



Muscle-building behaviors from adolescence to emerging adulthood: A prospective cohort study

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ABSTRACT

This study aimed to identify patterns of change in muscle-building behaviors from adolescence to emerging adulthood and determine what adolescent factors predict new-onset muscle-building behavior in emerging adulthood. Prospective cohort data from a diverse sample of 1,535 participants followed from adolescence (baseline, $M_{\text{age}} = 14.4 \pm 2.0$ years) to emerging adulthood (follow-up, $M_{\text{age}} = 22.1 \pm 2.0$ years) from the population-based EAT 2010–2018 (Eating and Activity over Time) study were analyzed. Changes in muscle-building behavior were identified (starting, stopping, persistent use, or never use). Log-binomial regression models examined adolescent predictors of starting (i.e., new-onset) muscle-building behaviors in emerging adulthood. Prevalence of any use in adolescence (EAT 2010) and/or emerging adulthood (EAT 2018) was 55.1% (males) and 33.0% (females) for protein powder/shakes, 6.7% (males) and 5.4% (females) for steroids, and 19.4% (males) and 6.5% (females) for other muscle-building substances (e.g., creatine, amino acids). In particular, 22.6% (males) and 13.7% (females) started protein powder/shakes, 2.2% (males) and 1.0% (females) started steroid use, and 9.0% (males) and 2.0% (females) started other muscle-building substances during emerging adulthood. Adolescent protein powder/shake consumption was associated with starting steroids/other muscle-building substances use in emerging adulthood in males (adjusted risk ratio [ARR] 2.09, 95% confidence interval [CI] 1.29–3.39) and females (ARR 4.81, 95% CI 2.01–11.48). Adolescent use of protein powders/shakes may lead to a two- to five-fold higher risk of new use of steroids and other muscle-building products in emerging adulthood. Clinicians, parents, and coaches should assess for use of muscle-building behaviors in adolescents and emerging adults and discourage use of harmful products.

1. Introduction

Muscle-building behaviors are commonly defined as those intended to increase muscle mass and tone and decrease body adiposity. These behaviors can include changing eating patterns, exercise, protein powders or shakes, steroids, and other muscle-building substances (e.g., creatine, amino acids, growth hormone) (Murray et al., 2017; 2016;

Nagata et al., 2020d; 2019a). Given the continually evolving body ideal that emphasizes muscularity (Eik-Nes et al., 2018; Pope et al., 2017; 1999), these behaviors are common among young people, particularly boys and young men. Among middle and high school students in Minnesota, 35% of boys and 21% of girls reported use of protein powders and 6% of boys and 5% of girls reported use of steroids in 2010 (Eisenberg et al., 2012). Furthermore, 12% of adolescent boys and 6% of

Abbreviations: ARR, adjusted risk ratio; BMI, body mass index; CI, confidence interval; EAT, Eating and Activity over Time; HMB, hydroxyl methylbutyrate.

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adolescent girls reported engaging in three or more muscle-enhancing behaviors (Eisenberg et al., 2012). Additionally, among a nationally representative sample of U.S. emerging adults ages 18–26 years in 2001–2002, over 25% of males and nearly 5% of females reported using any muscle-building behavior (including exercise, changing eating patterns, supplements, and steroid use), while nearly 16% of males reported using performance-enhancing substances (e.g., creatine, amino acids, protein supplements) and nearly 3% reported using anabolic-androgenic steroids (Nagata et al., 2020c). Given potential changes in muscle-building supplement use trends over the past two decades, more recent data are needed from population-based studies.

The high prevalence of muscle-building behaviors is concerning given that these behaviors may be associated with significant adverse health outcomes, including eating disorders (Murray et al., 2018; Nagata et al., 2021) and muscle dysmorphia (Murray et al., 2017). Similarly, performance-enhancing substances are largely underregulated by the FDA, may be adulterated with illicit and harmful substances (Cohen et al., 2018; Ganson et al., 2020b), may signal an unhealthy preoccupation with body shape and size, and have been linked to severe medical events and death (Or et al., 2019). Anabolic-androgenic steroid use is associated with mood disorders, aggression, violence (Pope et al., 2014), teen dating violence (Ganson and Cadet, 2019), and substance use disorders (Lundholm et al., 2010), as well as several medical complications related to key systems of the body (e.g., cardiovascular, neuroendocrine) (Ahlgrim and Guglin, 2009; Bispo et al., 2009; Daly et al., 2003; Nikolopoulos et al., 2011). Moreover, use of muscle-building products, such as creatine, has been identified as a potential predictor of problematic use of alcohol (Ganson et al., 2020a) and anabolic steroids (Nagata et al., 2020b); however, little is known about how more common muscle-building behaviors may be associated with future use of more hazardous muscle-building products. For instance, exercise and changing eating to enhance muscle could lead to use of protein powders or shakes, which may be linked to future steroid or illicit substance use.

Our prior research has described several sociodemographic and behavioral risk factors for muscle-building behaviors, including identifying as Black/African American (Nagata et al., 2019b), Asian, or Hispanic/Latinx (Eisenberg et al., 2012); and both lower body mass index z-score (Nagata et al., 2020c; 2019b) and higher body mass index category (e.g., overweight, obese) (Eisenberg et al., 2012). Sports team participation is also a risk factor for engaging in muscle-building behaviors in adolescence (Eisenberg et al., 2012; Nagata et al., 2020c; 2019b). Despite these findings, there remains little research on changes in muscle-building behavior use from adolescence to emerging adulthood, such as starting, stopping, persistent use, or never use. Furthermore, determining risk factors for starting muscle-building behaviors is important given that emerging adulthood is the age range in which these behaviors peak (Nagata et al., 2020c). This type of research is particularly important as body dissatisfaction, a major risk factor for muscle-building behaviors (Brewster et al., 2017), is persistent from adolescence through emerging adulthood (Bucchianeri et al., 2013). Therefore, the aims of this study are to, first, identify patterns of change in muscle-building behaviors from adolescence (ages 12–18 years) to emerging adulthood (ages 19–25 years), and, second, determine what sociodemographic and behavioral factors in adolescence predict new-onset muscle-building substance (e.g., protein powder/shake, steroid, and other muscle-building substances) use in emerging adulthood.

2. Method and materials

2.1. Study design and sample

Data were collected in EAT 2010–2018 (Eating and Activity over Time), a population-based cohort of youth recruited in metropolitan areas of Minnesota who have been followed from adolescence (ages 12–18 years) to emerging adulthood (ages 19–25 years). The overall goal of EAT 2010–2018 was to study weight status, dietary intake,

weight control behaviors, physical activity, and related factors among adolescents who transitioned to emerging adulthood. The racially/ethnically and socioeconomically diverse sample was recruited as adolescents from 20 public middle schools and high schools in the Minneapolis/St. Paul metropolitan area of Minnesota. Surveys and anthropometric measures were completed by 2793 adolescents at baseline (2009–2010). Contact information was not available for 410 original participants; 1568 completed follow-up as emerging adults (2017–2018), which was 65.8% of those who could be contacted.

After excluding 22 participants who did not provide sufficient data to examine changes in any of the muscle-building behaviors examined, as well as 11 participants who did not identify as male or female (i.e., selected “different identity”) at EAT 2018 (given that this group was too small to permit a stratified analysis), the present study included 1535 participants. At baseline, trained research staff administered surveys and measured height and weight during selected physical education, health, and science classes. The University of Minnesota’s Institutional Review Board Human Subjects Committee and the research boards of the participating school districts approved all study procedures. A vast majority (96.9%) of adolescents who were at school on the days of survey administration chose to participate and had parental consent; those without parental consent did not participate.

2.2. Survey and measures

The EAT 2010 and 2018 surveys included self-reported items assessing a range of factors of potential relevance to weight status and weight-related behaviors. Using an item adapted from previous studies (Eisenberg et al., 2012; Field et al., 2005; McCabe and Ricciardelli, 2001; Smolak et al., 2005), muscle-building behaviors were assessed by asking participants whether they had done any of “the following things in order to increase [their] muscle size or tone during the past year”: (a) “Changed [their] eating,” (b) “Exercised more,” (c) “Used protein powder or shakes,” (d) “Used steroids,” and (e) “Used another muscle-building substance (such as creatine, amino acids, hydroxyl methylbutyrate [HMB], DHEA [dehydroepiandrosterone], or growth hormone).” Response options for each behavior were “never,” “rarely,” “sometimes,” or “often” in 2010, and “yes” or “no” in 2018. To correspond to the response options in 2018, responses in 2010 were dichotomized as any use versus “never.”

Sex/gender was assessed in 2018 with the question, “Are you ... (1) Male, (2) Female, or (3) Different identity.” Additional sociodemographic, anthropometric, and sports team participation characteristics at EAT 2010 were used as independent variables, following our previous work (Eisenberg et al., 2012). School level at EAT 2010 was dichotomized into middle school (grades 6–8) and high school (grades 9–12). Race/ethnicity was assessed from the following question: “Do you think of yourself as (1) white, (2) black or African American, (3) Hispanic or Latino, (4) Asian American, (5) Hawaiian or Pacific Islander, or (6) American Indian or Native American;” participants were asked to check all that apply. A “mixed/other” race/ethnicity category was created to include those who marked multiple race groups or indicated they were Hawaiian/Pacific Islander or American Indian/Native American, as these groups were too small to permit meaningful analyses as separate categories. Of note, Asian American participants were a majority Hmong (81.3%). Socioeconomic status was based on an algorithm using parental education level (highest level of educational attainment of either parent), family eligibility for public assistance, eligibility for free or reduced-cost school meals, and employment status of the mother or father, and was categorized into low, medium, or high (Eisenberg et al., 2012; Neumark-Sztainer et al., 2003; 2002). Baseline body mass index (BMI) was calculated using measured height without shoes (to nearest 0.1 cm) and weight without heavy outerwear or shoes (to the nearest 0.5 lb), as assessed by EAT 2010 staff. BMI was converted into BMI percentile based on reference data from the Centers for Disease Control and Prevention. Sports team participation was assessed by the question,

Table 1

Use of muscle-building behaviors from adolescence to emerging adulthood in EAT (Eating and Activity over Time) 2010–2018, by sex.

	Change Eating	Exercise More	Protein Powder/Shakes	Steroids	Other Muscle-Building Substance
	% (n)	% (n)	% (n)	% (n)	% (n)
Males (N = 640)					
Never-users ^a	17.9 (115)	3.4 (24)	44.9 (286)	93.4 (595)	80.6 (515)
Stoppers ^b	28.7 (183)	24.6 (157)	18.8 (114)	4.5 (25)	9.3 (53)
Persistent users ^c	40.4 (259)	67.0 (423)	13.7 (87)	0.0 (0)	1.1 (7)
Starters ^d	13.1 (81)	5.0 (32)	22.6 (147)	2.2 (13)	9.0 (53)
Females (N = 895)					
Never-users ^a	24.7 (214)	9.7 (79)	67.1 (591)	94.6 (839)	93.5 (834)
Stoppers ^b	30.8 (282)	31.8 (280)	13.8 (125)	4.1 (38)	4.4 (39)
Persistent users ^c	30.0 (272)	48.5 (440)	5.5 (50)	0.3 (3)	0.1 (1)
Starters ^d	14.5 (125)	10.0 (85)	13.7 (121)	1.0 (7)	2.0 (17)

Note. Percentage is weighted to account for attrition over time and allow for extrapolation to the original population-based sample, while *n* represents observed count. Percentages reflect within-column distributions of patterns by sex.

^a Participants not reporting the behavior in adolescence or emerging adulthood.

^b Participants reporting the behavior in adolescence but not emerging adulthood.

^c Participants reporting the behavior in both adolescence and emerging adulthood.

^d Participants reporting the behavior in emerging adulthood but not adolescence, also described as new-onset use.

“During the past 12 months, on how many sports teams did you play?” Participants indicating that they played on one or more teams were compared with those reporting no sports team involvement.

2.3. Statistical analysis

All analyses were stratified by sex/gender given different prevalence and predictors of muscle-building behaviors in males and females (Eisenberg et al., 2012; Nagata et al., 2020c; 2019b). Four-category groups were defined for each type of muscle-building behavior, in which participants were categorized as never-users (not reporting the behavior at EAT 2010 or EAT 2018), stoppers (reporting the behavior at EAT 2010 but not EAT 2018), persistent users (reporting the behavior at both EAT 2010 and EAT 2018), or starters (reporting the behavior at EAT 2018 but not EAT 2010). Frequencies were summarized for each group by sex.

Sex-stratified log-binomial regression models were conducted, examining these problematic muscle-building behaviors at EAT 2018 as outcomes among individuals who did not report the respective behaviors at EAT 2010. New-onset use of protein powder/shakes was examined as one outcome; new-onset use of steroids and/or other muscle-building substances was examined as a combined outcome for regression analyses to maximize statistical power. The following sociodemographic and behavioral adolescent variables were simultaneously included as predictors (i.e., mutually adjusted for) in regression models: school level, race/ethnicity, socioeconomic status, weight status, sports team involvement, and adolescent use of muscle-building behaviors (i.e., eating, exercising). Adolescent report of changing eating and/or exercising more to enhance muscles was examined as a combined variable when predicting new-onset use of protein powder/shakes. Only one male and two female participants reported use of protein powder/shakes without changing eating or exercising more to build muscles during adolescence. Therefore, due to model stability concerns, only adolescent use of protein powder/shakes was examined as a muscle-building behavior when predicting new-onset use of steroids/other muscle-building substances. Attrition from EAT 2010 to EAT 2018 did not occur entirely at random, such that non-responders were more likely to be male, non-white, and have parents with low educational attainment. To account for differential loss to follow-up and allow for extrapolation back to the original EAT 2010 school-based sample, inverse probability weighting (IPW) was used (Seaman and White, 2013). All analyses were conducted using Stata 16.1 and incorporated weights from IPW to account for differential loss to follow-up.

3. Results

3.1. Sociodemographic characteristics

Overall, our analytic sample included 640 males and 895 females who were followed from adolescence to emerging adulthood. The mean age at baseline was 14.4 years (SD 2.0) and at follow-up was 22.1 (SD 2.0). The sample was diverse (18.6% white, 28.8% Black/African American, 20.0% Asian/Asian American, 17.2% Hispanic/Latinx, and 15.4% mixed or other in the weighted sample), 39.4% were in the lowest category of socio-economic status, and 55.3% participated in at least one sports team.

3.2. Changes in use of muscle-building behaviors from adolescence to emerging adulthood

Changes in use of muscle-building behaviors from adolescence to emerging adulthood, by sex, are shown in Table 1. Exercising more and changing eating were the most common behaviors that persisted from adolescence to emerging adulthood. Prevalence of any use in adolescence (EAT 2010) and/or emerging adulthood (EAT 2018) was 55.1% (males) and 33.0% (females) for protein powder/shakes, 6.7% (males) and 5.4% (females) for steroids, and 19.4% (males) and 6.5% (females) for other muscle-building substances (e.g., creatine, amino acids). Among male participants, 22.6% started using protein powder/shakes, 2.2% started using steroids, and 9.0% started using other muscle-building substances during emerging adulthood. Among female participants, 13.7% started using protein powder/shakes, 1.0% started using steroids, and 2.0% started using other muscle-building substances during emerging adulthood.

3.3. Predictors of new-onset muscle-building behaviors

Adolescent factors predicting new-onset (i.e., starting) use of protein powder/shakes and steroids/other muscle-building substances among male emerging adults are shown in Table 2. Adolescent behavioral predictors of new-onset protein powder/shake use among male emerging adults included changing eating or exercising more to build muscles (adjusted risk ratio [ARR] 1.90, 95% confidence interval [CI] 1.01–3.54) and sports team participation (ARR 1.39, 95% CI 1.06–1.84). Sociodemographic predictors of starting protein powder/shake use included Hispanic/Latinx ethnicity (ARR 1.89, 95% CI 1.28–2.81), mixed/other race/ethnicity (ARR 1.76, 95% CI 1.17–2.63), and < 5th

Table 2

Adolescent factors (2009–2010) predicting new-onset (starting) use of protein powder/shakes and steroids/other muscle-building substances in emerging adulthood (2017–2018) among male participants in EAT 2010–2018 who were non-users at baseline.

	Protein Powder/Shakes (N = 399) ^a		Steroids/Other Muscle-Building Substances (N = 521) ^b	
	n	Mutually Adjusted RR (95% CI)	n	Mutually Adjusted RR (95% CI)
School level in 2010				
Middle school (ref)	196	–	243	–
High school	203	1.10 (0.90, 1.35)	278	0.97 (0.60, 1.57)
Race/ethnicity				
White (ref)	116	–	154	–
Black/African American	82	1.24 (0.81, 1.91)	105	2.43 (1.04, 5.67)*
Hispanic/Latinx	62	1.89 (1.28, 2.81)**	95	2.28 (0.91, 5.71)
Asian/Asian American	94	1.15 (0.71, 1.86)	108	1.49 (0.53, 4.19)
Mixed/other	45	1.76 (1.17, 2.63)**	59	2.53 (0.98, 6.52)
Socioeconomic status				
Low	123	0.89 (0.66, 1.21)	157	1.37 (0.79, 2.37)
Middle (ref)	158	–	200	–
High	118	1.23 (0.89, 1.69)	164	1.22 (0.63, 2.35)
BMI percentile				
<5	12	1.46 (1.07, 1.99)*	13	0.88 (0.14, 5.51)
≥5 ≤ and < 85 (ref)	224	–	286	–
≥85 ≤ and < 95	51	0.95 (0.62, 1.44)	71	0.69 (0.31, 1.52)
≥95	112	0.95 (0.70, 1.28)	151	0.87 (0.51, 1.48)
Sports team involvement				
No (ref)	174	–	207	–
Yes	225	1.39 (1.06, 1.84)*	314	1.25 (0.72, 2.15)
Adolescent muscle-building behaviors				
Changing eating/exercising more	355	1.90 (1.01, 3.54)*	– ^c	–
Protein powder/shakes	–	–	132	2.09 (1.29, 3.39)**

*p < 0.05, **p < 0.01, ***p < 0.001.

Note. RR = risk ratio; CI = confidence interval. Risk ratios represent associations mutually adjusted for all predictors.

^a The 399 males who reported not using protein powder/shakes in adolescence and provided relevant covariate data were included in this model, of whom 35.3% (n = 138) reported new-onset use in emerging adulthood.

^b The 521 males who reported not using steroids/other muscle-building substances in adolescence and provided relevant covariate data were included in this model, of whom 11.5% (n = 53) reported new-onset use in emerging adulthood.

^c Due to model stability concerns related to a few participants (1 male) reporting use of protein powder/shakes without changing eating/exercising more to enhance muscles during adolescence, only adolescent use of protein powder/shakes was examined as a muscle-building behavior when predicting new-onset use of steroids/other muscle-building substances.

BMI percentile (ARR 1.46, 95% CI 1.07–1.99). Adolescent predictors of new-onset use of steroids/other muscle-building substances among male emerging adults included protein powder/shake use (ARR 2.09, 95% CI 1.29–3.39) and Black/African American race (ARR 2.43, 95% CI 1.04–5.67).

Among female emerging adults (Table 3), use of protein powder/shakes in adolescence predicted new-onset steroid/other muscle-building substances use in emerging adulthood (ARR 4.81, 95% CI 2.01–11.48). However, no adolescent sociodemographic or behavioral predictors were significantly associated with new-onset protein powder/shake use. Fig. 1 shows the adjusted prevalence of new-onset steroid/

Table 3

Adolescent factors (2009–2010) predicting new-onset use of protein powder/shakes and steroids/other muscle-building substances in emerging adulthood (2017–2018) among female participants in EAT 2010–2018 who were non-users at baseline.

	Protein Powder/Shakes (N = 669) ^a		Steroids/Other Muscle-Building Substances (N = 787) ^b	
	n	Mutually Adjusted RR (95% CI)	n	Mutually Adjusted RR (95% CI)
School level in 2010				
Middle school (ref)	314	–	373	–
High school	355	1.21 (0.86, 1.71)	414	1.00 (0.43, 2.34)
Race/ethnicity				
White (ref)	138	–	163	–
Black/African American	164	0.67 (0.40, 1.11)	185	2.76 (0.48, 16.03)
Hispanic/Latinx	113	0.77 (0.42, 1.38)	146	1.51 (0.21, 10.67)
Asian/Asian American	147	0.76 (0.43, 1.33)	169	1.23 (0.16, 9.28)
Mixed/other	107	0.71 (0.40, 1.25)	124	3.25 (0.54, 19.36)
Socioeconomic status				
Low	271	0.76 (0.52, 1.12)	324	1.00 (0.40, 2.53)
Middle (ref)	257	–	297	–
High	141	0.85 (0.52, 1.38)	166	0.86 (0.22, 3.41)
BMI percentile				
<5	^c	^c	12	2.08 (0.30, 14.59)
≥5 ≤ and < 85 (ref)	441	–	496	–
≥85 ≤ and < 95	123	1.13 (0.74, 1.73)	145	0.85 (0.30, 2.43)
≥95	105	1.05 (0.64, 1.70)	134	0.22 (0.04, 1.38)
Sports team involvement				
No (ref)	332	–	381	–
Yes	337	1.20 (0.84, 1.69)	406	0.51 (0.21, 1.27)
Adolescent muscle-building behaviors				
Changing eating/exercising more	528	1.07 (0.69, 1.65)	– ^d	–
Protein powder/shakes	–	–	127	4.81 (2.01, 11.48)***

Note. RR = risk ratio; CI = confidence interval. Risk ratios represent associations mutually adjusted for all predictors.

*p < 0.05, **p < 0.01, ***p < 0.001.

^a The 669 females who did not report using protein powder/shakes in adolescence and provided relevant covariate data were included in this model, of whom 17.0% (n = 113) reported new-onset use in emerging adulthood.

^b The 787 females who did not report using steroids/other muscle-building substances in adolescence and provided relevant covariate data were included in this model, of whom 2.6% (n = 19) reported new-onset use in emerging adulthood.

^c “Underweight” and “healthy weight” categories were combined for this model due to insufficient cell sizes.

^d Due to model stability concerns related to a few participants (2 females) reporting use of protein powder/shakes without changing eating/exercising more to enhance muscles during adolescence, only adolescent use of protein powder/shakes was examined as a muscle-building behavior when predicting new-onset use of steroids/other muscle-building substances.

other muscle-building substance use in emerging adulthood by sex/gender and adolescent use of protein powder/shakes. Adolescent boys consuming protein powder/shakes (18.5%, 95% CI 12.0–25.0%) compared to those who did not consume protein powder/shakes (8.9%,

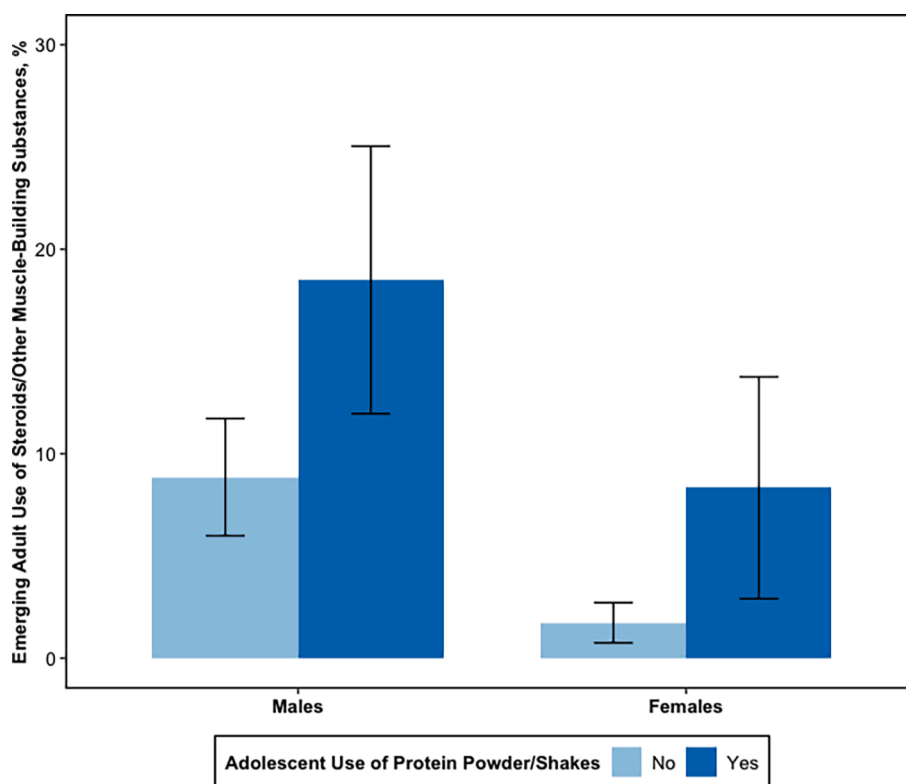


Fig. 1. Adjusted prevalence of new-onset steroid/other muscle-building substance use in emerging adulthood by sex/gender and adolescent use of protein powder/shakes (error bars represent 95% confidence intervals) in EAT 2010–2018.

95% CI 6.0–11.7%) had higher new-onset steroid and other muscle-building substance use in emerging adulthood ($p = 0.003$). Adolescent girls consuming protein powder/shakes (8.3%, 95% CI 2.9–13.8%) compared to those who did not consume protein powder/shakes (1.7%, 95% CI 0.8–2.7%) had higher new-onset of steroid and other muscle-building substance use in emerging adulthood ($p < 0.001$).

4. Discussion

In this population-based longitudinal cohort study, we expand on our previous cross-sectional findings (Eisenberg et al., 2012) to show use of muscle-building behaviors from adolescence to emerging adulthood (eight-year follow-up). We find that muscle-building behaviors are common, including new-onset use across this period, particularly among males. It is notable that almost one-quarter of male participants started using protein powders in the transition to emerging adulthood and almost 10% newly started other muscle-building substances. Consuming protein powders/shakes in adolescence was associated with a two- to nearly five-fold higher risk of starting use of steroids and other muscle-building substances in emerging adulthood. Changing eating or exercising more in adolescence predicted newly starting use of protein powders/shakes in emerging adulthood among males. It is also reassuring that there were few persistent users of steroids or other muscle-building substances, and, generally, more people stopped rather than started using steroids or other muscle-building substances in emerging adulthood.

Emerging adulthood is an important developmental period characterized by educational, economic, and social transitions when people develop identity, coping skills, and health behaviors that may persist through their adult life (Stroud et al., 2015). A prior population-based study of adolescents and emerging adults reporting data from 1994 to 2002 showed that the prevalence of muscle-building behaviors peaks around age 21 years in males (Nagata et al., 2020c). We add to these findings with more contemporary cohort data from 2010 to 2018 and by

reporting starters, stoppers, and persistent users of muscle-building behaviors.

We find that adolescent use of protein powders/shakes may precede the use of steroids in emerging adulthood. Specifically, adolescent protein powder/shake consumption was associated with over twice the risk of subsequent steroid and other muscle-building substance use in males and nearly five-fold risk in females. A previous study from 2001 to 2008 similarly found that performance-enhancing substance use (such as creatine) was prospectively associated with a three-fold higher odds of steroid use in emerging adulthood (Nagata et al., 2020b); however, that study did not specifically examine protein powders, which are more commonly used. We found that nearly a third of adolescent boys and nearly a fifth of adolescent girls report consumption of protein powders/shakes. These products are accessible over-the-counter, underregulated by the US Food and Drug Administration, and potentially adulterated (Cohen et al., 2018). We also found that changing eating or exercising more in adolescence is associated with a nearly two-fold higher risk of subsequent consumption of protein powder/shakes in emerging adulthood. Thus, even behaviors not commonly viewed as hazardous – when done with the goal of muscle enhancement – may be a proxy or marker for increased risk given a preoccupation with body shape.

Demographic patterns by sex/gender and race/ethnicity are noteworthy. Overall, we found that persistent muscle-building behaviors from adolescence to emerging adulthood were common especially among male participants (67% exercising more, 40% change eating, and 14% protein powder/shakes). These higher rates may reflect pressures for the idealized masculine body, which is big and muscular (Nagata et al., 2020a). Black/African American race was associated with starting steroid and other muscle-building substance use in males, similar to prior research finding higher rates of weight gain attempts and muscle-building behaviors in this population (Nagata et al., 2020c; 2019b). Black young men may particularly experience societal masculinity pressures to appear bigger and more muscular, particularly for personal safety (Howard et al., 2013). Hispanic/Latinx and mixed/other race/

ethnicities were associated with starting protein powder/shake consumption among males, similar to previous studies (Eisenberg et al., 2012). In addition to a greater drive for muscularity among ethnic minority groups as a means of promoting masculinity (Swami, 2016), there is evidence that certain supplement manufacturers may specifically target marketing at Hispanic/Latinx communities (Martínez, 2013). Sociocultural pressures regarding body ideals may interact with targeted marketing, cultural values, community norms, media portrayals, and other aspects of the social environment to contribute to differential use of muscle-building behaviors across racial and ethnic groups. This warrants further study.

4.1. Limitations and strengths

Several limitations of the study should be noted. There may have been underreporting of illegal substance use, such as steroids due to social desirability bias. Other muscle-building behaviors (e.g., creatine, amino acids, HMB, DHEA, growth hormone) were grouped into a single item and data were not collected on duration, frequency, or dosage of usage. The “changing eating” category did not provide specific examples and could have been interpreted in different ways (e.g., eating more or less). Although the categories were the same, the response options were coded slightly differently in 2010 and 2018. In addition, the measure of sex/gender was vague, and responses could include a mix of assigned sex and identified gender which cannot be disentangled in this analysis. Data for the current study come from Minnesota and may not be representative of the entire US or other countries. Nonetheless, strengths include a large, diverse, prospective sample followed across two life stages in which patterns of health behavior are often established, and the longitudinal design permits an understanding of temporality of these behaviors. The follow-up data are from 2018, making these some of the most up-to-date US data on use of muscle-building substance use from a population-based sample of civilian emerging adults. Five measures of muscle-building behaviors were assessed to provide a more comprehensive picture of the range of less hazardous and more hazardous muscle-building behaviors.

4.2. Implications

Pediatricians and other clinicians, as well as parents and coaches, should consider assessing for muscle-building behaviors in adolescents and emerging adults and discouraging the use of muscle-building supplements and protein powders. Youth should be encouraged to focus on function rather than appearance and to accept different body shapes and sizes. Policymakers should consider prohibiting the sale of muscle-building supplements to minors, given that these products are available over-the-counter and may be laced with harmful substances, such as steroids (Cohen et al., 2018; Eichner and Tygart, 2016). Most governments, including the US Food and Drug Administration, minimally regulate these products (Ganson et al., 2020b). Legislation in Massachusetts (H.2331/S.1524) and New York (S16A/A431A) proposes to prohibit the sale of over-the-counter muscle-building supplements to minors.

5. Conclusion

In conclusion, we find that muscle-building behaviors are common from adolescence to emerging adulthood. Consumption of protein powders/shakes in adolescence may signal increased risk for use of other muscle-building behaviors, including steroid use in emerging adulthood. Products such as protein powders and shakes may be associated with future use of steroids; thus, adolescents who use these products should be counseled to avoid other products such as muscle-building dietary supplements and steroids.

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CRediT authorship contribution statement

Jason M. Nagata: Conceptualization, Writing – original draft. **Vivienne M. Hazzard:** Writing – original draft. **Kyle T. Ganson:** Writing – original draft. **S. Bryn Austin:** Writing – review & editing. **Dianne Neumark-Sztainer:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Marla E. Eisenberg:** Conceptualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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