Muscle Dissatisfaction and Muscle-Enhancing Substance Use: A Population-Based Twin Study in Young Adult Men

Anu Raevuori,[1] Anna Keski-Rahkonen,[1,2,3] Richard J. Rose,[4] Aila Rissanen,[2] and Jaakko Kaprio[1,5]

[1] *Department of Public Health, University of Helsinki, Finland*
[2] *Obesity Research Unit, Department of Psychiatry, Helsinki University Central Hospital, Finland*
[3] *Department of Epidemiology, Columbia University, United States of America*
[4] *Department of Psychology, Indiana University, Bloomington, Indiana, United States of America*
[5] *Department of Mental Health, National Public Health Institute, Helsinki, Finland*

In the population-based *FinnTwin16* study, proportions of genetic and environmental factors contributing to muscle dissatisfaction and muscle-enhancing substance use were assessed in 319 pairs of twin brothers: 141 monozygotic (MZ) and 178 dizygotic (DZ) pairs. In addition there were 86 twin individuals from pairs in which only one co-twin responded. Of all respondents, 30% experienced high muscle dissatisfaction. The corresponding proportion of muscle-enhancing substance use was 10%. The subjects were similar in age (23.8 years, 95% confidence interval [CI] 23.76–23.84), body mass index (23.7, 95% CI 23.5–23.9), and waist circumference (84.5 cm, 95% CI 83.7–85.2), independent of their muscle dissatisfaction or muscle-enhancing substance use status and independent of their zygosity. The MZ polychoric correlation for muscle dissatisfaction was .39 (95% CI .17–.58) and .27 for DZ pairs (95% CI .07–.46). The MZ tetrachoric correlation for muscle-enhancing substance use was .65 (95% CI .28–.87) and .56 for DZ pairs (95% CI .26–.78). The AE model, where additive genetic factors (A) accounted for 42% (95% CI .23–.59) and unique environmental factors (E) 58% (95% CI .41–.77) of the liability, provided the best fit for muscle dissatisfaction. The CE model, where common environmental factors (C) accounted for 60% (95% CI .37–.77) and unique environmental factors (E) 40% (95% CI .23–.63) of the liability, provided the best fit for muscle-enhancing substance use. Both genetic and unique (nonfamilial) environmental factors are involved in muscle dissatisfaction in the population. Nongenetic factors (both familial and nonfamilial) appear to best explain the use of muscle-enhancing substances.

Body image concerns are increasingly widespread among men in Western societies (McCabe & Ricciardelli, 2004). In general, men are more concerned about body shape, muscle mass and definition than over their weight (Pope et al., 2000). Population surveys reveal that young men commonly report dissatisfaction with muscle size and shape (Cohane & Pope, 2001).

Muscle dissatisfaction can be characterized by dissatisfaction with one's muscle tone and size, and dissatisfaction with overall body shape (e.g., waist and hip circumference in relation to size of shoulders and upper arms, and the shape and size of musculature in thighs, calves, and buttocks).

Muscle dissatisfaction seems to be a purely subjective condition that does not necessarily relate to the individual's objective muscularity: in our earlier study (Raevuori et al., 2006), the body mass index (BMI) and waist circumference of muscle dissatisfied subjects did not differ from those satisfied with their musculature. However, muscle dissatisfaction may lead to the use of muscle-enhancing substances, such as creatinine or anabolic steroids (Brower et al., 1994). In addition, it has serious adverse psychological associations (McCabe & Ricciardelli, 2004).

Muscle dysmorphia, a subtype of *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; DSM-IV; American Psychiatric Association, 1994) body dysmorphic disorder, is an extreme condition characterized by pathological preoccupation with body muscularity, excessive training, social and occupational impairment, and a high risk of comorbid mood, anxiety and eating disorder symptoms (Olivardia et al., 2000). Unlike muscle dissatisfied individuals, muscle dysmorphic subjects are often objectively extremely muscular. Its relationship to

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Address for correspondence: Dr. Anu Raevuori, Department of Public Health, PO Box 41, 00014 University of Helsinki, Finland. E-mail: anu.raevuori@helsinki.fi

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muscle dissatisfaction remains uncertain; it is not known whether muscle dysmorphia is an extreme end of the muscle dissatisfaction continuum or whether it is a separate condition.

Few studies have addressed the genetic epidemiology of men's body shape concerns. Current body size and the discrepancy between current and ideal body size on men appear highly genetically determined (Wade et al., 2001), unlike ideal body size, body dissatisfaction, and drive for thinness that appear environmentally determined (Wade et al., 2001; Keski-Rahkonen et al., 2005). Also, individual variation in undue influence of weight on self-evaluation in men is best explained by shared and individual environmental influences (Reichborn-Kjennerud et al., 2004). However, although these studies addressed men's overvaluation of weight and their dissatisfaction with body size and shape, they used instruments that do not differentiate lean body mass from fat mass.

To our knowledge, there are no twin studies of a key area of male appearance concerns, muscle dissatisfaction, and its behavioral correlates, such as muscle-enhancing substance use. The aim of this study was to assess proportions of genetic and environmental factors contributing to muscle dissatisfaction and muscle-enhancing supplement use among young Finnish adult male twins representing the general young adult population. We hypothesized that if these conditions have a genetic component, monozygotic (MZ) twins would demonstrate greater similarity in relation to muscle dissatisfaction or supplement use than do dizygotic twins (DZ).

Materials and Methods

Sample

The data reported are from *FinnTwin16*, a longitudinal population-based study of five consecutive nationwide birth cohorts of Finnish Twins born between 1975 and 1979. Data collection was approved by local ethics committees.

The present study is based on the fourth wave (mean age at response 23.8 years) questionnaire which assessed personality, social relationships, general health, and health habits. After collecting data on body dissatisfaction from the 1975–1977 birth cohorts using the Eating Disorder Inventory (Garner, 1991) in semiannual data collection in autumn 2000 through the end of 2001, we realized that our assessment questions focused solely on female-specific areas of appearance concern. To better understand appearance concerns in males, we addressed muscle dissatisfaction in the 1978–1979 birth cohorts, who were mailed questionnaires in 2002. Thus, instead of the whole five birth cohorts, our study population comprised of two birth cohorts. The number of complete male–male twin pairs who answered the Muscle Dissatisfaction item was 318. In addition, 85 males from pairs in which only one co-twin had responded were included. The corresponding numbers for Muscle-Enhancing Substance Use were 319 pairs and 86 male twin individuals. The overall response rate among men was 83% for this questionnaire.

Twin zygosity was determined by a questionnaire and was in some cases supplemented with additional information from photographs, fingerprints, and DNA marker studies as described previously (Rose et al., 2001; Sarna et al., 1978). The twin pairs were classified as MZ and DZ. The number of MZ pairs was 141 and the number of DZ pairs was 178.

Measures

Muscle dissatisfaction. Muscle dissatisfaction (MD) was assessed based on the following questionnaire item: 'I would like to be more muscular'. The six original responses were recategorized into 'Always or commonly' (High MD), 'Often' (Intermediate MD), and 'Sometimes, rarely, or never' (Low MD).

Muscle-enhancing substance use. Supplement and/or steroid use (muscle-enhancing substance use, MSU) was assessed based on a question: 'Have you ever used hormone preparations, dietary supplements, or other special preparations in order to increase your muscle mass or to maximise the effects of gym training?' The four response alternatives were: 'Yes, continuously during the last three months', 'Yes, continuously at least three months sometimes earlier', 'I have sometimes tried', and 'I have never tried nor used'. To differentiate established use, the item was dichotomized so that men who reported having engaged in muscle-enhancing substance use for 3 months or more either recently or previously were considered muscle-enhancing substance users, while others were not considered as users.

Anthropometrics. Values for height (cm), waist circumference (cm) and weight (kg) were based on self-reported data, from which BMIs were calculated. The correlations between self-reported and later measured values were excellent, .98 for height, .91 for BMI, and .81 for waist in a subsample (n = 133) of these men, who were measured on average 2 years later.

Psychological measures. Several standardized questionnaires, like General Health Questionnaire (GHQ-20; Goldberg & Hillier, 1979), Rutgers Alcohol Problem Index (RAPI; White & Labouvie, 1989) and three subscales of Eating Disorder Inventory-1 (Garner, 1991), were included in the questionnaire.

Statistical Analysis

Assessment of twin similarity was first conducted by computing intrapair correlation coefficients based on tetrachoric/polychoric correlations for pairwise contingency tables of (i.e., muscle dissatisfaction in twin A vs. muscle dissatisfaction in twin B, and corresponding for substance use; Neale et al., 2002; Neale & Cardon, 1992). These correlations represent the bivariate distribution of a latent continuous variable that would reproduce the contingency tables given threshold values between the classes of the categorical variable.

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Table 1

The Distribution of Muscle Dissatisfaction and Muscle-Enhancing Substance Use Among MZ and DZ Twin Individuals

	MZ (%)	DZ (%)	Total *n*
Muscle Dissatisfaction			
High	31%	30%	220
Intermediate	16%	12%	99
Low	53%	57%	402
Total number (*n*)	307	414	721
Muscle-Enhancing Substance Use			
Substance Use	9%	11%	74
Nonsubstance Use	91%	89%	650
Total number (*n*)	307	417	724

Note: For DZ individuals on MD, the percentages add up to 99% due to rounding of individual percentages.

A standard model-fitting method, structural equation modeling, was performed using Mx, a program for analysis of twin and family data (Neale et al., 2002; Neale & Cardon, 1992) by fitting full information maximum likelihood models directly to the raw ordinal data. Scripts were based on the GenomEUtwin script library (www.psy.vu.nl/mxbib/). This method utilizes all available information, including information from pairs in which only one twin has responded. The twin model decomposes variance in the underlying latent variable into additive (A) genetic effects, effects due to dominance (D), environmental effects common (C) to family members (twin siblings), and environmental effects (E) unique to each subject (Neale & Cardon, 1992).

Alternative models of the variance components (ACE, AE, CE and E) were compared by means of the principle of parsimony. Models with fewer parameters were preferred if they did not substantially worsen model fit.

Results

The distribution of muscle dissatisfaction and muscle-enhancing substance use did not differ significantly between MZ and DZ men (Table 1). Of all respondents, 30% experienced high muscle dissatisfaction. The proportion of muscle-enhancing substance users was 10%. The men were similar in age (23.8 years, 95% confidence interval [CI] 23.76–23.84), BMI (23.7, 95% CI 23.5–23.9) and waist circumference (84.5 cm, 95% CI 83.7–85.2) in all classes. Psychological distress measured by GHQ-20, alcohol use measured by RAPI, and symptoms of disordered eating measured by three subscales of Eating Disorder Inventory did not differ between MZ and DZ twin individuals, but were significantly associated with muscle dissatisfaction (Raevuori et al., 2006) and marginally significantly associated with muscle-enhancing substance use.

Table 2 and Table 3 show the intraclass correlations in MZ and DZ pairs for muscle dissatisfaction and muscle-enhancing supplement use. Among all respondents, MZ correlations were higher than DZ correlations. The MZ polychoric correlation for muscle dissatisfaction was .39 (95% CI .17–.58) and was .27 for DZ pairs (95% CI .07–.46). The MZ tetrachoric correlation for muscle-enhancing substance use was .65 (95% CI .28–.87) and correspondently was .56 for DZ pairs (95% CI .26–.78).

In genetic modeling for muscle dissatisfaction (Table 4), a pure E model could be rejected meaning that familial factors are needed to account the pairwise distribution of the data. The remaining models (AE, ACE and CE) of familial aggregation provided adequate fit. When compared to ACE model, the AE model provided a better fit (p = .51) than the CE model (p = .42). In the ACE model, neither A nor C effects were individually significant given their wide confidence intervals: thus, a more parsimonious model was sought. The AE model, where A accounted for 42% (95% CI .23–.59) and E 58% (95% CI .41–.77) of the liability, provided the best fit for muscle dissatisfaction (p = .51). This model result indicates that genetic factors and unique experiences are necessary for an adequate description of individual differences in muscle dissatisfaction in the young adult male population.

In genetic modeling for muscle-enhancing substance use (Table 5), the E model could be rejected meaning that familial factors are needed to account the pairwise distribution of the data. The remaining

Table 2

Pairwise Muscle Dissatisfaction Concordance Rates of the Twins

			Concordant for Muscle Dissatisfaction			Discordant for Muscle Dissatisfaction					
	n (individuals)	*n* (pairs)	high/high *n* (%)	im[1]/im *n* (%)	low/low *n* (%)	high/im[1] *n* (%)	high/low *n* (%)	im[1]/low *n* (%)	Total of discordants *n* (%)	Polychoric correlation coefficient	95% CI
MZ	282	141	20 (14)	4 (3)	52 (37)	13 (9)	32 (23)	20 (14)	65 (46)	.39	.17–.58
DZ	354	177	23 (13)	4 (2)	67 (38)	12 (7)	49 (28)	22 (12)	83 (47)	.27	.07–.46
Total	636	318	43 (14)	8 (3)	119 (37)	25 (8)	81 (25)	42 (13)	148 (47)	—	—

Note: [1] Intermediate.

In addition, 85 twin individuals of whom only one co-twin responded.

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Table 3

Pairwise Muscle-Enhancing Substance Use Concordance Rates of the Twins

			Concordant for Muscle-Enhancing Substance Use		Discordant for Muscle-Enhancing Substance Use		
	n (individuals)	*n* (pairs)	MSU *n* (%)	non-MSU *n* (%)	MSU/non-MSU *n* (%)	Polychoric correlation coefficient	95% CI
MZ	282	141	5 (4)	121 (86)	15 (11)	.65	.28–.87
DZ	356	178	8 (4)	145 (8)	25 (14)	.56	.26–.78
Total	638	319	13 (4)	266 (83)	40 (13)	—	—

Note: In addition 86 twin individuals of whom only one co-twin responded.

MSU = muscle-enhancing substance use.

models (AE, ACE and CE) of familial aggregation each provided adequate fit. The CE model (difference in fit p = .67) was better than AE model (difference in fit p = .14) when either was compared to ACE model. Thus, we chose the CE as being most likely to fit the data the best.

In the CE model, C accounted for 60% (95% CI .37–.77) and E 40% (95% CI .23–.63) of the liability. This implies that familial and nonfamilial environmental effects best explain the use of muscle-enhancing supplements.

Discussion

Of few twin studies in body dissatisfaction in men (Keski-Rahkonen et al., 2005; Reichborn-Kjennerud et al., 2004; Wade et al., 2001), this is, to our knowledge, the first one to specifically explore the genetic epidemiology of male muscle dissatisfaction and muscle-enhancing substance use. The greater correlation of MZ twins suggests a genetic and nonshared environmental effect in muscle dissatisfaction that was confirmed by twin modeling. However, nongenetic influences best explained the development of muscle-enhancing substance use — although the presence of some genetic effects could not be excluded.

In an earlier analysis of body dissatisfaction (Keski-Rahkonen et al., 2005), we found no evidence of genetic influences in males, although its heritability in females was high to moderate. Our current analyses suggest a moderate genetic influence on muscle dissatisfaction in males. The assessment of muscularity is likely to address the key area of body image concerns in males, whereas the Body Dissatisfaction and Drive for Thinness subscales of the Eating Disorder Inventory largely focus on female-specific body image problems. The Muscle Dissatisfaction item also rendered itself more readily for twin modeling, because it was more normally distributed, whereas men's responses to Eating Disorder Inventory items were highly skewed and had to be dichotomized for modeling.

Results of the two other large twin studies on body size, shape and weight attitudes in males (Reichborn-Kjennerud et al., 2004; Wade et al., 2001) are hardly applicable to muscle dissatisfaction because the amount of body fat heavily influences the traits measured in both studies. Nevertheless, in the study by Wade et al. (2001), the discrepancy of ideal versus current body appeared significantly genetically influenced. The construct measured by Reichborn-Kjennerud et al. (2004),

Table 4

Comparison of Alternative Genetic Models Fit to FinnTwin16 Data on Muscle Dissatisfaction

	Components of Variance Estimates and 95% CI			Goodness-of-Fit Tests		
Model	Additive genetic effects (A)	Common environment (C)	Unique environment (E)	chi^2 change	*df*	*p* value
ACE	.24	.15	.61			
	(.00–.58)	(.00–.45)	(.42–.81)	—	—	—
AE best fit	.42		.58	.43	1	.51
	(.23–.59)	—	(.41–.77)			
CE		.32	.68	.66	1	.42
	—	(.17–.46)	(.54–.83)			
E			1.00	17.64	2	< .00001
	—	—	(1.00–1.00)			

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Table 5

Comparison of Alternative Genetic Models Fit to FinnTwin16 Data on Muscle-Enhancing Substance Use

	Components of Variance Estimates and 95% CI			Goodness-of-Fit Tests		
Model	Additive genetic effects (A)	Common environment (C)	Unique environment (E)	chi^2 change	*df*	*p* value
ACE	.17	.48	.35			
	(.00–.85)	(.00–.76)	(.13–.62)	—	—	—
AE	.73		.27	2.15	1	.14
	(.46–.89)	—	(.11–.54)			
CE		.60	.40	.18	1	.67
best fit	—	(.37–.77)	(.23–.63)			
E			1.00	23.15	2	< .00001
	—	—	(1.00–1.00)			

undue influence of weight on self-evaluation, is also conceptually very complex.

Moreover, somatoform disorders, especially body dysmorphic disorder, are shown to cluster in families (Bienvenu et al., 2000). The relevance of the finding in relation to muscle dissatisfaction or males' body dissatisfaction in population level is unclear.

To our knowledge, this is the first twin study to address the genetic epidemiology of muscle-enhancing substance use, which we found mainly environmentally influenced. We have previously observed that the limited availability of these substances may protect young men who live in rural areas (Raevuori et al., 2006). It would have been of interest to test whether our results would be different, had we stratified our sample by the place of residence; unfortunately our sample size did not allow such stratification. Also, although social norms generally oppose the use of anabolic steroids, perhaps the use of other muscle-enhancing substances is more widely tolerated. This phenomenon might be similar to that which was observed of regular tobacco use in women when availability and social norms gradually changed during the 20th century (Kendler et al., 2000). The heritability of many behavioral traits may be greater in permissive environments that provide a greater diversity of exposures than in restrictive environments (Dick et al., 2001; Kendler, 2001; Winter et al., 1999).

The strengths of our study include good population coverage of two full birth year cohorts of twins, a high response rate, and moderately large sample size.

This study also has important limitations. Questionnaire assessment is affected by self-reporting bias. The assessment of muscle dissatisfaction as well as the use of muscle-enhancing substances were based on single items, and height, weight and waist circumference were based on self-report. However, in a subsample of the data set, correlations between self-reports of height, and waist circumference and actual measurements were high. The original six-category variable measuring muscle dissatisfaction was rather normally distributed among the men studied. In our previous paper (Raevuori et al., 2006) it was also highly correlated with the well-validated Body Dissatisfaction scale of the Eating Disorder Inventory, which has been used to assess body shape concerns in various earlier clinical and population studies. Therefore we suggest that despite being based on single items, our conclusions are reliable. We had no direct information on participants' muscle mass. Adding waist circumference to measures was an attempt to compensate the weakness of BMI alone to distinct between lean and fat body mass. Combination of these two measures is shown to be a fairly accurate method in assessment of body fat mass (Bosy-Westphal et al., 2006; Neovius et al., 2005). We further assumed that in young men, the nonfat, lean body mass would be a reliable enough measure for muscle mass in population level.

The question on muscle-enhancing substance use did not separate the use of illicit hormone-like substances, such as anabolic steroids, from various licit supplements. We highly recommend assessing these two types of substances separately in future study designs. In addition, with our sample size, the power to accurately discriminate between AE/CE models for the relatively low prevalent trait of muscle-enhancing substance use was limited. It is noteworthy that even though we chose CE model as the best fitting model, both submodels, AE and CE, fit the data well. With a larger sample size or with higher substance usage prevalence, distinguishing between the models would have been more reliable. Finally, the recategorization of our main variables, MD and MSU, raises questions; but despite the moderate size of our sample, preserving the original six- and four-scaled categorical variables led to small cell sizes and problems in the analyses.

This study was the first twin study to explore genetic and environmental influences contributing to muscle dissatisfaction and muscle-enhancing substance use in young adult males. We found a significant genetic component in male muscle dissatisfaction as muscle-enhancing substance use seemed to be largely

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environmentally modified. Most complex behavioral and medical conditions, from self-esteem (Kendler et al., 1998) to low back pain (Hestebaek et al., 2004), have been shown to have a moderate genetic influence and our results in muscle dissatisfaction are consistent with that. The same seems to be true for many behavioral traits at least in permissive environments (Kendler, 2001), but we found virtually no genetic effect on muscle-enhancing substance use. We welcome future twin studies in the area.

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