is because there is limited regulatory oversight, so users can unintentionally consume harmful substances. Massachusetts has proposed restricting sales to individuals under 18 years, but with any new proposal, policymakers and people want to know how much it will cost and will it increase health disparities. We investigated using both economic- and equity-related methods. We found that the policy would not just be cost-effective; it would save both the healthcare system and society money from preventing more than 100 000 adverse medical events (eg, eating disorder cases and liver injuries). Healthcare savings would be $14 million per year, and societal savings would be closer to $30 million annually. Latine residents would see the highest increase in overall health, followed by Black and White residents, respectively. In short, restricting the sale of these supplements to minors offers both health and economic benefits.

Key words: eating disorders; prevention; health policy; distributional cost-effectiveness analysis; health equity; adverse medical events; diet pills; muscle-building supplements; economic evaluation; adolescent health; public health policy; cost-effectiveness analysis.

Introduction

Eating disorders (ED) account for over 10 000 deaths, 33 000 hospital admissions, and over $64 billion in costs to the economy annually in the United States.[1] These psychiatric conditions greatly influence individuals' health-related quality of life. Considering that more than half receive their first diagnosis of eating disorders by the age of 18 years, primary prevention plays a crucial role in reducing their prevalence and alleviating the economic burdens they impose.[1]

Over-the-counter (OTC) diet pills, which include the OTC drug orlistat and myriad weight-loss supplements, and muscle-building dietary supplements (MBS) face little regulation and are prospectively linked with eating disorder diagnoses and other adverse medical events (AEs), including organ

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failure, heart attacks, and the use of illegal muscle-building drugs such as anabolic-androgenic steroids (AAS).[2-5] Studies have suggested racial and ethnic disparities in the use of OTC diet pills, muscle-building supplements, and anabolic steroids, with some studies reporting disproportionately high prevalence among Black/African American and Latine/Hispanic individuals.[6-8] Disparities are likely driven in part by industry marketing practices that target racially minoritized populations.[9-11]

Limited federal regulatory oversight of dietary supplements puts youth at risk of unknowingly consuming banned substances and hazardous chemicals.[2,12] Restructuring accessibility to OTC diet pills and muscle-building supplements via an age-restriction policy, therefore, has the potential to reduce the upward trend in ED among youth through young adulthood. Several US states, including Massachusetts (MA), have proposed age restrictions to ban the sale of OTC diet pills and muscle-building supplements to minors under 18 years.[13] The proposed legislation aims to regulate these products purchased within the respective state to behind-the-counter status, a regulatory measure akin to those already implemented for harmful substances such as tobacco and pseudoephedrine. The state of New York recently passed a similar bill into law, which became effective in April 2024.[14]

Critiques of health economics[15] call for a greater awareness of unintentional widening of health inequities by health interventions. Distributional cost-effectiveness analysis (DCEA) is a methodology used to assess the differential effects on various segments of a population.[16,17] This approach extends the traditional cost-effectiveness analysis (CEA) by considering not only the overall efficiency and effectiveness of an intervention but also how its costs and benefits are distributed among subgroups within the population.

We conducted a CEA of the age-restriction policy aimed at preventing ED and other adverse medical events among youth in MA. Subsequently, we performed an aggregate DCEA to explore health equity implications based on the key equity variable of race/ethnicity.

Study design and data sources

This study was conducted to estimate economic and equity implications of the proposed age-restriction law for the health and financial wellbeing of all who live in MA. We compared the costs and effectiveness with the existing status quo, where no age-restriction law is in place. This study adhered to the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) 2022.[18]

Logic model

The logic model informing this study involves 2 main pathways (Figure 1). The first pathway posits that the implementation of the age-restriction policy would lead to fewer youths buying and using OTC diet pills, resulting in a reduction in the incidence of ED and other AEs. The second pathway depicts fewer youth buying and using muscle-building supplements, resulting in a reduction in immediate AEs and a reduction in youth initiating use of AAS, which leads to additional AEs avoided.

Study population

Using U.S. Census data from 2023, 2 total population cohorts were created for individuals aged 0 to 17 years old among the MA population—1 for females and 1 for males (Table 1). It was important to account for gender differences in the use of OTC diet pills, MBS, and AAS. We modeled these groups as closed cohorts over a 30-year period. The comparator is the same population under the status quo, that is, no age-restriction policy is implemented.

Intervention effectiveness

The effectiveness of the proposed policy on use of OTC diet pills and muscle-building supplements was estimated using parallel evidence from previous studies on age-restriction policies.[20,21]

Health outcomes

We estimated the health outcomes of this study along 2 pathways (Figure 1). Outcomes along the OTC diet pill pathway included number of ED avoided, number of other (non-ED) AEs prevented post-OTC diet pill use, and the gains in quality-adjusted life years (QALYs). The outcomes resulting from the MBS pathway included the number of AEs avoided post-MBS use, AEs avoided post-AAS use, and QALYs saved.

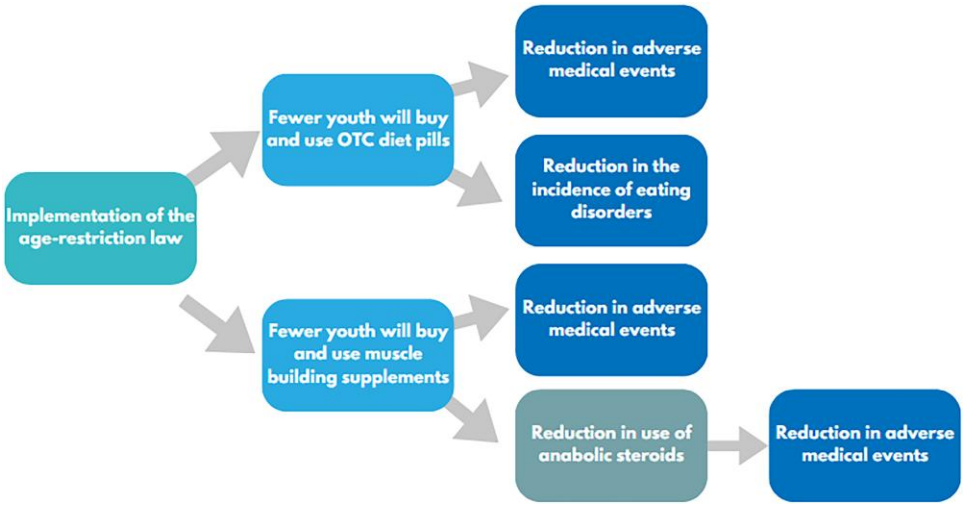

Figure 1. Logic model for the current study. Source: Authors' summary.

Table 1. Model inputs for cost-effectiveness and aggregate distributional cost-effectiveness analyses.

Variable	Value	Unit	Min	Max	Source
Values used in both pathways					
MA 0-17 years old population by gender					
CEA, all, female	685 577	N	n/a	n/a	US Census Bureau 2019[19]
CEA, all, male	658 692	N	n/a	n/a	US Census Bureau 2019[19]
DCEA, Black, female	65 130	N	n/a	n/a	US Census Bureau 2019[19]
DCEA, Black, male	62 576	N	n/a	n/a	US Census Bureau 2019[19]
DCEA, Latine, female	89 811	N	n/a	n/a	US Census Bureau 2019[19]
DCEA, Latine, male	86 289	N	n/a	n/a	US Census Bureau 2019[19]
DCEA, White, female	477 162	N	n/a	n/a	US Census Bureau 2019[19]
DCEA, White, male	458 449	N	n/a	n/a	US Census Bureau 2019[19]
Effectiveness of the intervention					
Reduction in use of OTC diet pills and MBS among study population	26	%	7	46	Friedman et al. 2021[20]; Long et al. 2022[21]
Incremental intervention costs per person	2.39	$	n/a	n/a	Long et al. 2022[21]
Diet pill pathway					
Prevalence of diet pill use, 0-17 years old					
CEA, all, female, 0-17 years old	14 579	N	n/a	n/a	US Census Bureau 2019[19]; Long et al. 2022[21]
CEA, all male, 0-17 years old	7674	N	n/a	n/a	US Census Bureau 2019[19]; Long et al. 2022[21]
DCEA, Black, female	1385	N	n/a	n/a	US Census Bureau 2019[19]; Long et al. 2022[21]
DCEA, Black, male	729	N	n/a	n/a	US Census Bureau 2019[19]; Long et al. 2022[21]
DCEA, Latine, female	2435	N	n/a	n/a	US Census Bureau 2019[19]; Long et al. 2022[21]
DCEA, Latine, male	1124	N	n/a	n/a	US Census Bureau 2019[19]; Long et al. 2022[21]
DCEA, White, female	9819	N	n/a	n/a	US Census Bureau 2019[19]; Long et al. 2022[21]
DCEA, White, male	5026	N	n/a	n/a	US Census Bureau 2019[19]; Long et al. 2022[21]
Prevalence of ED, MA					
Female, 0-17 years old	11 962	N	n/a	n/a	US Census Bureau 2019[19]; Long et al. 2022[21]; Streatfeild et al. 2021[1]
Male, 0-17 years old	4276	N	n/a	n/a	US Census Bureau 2019[19];Long et al. 2022[21]; Streatfeild et al. 2021[1]
Lifetime prevalence of ED at age 40 years					
Female	19.7	%	15.8	23.9	Ward et al. 2019[22]
Male	14.3	%	9.7	19	Ward et al. 2019[22]
Eating disorder duration					
AN, average duration regardless of treatment	2.5	years	1.7	25	Austin et al. 2021[23]; Hamilton et al. 2022[24]; Hudson et al. 2007[25]; Eddy et al. 2017[26]; Steinhausen et al. 2002[27]; Steinhausen et al. 2009[28]
BN, average duration regardless of treatment	8.3	years	4.4	25	Austin et al. 2021[23]; Hamilton et al. 2022[24]; Hudson et al. 2007[25]; Eddy et al. 2017[26]; Steinhausen et al. 2002[27]; Steinhausen et al. 2009[28]
BED, average duration regardless of treatment	10.4	years	5.6	25	Austin et al. 2021[23]; Hamilton et al. 2022[24]; Hudson et al. 2007[25]; Eddy et al. 2017[26]; Steinhausen et al. 2002[27]; Steinhausen et al. 2009[28]
OSFED, average duration regardless of treatment	5.3	years	3.7	25	Austin et al. 2021[23]; Hamilton et al. 2022[24]; Hudson et al. 2007[25]; Eddy et al. 2017[26]; Steinhausen et al. 2002[27]; Steinhausen et al. 2009[28]
Risk of developing AE post-OTC diet pill use					
Depression (female)	0.187	%	0.072	0.302	Patten 2005[29]
Depression (male)	0.130	%	0.044	0.215	Patten 2005[29]
Gastrointestinal pain	0.047	%	0.031	0.066	Geller et al. 2015[30]
Hypertension	0.132	%	0.100	0.297	Ahmed et al. 2019[31]
Liver injury	0.193	%	0.090	0.260	Navarro et al. 2014[32]
Suicidality	0.019	%	0.001	0.063	Ahmed et al. 2019[31]
Tachycardia	0.128	%	0.101	0.249	Ahmed et al. 2019[31]; Geller et al. 2015[30]
QALYs saved per AE post-OTC diet pill use					
Depression	0.129	N	0.033	1.045	ten Have et al. 2017[33]; GBD 2019 Diseases and Injuries Collaborators 2020[34]
Gastrointestinal pain	0.002	N	0.001	0.007	Ahmed et al. 2019[31]; GBD 2019 Diseases and Injuries Collaborators 2020[34]
Hypertension	0.025	N	0.001	1.080	NIH 2024[35]; GBD 2019 Diseases and Injuries Collaborators 2020[34]; Authors' estimate

(*continued*)

Table 1. Continued

Variable	Value	Unit	Min	Max	Source
Liver injury	0.025	N	0.008	0.091	Navarro et al. 2014[32]; GBD 2019 Diseases and Injuries Collaborators 2020[34]
Suicidality	0.587	N	0.159	3.228	Ahmed et al. 2019[31]; GBD 2019 Diseases and Injuries Collaborators 2020[34]
Tachycardia	0.015	N	0.005	0.063	Ahmed et al. 2019[31]; GBD 2019 Diseases and Injuries Collaborators 2020[34]
Cost per AE post-OTC diet pill use					
Tachycardia	3122	$	2066	6110	Dexter et al. 2011[36]
Hypertension	2507	$	2251	2764	Kirkland et al. 2018[37]
Liver injury	35 942	$	25 685	89 193	Henry Ford Health System 2011[38]
Gastrointestinal pain	1105	$	553	2211	Peery et al. 2019[39]; Geller et al. 2015[30]
Depression (female)	21 956	$	19 282	25 064	Kavelaars et al. 2023[40]
Depression (male)	21 956	$	19 282	25 064	Kavelaars et al. 2023[40]
Suicidality	389	$	309	8862	Shepard et al. 2016[41]; Sgobin et al. 2014[42]
ED-related societal cost savings	260	$ per capita	152	269	Long et al. 2022[21]
Muscle-building supplements pathway					
OTC muscle-building supplement use					
Female, never users	93.5	%	n/a	n/a	Nagata et al. 2022[7]
Male, never users	80.6	%	n/a	n/a	Nagata et al. 2022[7]
Risk of any AE, post-muscle-building supplement	37.1	%	29.8	44.4	Ganson et al. 2024[43]
Risk of severe AE given at least 1 AE present	35.2	%	21.9	41.0	Or et al. 2019[12]; Park et al. 2013 (CDC)[44]
Weighted average savings per avoided AEs post-MBS use					
CEA, all	10 377	$	n/a	n/a	Johnston et al. 2011[45]; AHRQ 2020[80]; Ho et al. 2023[46]; US Bureau of Labor Statistics 2024[47]; Hartman and Brandon 2023[48]; Gonzales et al. 2018[49]
DCEA, Black residents	9663	$	n/a	n/a	Johnston et al. 2011[45]; AHRQ 2020[80]; Ho et al. 2023[46]; US Bureau of Labor Statistics 2024[47]; Hartman and Brandon 2023[48]; Gonzales et al. 2018[49]
DCEA, Latine residents	8108	$	n/a	n/a	Johnston et al. 2011[45]; AHRQ 2020[80]; Ho et al. 2023[46]; US Bureau of Labor Statistics 2024[47]; Hartman and Brandon 2023[48]; Gonzales et al. 2018[49]
DCEA, White residents	10 706	$	n/a	n/a	Johnston et al. 2011[45]; AHRQ 2020[80]; Ho et al. 2023[46]; US Bureau of Labor Statistics 2024[47]; Hartman and Brandon 2023[48]; Gonzales et al. 2018[49]
Weighted average QALYs saved per AE avoided					
CEA, all	0.0062	N	n/a	n/a	Or et al. 2019[12]; GBD 2019 Diseases and Injuries Collaborators 2020[34]; Lam and Wong 2021[50]; Cleveland Clinic 2022[51]; NIH 2022[52]
DCEA, Black residents	0.0069	N	n/a	n/a	CHIA 2023[53]; Or et al. 2019[12]; GBD 2019 Diseases and Injuries Collaborators 2020[34]; Lam and Wong 2021[50]; Cleveland Clinic 2022[51]; NIH 2022[52]
DCEA, Latine residents	0.0060	N	n/a	n/a	CHIA 2023[53]; Or et al. 2019[12]; GBD 2019 Diseases and Injuries Collaborators 2020[34]; Lam and Wong 2021[50]; Cleveland Clinic 2022[51]; NIH 2022[52]
DCEA, White residents	0.0063	N	n/a	n/a	CHIA 2023[53]; Or et al. 2019[12]; GBD 2019 Diseases and Injuries Collaborators 2020[34]; Lam and Wong 2021[50]; Cleveland Clinic 2022[51]; NIH 2022[52]
Median weekly earnings					
CEA, all	1100	$	n/a	n/a	US Bureau of Labor Statistics 2024[47]
DCEA, Black residents	913	$	n/a	n/a	US Bureau of Labor Statistics 2024[47]
DCEA, Latine residents	851	$	n/a	n/a	US Bureau of Labor Statistics 2024[47]
DCEA, White residents	1126	$	n/a	n/a	US Bureau of Labor Statistics 2024[47]
Mean retirement age					
CEA, all	64.9	Years	n/a	n/a	Gonzales et al. 2018[49]
DCEA, Black adjustment factor	0.993	N	n/a	n/a	Gonzales et al. 2018[49]
DCEA, Latine adjustment factor	0.995	N	n/a	n/a	Gonzales et al. 2018[49]
DCEA, White adjustment factor	1.002	N	n/a	n/a	Gonzales et al. 2018[49]
MBS pathway, post-AAS use					
Use of AAS post-muscle-building supplement use					
Males	86	%	n/a	n/a	Estimate using GUTS data[54]
Females	1:15	Ratio to males	1:50	1:8	Pope et al. 2014[55]
DCEA, Black, male additional risk	8	Percentage points	n/a	n/a	Nagata et al. 2022[7]
DCEA, Latine	6	Percentage points	n/a	n/a	Nagata et al. 2022[7]
DCEA, White	−5	Percentage points	n/a	n/a	Nagata et al. 2022[7]

(*continued*)

Table 1. Continued

Variable	Value	Unit	Min	Max	Source
Risk of developing AEs after AAS use					
Anxiety, female	0.070	%	0.023	0.438	Scarth et al. 2022[56]; Lindqvist et al. 2017[57]; Gestsdottir et al. 2021[58]
Anxiety, male	0.070	%	0.029	0.280	Lindqvist et al. 2017[57]; Karagun et al. 2024[59]; Gestsdottir et al. 2021[58]
Cardiovascular disease	0.056	%	0.034	0.092	Armstrong et al. 2018[60]; Thiblin et al. 2015[61]
Depression, female	0.125	%	0.046	0.376	Scarth et al. 2022[56]; Gestsdottir et al. 2021[58]
Depression, male	0.100	%	0.040	0.181	Hauger et al. 2020[62]; Rasmussen et al. 2018[63]; Gestsdottir et al. 2021[58]
Infertility, female	0.100	%	0.035	0.180	Pärssinen et al. 2000[64]; Strauss et al. 1985[65]; Rahnema, et al. 2015[66]
Infertility, male	0.110	%	0.035	0.180	Mulawkar et al. 2023[67]
Liver injury	0.126	%	0.082	0.184	Schwingel et al. 2015[68]
Myocardial infarction	0.137	%	0.090	0.170	Fyksen et al. 2022[69]
QALYs saved per AE post-AAS use					
Anxiety	0.105	N	0.025	0.836	GBD 2019 Diseases and Injuries Collaborators 2020[34]; ten Have et al. 2017[33]
Cardiovascular disease	0.048	N	0.024	0.412	Kavelaars et al. 2023[40]; Sampaio et al. 2021[70]; Fadah et al. 2023[71]; GBD 2019 Diseases and Injuries Collaborators 2020[34]
Depression	0.353	N	0.089	2.655	Nieschlang et al. 2015[72]; GBD 2019 Diseases and Injuries Collaborators 2020[34]
Infertility (female)	0.011	N	0.002	0.035	Nieschlag & Vorona 2015[72]
Infertility (male)	0.008	N	0.001	0.045	Esposito et al. 2023[73]
Liver injury	0.025	N	0.008	0.091	Patil et al. 2022[74]; Lam & Wong 2021[50]
Myocardial infarction	0.009	N	0.003	0.032	Patil et al. 2022[74]; Lam & Wong 2021[50]
Cost per AE post-AAS use					
Anxiety	19 188	$	18 144	20 168	Kavelaars et al. 2023[40]
Cardiovascular disease	23 549	$	10 247	48 552	Nicholson et al. 2016[75]
Depression	21 956	$	19 282	25 064	Kavelaars et al. 2023[40]
Infertility (female)	113 624	$	77 225	170 820	Katz et al. 2011[76]; Collins et al. 2001[77]
Infertility (male)	25 655	$	5496	63 688	Blue Cross Blue Shield of Massachusetts, 2005[78]
Liver injury	35 942	$	25 685	89 193	Henry Ford Health System 2011[38]
Myocardial infarction	19 020	$	18 916	19 228	Tajeu et al. 2024[79]
CEA, all, average MA hospital costs per stay	17 835	$	n/a	n/a	AHRQ 2020[80]
DCEA, Black adjustment factor	1.058	N	n/a	n/a	AHRQ 2020[80]
DCEA, Latine adjustment factor	0.960	N	n/a	n/a	AHRQ 2020[80]
DCEA, White adjustment factor	1.004	N	n/a	n/a	AHRQ 2020[80]

Pert-Beta distribution was used for all inputs with a minimum and maximum listed. All monetary amounts are shown in 2023 USD.
Source: Citations.[1,7,12,19-80]
AAS, anabolic-androgenic steroid; AE, adverse medical event; AN, anorexia nervosa; BED, binge eating disorder; BN, bulimia nervosa; CEA, cost-effectiveness analysis; ED, eating disorder; MA, Massachusetts; MBS, muscle-building supplements; OSFED, other specified feeding or eating disorder; OTC, over-the-counter; QALY, quality-adjusted life year; n/a, not applicable or not available.

For the OTC diet pill pathway, we calculated the expected total number of the 4 most prevalent eating disorders (anorexia nervosa, bulimia nervosa [BN], binge eating disorder [BED], and other specified feeding and eating disorder [OSFED]) among our cohorts after 30 years (Table 1 and Table S1). Since the entire population is covered by the intervention, the number of incremental ED avoided was estimated as the intervention effectiveness times this expected total. Our first sensitivity analysis included an additional modest reduction in severity for the children that started with an ED, but no OTC diet pill use, as a portion of them would not get access to OTC diet pills they otherwise might have, which could then improve their 30-year morbidity. The values for the distribution for this assumption was based on Ward et al.'s findings regarding persons with ED relapse (Table 1).[22] Our second sensitivity analysis (estimating a reduced cost-effectiveness) included only 2 of the 4 ED, BN, and OSFED.

Further, we estimated the probability of AEs (other than ED) post-OTC diet pill over 30 years. In refining our search, the most frequent AEs post-OTC diet pill use were tachycardia, hypertension, gastrointestinal pain, depression, and liver injury (Table 1). In our sensitivity analysis estimating a greater cost-effectiveness, we expanded this list to add suicidality. Our second sensitivity analysis (estimating a reduced cost-effectiveness) removed the AEs related to males as that pathway contained the greatest amount of uncertainty.

For the MBS pathway, we estimated the overall anticipated incidence of AEs linked to the use of muscle-building supplements (immediate) and subsequent AAS after 30 years. Drawing on the work conducted by Ganson et al.,[43] we applied an overall risk for any AEs following the use of MBS, used Or and colleagues' findings to refine our estimates to focus on risk of "severe" AEs, and bundled them into a single, weighted, incremental health outcome.[12] This outcome included 6 components: disability, death, life-threatening events, hospitalizations, emergency room visits, and/or interventions to prevent disability.[12]

Additionally, we included the probability of experiencing the 5 most common AEs post-AAS use: cardiovascular disease,

male infertility, liver injury, anxiety, and depression (Table 1).[56-68] For the first sensitivity analysis, we expanded this list to 7 to include heart attack and female infertility.[52,72]

We calculated the QALYs for each ED, considering their average duration[23-28] multiplied by the health-related quality of life scores from Long et al.[21] Similarly, for each of the AEs we multiplied their average duration (Tables S2 and S3) by the disability weights obtained from the Global Burden of Disease study.[34]

Costs and cost-effectiveness

For the OTC diet pill pathway, we derived our estimate of the total costs associated with ED from Long et al. (Table 1).[21] The total costs encompassed expenses related to vendors, ED-specific healthcare costs in outpatient and inpatient settings, emergency department visits, diagnostic tests, transportation, as well as indirect costs such as caregivers' opportunity costs. We multiplied this per-person total by our study population.

For all other AEs prevented (in both the OTC diet pill pathway and the MBS pathway), we estimated healthcare cost savings associated with the reduction of AEs resulting from decreased use of OTC diet pills, MBS, or AAS over the 30-year period (Table 1).

We then estimated the intervention costs as a per person per year amount to account for impacted vendors. Finally, we looked at the incremental cost-effectiveness ratio (ICER) by dividing the incremental costs by the incremental QALYs gained.

Statistical analysis

The CEA was conducted from both a societal perspective and a health systems perspective with a time horizon of 30 years, 2023-2053. The societal perspective included various indirect costs where available, for example, opportunity costs of family caregivers. All costs were adjusted to 2023 US dollars; all QALYs and dollars were discounted by the standard rate of 3%.

We used Monte Carlo simulation (10 000 iterations) to predict possible outcomes of an uncertain event. This allowed 80 inputs to vary simultaneously and probabilistically along a Pert-Beta distribution, which we chose for all the probabilistic inputs. Additional Monte Carlo simulations were run for each of the 2 sensitivity analyses and each of 3 subgroups for the aggregate DCEA. All analyses were conducted using Microsoft Excel and Palisade @Risk (https://www.palisade.com/risk/). All major input parameters used for this study are summarized in Table 1 (additional details in Tables S1-S3).

Aggregate DCEA

Different subpopulations can reap the benefits or costs of a given intervention differently. After examining the available data and policy salience in the MA context, we chose the equity variable of race/ethnicity for our pragmatic, aggregate DCEA. Data allowed 3 subgroup categories: non-Hispanic Black/African American (henceforth Black), Latine/Hispanic (Latine), and non-Hispanic White (White). The analysis was conducted based on the conceptual framework of the "staircase of inequality" developed for this study (Figure S1). The "staircase" portion of the framework included the following "steps": (1) need (users of OTC diet pills and MBS, prevalence of ED among minors), (2) receipt (of prevention, of treatment for ED), (3) short-term effects (costs/savings to society, ED prevented), and (4) lifetime health benefits (QALYs gained).

For each input, we investigated if the race/ethnicity variable would have a different value compared to the best estimates for the CEA (Table 1). Due to data limitations and the fact that all minors are subject to the intervention, we focused on calculating just the difference in QALYs and costs/savings between the intervention and the status quo resulting in a pragmatic aggregate DCEA.[81]

Results

Health gains

We found that over 30 years, the proposed age-restriction policy would prevent 57 034 (95% uncertainty interval, UI: 26 833-89 271) ED diagnoses among the MA population; 32 370 (95% UI: 15 113-51 525) among females and 24 664 (95% UI: 11 402-40 119) among males (Table 2, Table S4). Additionally, it would prevent 22 358 (95% UI: 2609-49 605) diet pill-related AEs and 24 201 (95% UI: 10 959-40 038) muscle-building supplement- and AAS-related AEs (Table 2, Table S4).

Costs

The policy implementation would not incur incremental costs but rather yield discounted societal savings of $898 million (95% UI: $511 million-$1.4 billion, Table 2) and a health systems' savings of $445 million (95% UI: $123-$857 million) to MA over the 30-year timeframe. These savings translate into $30 million (95% UI: $17-$47 million) and $14 million (95% UI: $4-$29 million) per year from a societal and health systems' perspective, respectively. The inputs that had the greatest influence on the final estimate was the success rate of the intervention, the number of female AAS users, and the proportion of the population using OTC diet pills (Figures S2 and S3).

Table 2. Cost-effectiveness results for the 30-year timeframe, Massachusetts, 2023 USD.

Totals, 30-year horizon in MA, United States of America	
Number of eating disorders avoided	57 034 (95% UI: 26 833-89 271)
Number of other, non-ED adverse medical events avoided, post-OTC diet pill use	22 358 (95% UI: 2609-49 605)
Number of AEs avoided post-muscle-building supplement and post-AAS use	24 201 (95% UI: 10 959-40 038)
Total QALYs gained	51 749 QALYs (95% UI: 22 065-91 183)
Total QALYs gained per person	0.0385 (95% UI: 0.0164-0.0678)
Total societal costs saved	$898 million (95% UI: $511 million-$1.413 billion)
Total health systems' savings	$425 million (95% UI: $123 million-$857 million)
	Savings per year, MA, United States of America
Total societal costs saved per year	$30 million (95% UI: $17-$47 million)
Total health systems' savings per year	$14 million (95% UI: $4 million-$29 million)

Source: Authors' analysis.
AAS, anabolic-anaerobic steroid use; OTC, over-the-counter; QALY, quality-adjusted life year; UI, uncertainty interval.

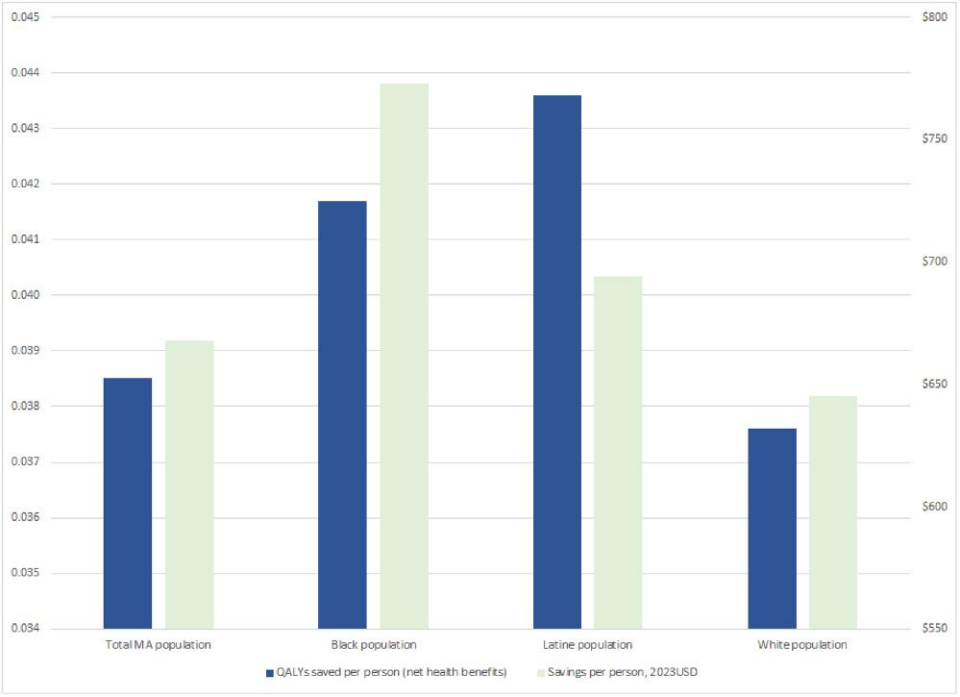

Figure 2. Health and economic gains related to the age-restriction policy on 3 racial/ethnic subgroups. Source: Authors' analysis.

Cost-effectiveness

The proposed age-restriction policy would yield a total gain of 51 749 QALYs (95% UI: 22 065-91 183), with an average of 0.039 (95% UI: 0.016-0.068) QALYs per person. The primary driver of these health gains was the intervention success rate, the number of female AAS users, and the average duration of BED, which is estimated to be longer than any other ED (Figure S4). No ICER is reported because we found the intervention to be cost-saving compared to the status quo.

Accounting for uncertainty

In the first sensitivity analysis, the cost-effectiveness of the intervention was increased by including 3 additional AEs, for which we found some evidence in the literature, and by adding modest reductions in morbidity among minors who started with an ED but not OTC diet pill use. Our results were consistent with the base cases (Table S5) and showed annual societal savings of $31 million (95% UI: $18-$49 million), annual health systems savings of $15 million (95% UI: $5-$30 million), and 52 549 (95% UI: 22 336-94 758) total QALYs gained.

The second sensitivity analysis reduced the cost-effectiveness of the intervention by limiting the types of ED prevented and eliminating the segment of the model with the greatest uncertainty, that is, all non-ED AEs post-OTC diet pill use among males (Table S6). Nevertheless, our findings remained robust with annual societal savings of $28 million (95% UI: $17-$43 million), annual health systems savings of $12 million (95% UI: $4-$24 million), and 11 875 (95% UI: 4609-22 461) total QALYs gained.

Aggregate distributional cost-effectiveness

While the overall findings of the aggregate DCEA paralleled those of our CEA findings, we also detected differences in economic and health gains among the 3 racial/ethnic subgroups (Figure 2). We found an average societal savings per person of $645, $694, and $773 for White, Latine, and Black MA residents, respectively. Moreover, we found societal health gains of 0.044 QALYs per person for the Latine subpopulation, 0.042 QALYs per person for the Black subpopulation, and 0.038 QALYs per person for the White subpopulation, suggesting a reduction in overall health inequity between Black and Latine residents and White residents.

Discussion

We found that an age-restriction policy aiming to ban the sales of OTC diet pills and muscle-building supplements could prevent over 57 000 ED diagnoses among the MA population and over 46 500 other AEs over a 30-year time horizon. Accounting for the annual intervention costs still resulted in a finding of societal cost savings of over $898 million ($30 million per year). From a health systems-specific perspective, we still found the intervention to be cost-saving, that is, $14 million per year and $425 million over a 30-year time horizon. Moreover, we found evidence that the policy would modestly decrease health inequity as the Latine subpopulation gained the most QALYs per person, followed by the Black and White subpopulations, respectively. Thus, this age-restriction policy is strongly preferable to the comparator of the status quo.

While traditional cost-effectiveness analyses often exclude startup costs, policymakers frequently ask, "How much will this new policy cost?" A previous study examined startup opportunity costs for MA related to this policy.[82] The authors valued these activities at less than $48 000 in total,[82] suggesting that this intervention would be cost-saving even when initial startup costs are included. Furthermore, our DCEA findings suggested that the proposed age-restriction policy will reduce health inequity, meaning that the policy is likely

to increase both population health and financial wellbeing while simultaneously reducing health disparities. Indeed, New York passed a very similar bill into law in 2023.[83]

Our findings support the effectiveness of age-restriction policies in protecting the health of minors, aligning with the well-established evidence from the Tobacco 21 law and the National Minimum Drinking Age Act of 1984.[84,85] Age-restriction laws have the potential to safeguard youth health and reduce long-term adverse health effects. For instance, a study comparing the long-term health effects of increasing cigaret excise taxes and raising the legal smoking age to 21 years demonstrated the effectiveness of such laws, significantly reducing youth smoking prevalence by 13%.[86] This reduction would also lead to a decrease in adult smoking prevalence and a cumulative gain of 109 million QALYs.[86]

Although our 30-year time frame resulted in additional reductions to the QALYs and cost savings through discounting, we aimed to match the time frame of key citations.[21,22] Additionally, evidence from age-restriction polices for tobacco usage suggested that a longer view is worth considering.[86] Finally, there is evidence showing that most ED are diagnosed by age 40.[22]

The economic and health gains, along with equity considerations highlighted in this study, underscore the need for effective public health measures to safeguard the wellbeing of youth. While our analysis focused specifically on the cost-effectiveness of the age-restriction law on ED diagnoses and other AEs associated with the use of OTC diet pills, MBS, and AAS, it also suggested broader implications, particularly in terms of increasing public awareness of the negative impact of these products on youth health and wellbeing.

Limitations

The study has some limitations. First, due to data availability, we relied on parallel evidence from the tobacco-control literature for our estimate of intervention effectiveness. Second, due to limited race/ethnicity-specific data, our aggregate DCEA focused on only the 3 largest subgroups. That left an unknown change in equity for approximately 8% of the population. However, given the overwhelmingly positive findings for the base case CEA, and our success in analyzing the health gains for the White and Black subgroups, which are often found at the extreme positive and extreme negative end of health equity distributions, respectively, we anticipate future findings will remain consistent.

Third, data limitations also affected our ability to explore other equity categories of salience, which include urbanicity, socioeconomic status, gender identity, and sexual orientation. New data sources and studies are required to gain further health inequity insights related to this public health policy.

Fourth, our societal opportunity costs for the aggregate DCEA are assumed to be zero based on expected light enforcement actions. Following the tobacco model, cities and towns may decide independently to employ underage "secret shoppers."[87] This implies flexible funds available to municipalities for enforcement, which will be rare. Otherwise, enforcement will be via the passive pathway of tips called into the Attorney General's office, and no additional infrastructure needs to receive those calls are anticipated.

Even without new state enforcement allocations, we expect the policy to be at least modestly effective for several reasons. The act of moving products behind counters or into locked cabinets will reduce accessibility, and the illegality of purchasing such products is enough to deter some would-be underaged buyers. Further, the success rate of the intervention we used was modest (26%) and the sensitivity analyses produced consistent results with our base case.

Conclusions and implications

Our findings indicated that restricting the sale of OTC diet pills and muscle-building supplements to minors will produce both health gains and reduce societal direct and indirect costs. Additionally, we estimated the Latine population would experience the highest per capita health benefits, followed by the Black and White populations. As a result, policymakers and the public may have increased confidence in the effectiveness, fiscal responsibility, and positive equity impacts of this prevention policy.

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Supplementary material

Supplementary material is available at *Health Affairs Scholar* online.

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Conflicts of interest

Please see ICMJE form(s) for author conflicts of interest. These have been provided as supplementary materials.

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