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The Michigan State University Twin Registry (MSUTR): An Update

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Abstract

The primary aim of the Michigan State University Twin Registry (MSUTR) is on understanding developmental changes in genetic, environmental, and neurobiological influences on internalizing and externalizing disorders, with antisocial behavior and disordered eating representing our particular areas of interest. The MSUTR has two broad components: a large-scale, population-based registry of child, adolescent, and adult twins and their families (current N~20,000) and a series of more focused and in-depth studies drawn from the registry (current N~4,000). Participants in the population-based registry complete a family health and demographic questionnaire via mail. Families are then recruited for one or more of the intensive, in-person studies from the population-based registry based on their answers to relevant items in the registry questionnaire. These in-person assessments target a variety of biological, genetic, and environmental phenotypes, including multi-informant measures of psychiatric and behavioral phenotypes, census and neighborhood informant reports of twin neighborhood characteristics, buccal swab and salivary DNA samples, assays of adolescent and adult steroid hormone levels, and/or videotaped interactions of child twin families. This article provides an overview of the MSUTR and describes current and future research directions.

Keywords

twins; children-of-twins; antisocial behavior; disordered eating; Michigan State University Twin Registry

The overall focus of the Michigan State University Twin Registry (MSUTR) is on understanding developmental changes in genetic, environmental, and neurobiological influences on internalizing and externalizing disorders. Although most common psychiatric disorders are assessed as part of the MSUTR, the primary externalizing phenotype is antisocial behavior (i.e., aggression, rule-breaking behaviors, and conduct disorder symptoms), while the primary internalizing phenotype examined is disordered eating (i.e., anorexia nervosa, bulimia nervosa, and disordered eating symptoms). Several features of the MSUTR distinguish it from other twin registries. First, the registry takes a lifespan perspective by assessing twins during childhood, adolescence, and adulthood. This lifespan perspective ensures that genetic, environmental, and biological risk factors specific to

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particular developmental periods are identified and examined for their relevance for antisocial behavior and disordered eating.

Second, there is a focus on understanding mechanisms of etiologic effects. While standard twin biometric model-fitting analyses are used to examine relative contributions of genetic and environmental factors, these analyses are extended by the direct assessment of candidate genes, measured environmental factors (e.g., parent–child interactions, neighborhood characteristics), and biological risk factors (e.g., steroid hormone concentrations). These extended assessments allow for the examination of gene × environment interactions, as well as the mediation of genetic effects by neurobiological factors.

Third, the MSUTR has a particular focus on sex differences in psychopathology and the information that sex differences can convey about developmental changes and the genetic and neurobiological substrates of behavior. Eating disorders and antisocial behavior show opposite patterns of sex differences (i.e., eating disorders are more common in females while antisocial behavior is more common in males) and are thus ideal candidates for examining sex differences in etiological factors. We have thus intentionally assessed a range of phenotypic (e.g., personality characteristics; neuropsychological functioning) and biological (e.g., gonadal and stress hormone concentrations; ovarian hormone receptor genes) factors that are linked to sex differences in behavior.

Finally, whenever possible, the MSUTR has included multi-method assessments of phenotypes and environmental risk factors. Multiple informants (i.e., parent reports, twin reports, teacher reports, and/or neighborhood informant samples) are used in studies of child and adolescent twins, and co-twin reports are used in personality assessments of adult twins. Observational as well as survey methods comprise our assessments of parent–child, familial, and spousal relationships. This multi-method approach allows us to more rigorously define our phenotype (Burt, 2012; Burt & Klump, 2012), examine informant effects on heritability estimates (Marceau et al., 2012; Nikolas et al., in press), and obtain a more fine-tuned understanding of environmental risks and their contributions to psychiatric outcomes (Burt et al., 2012; Burt & Klump, in press-a, 2012; Nikolas et al., 2012).

In summary, the MSUTR seeks to use developmental features of psychopathology to understand the genetic, environmental, and neurobiological risk factors for internalizing and externalizing disorders across the lifespan. In the present article, we describe MSUTR recruitment methods, study assessments, and individual research projects.

Recruitment Methods

Although the MSUTR began as a university-based twin registry assessing undergraduate men and women, we have been recruiting twins via birth records since the start of 2004. The Michigan Department of Community Health (MDCH) identifies twin pairs residing in Michigan who meet our study age criteria (see criteria below) and whose addresses or parents' addresses (for twins who are minors) can be located using driver's license information obtained from the state of Michigan. Twins are identified either directly from birth records or via the Michigan Twins Project, a large-scale twin registry within the

MSUTR that doubles as a recruitment resource for smaller, more intensive projects. Because birth records are confidential in Michigan, recruitment packets are mailed directly from the MDCH to eligible twin pairs. Twins indicating interest in participation via pre-stamped postcards or e-mails/calls to the MSUTR project office are then contacted by study staff to determine study eligibility and to schedule their assessments.

Four recruitment mailings are used for each study to ensure optimal twin participation. Overall response rates across studies (56–85%) are on par with or better than those of other twin registries that use similar types of anonymous recruitment mailings. In the one study that has been completed thus far (i.e., the population-based portion of the Twin Study of Behavioral and Emotional Development in Children, TBED C), participating families endorsed ethnic group memberships at rates comparable to area inhabitants (e.g., Caucasian: 86.4% and 85.5%, African American: 5.4% and 6.3% for the participating families and the local census, respectively). Similarly, 14.0% of families in this sample lived at or below federal poverty guidelines, as compared to 14.8% across the state of Michigan. A comparison of participating and non-participating twins and their families is presented in Table 1. We conclude that our recruitment procedures appear to yield samples that are representative of both recruited families and the general population of the state of Michigan.

MSUTR Projects

Parent twin registry

The Michigan Twins Project is an ongoing, population-based, mail-in registry of 20,000+ twins (10,000 pairs) aged 3–25 years born in Michigan. Although the brief questionnaire completed as part of participation in the Michigan Twins Project can be used to immediately generate new knowledge (Burt & Klump, in press-c; Racine et al., submitted-a), the primary purpose of the Michigan Twins Project is to serve as a world-class ‘participant bank’ from which researchers can identify and recruit sub-samples of twins and their families for genetic and genetically informative research. The more focused, in-depth studies making use of this recruitment resource are described below.

In-Depth studies

TBED-C—Investigations of risk factors for psychopathology must necessarily include an examination of childhood where internalizing and externalizing disorders are believed to have their earliest origins. In particular, childhood-onset antisocial behavior (found in roughly 5–10% of children, primarily males) represents a relatively severe condition that is likely to culminate in negative adult outcomes (i.e., substance dependence, incarceration; [Moffitt, 2003]). In contrast, eating disorders are relatively rare in childhood (American Psychiatric Association, 2000). The primary focus of the MSUTR *TBED-C* is thus on understanding the etiology of childhood-onset antisocial behavior and related phenotypes. We also include twin reports of disordered eating and assess internalizing symptoms, other externalizing behaviors, and environmental risk factors that may represent precursors to antisocial and disordered eating symptoms.

The MSUTR *TBED-C* examines twins between the ages of 6 and 10, and to date, has assessed a total of 1,700 same-sex twins (47% female; 50% monozygotic). Our particular aims are to: (1) examine genetic and environmental contributions to antisocial behavior; (2) perform genetic association studies; (3) examine gene–environment interplay, using both biometric models and measured-gene × measured-environment analyses. In service to our final aim, we measure multiple aspects of the twins' 'environment', including parent–child relationships, peer deviance, parental personality and psychopathology, structural and social characteristics of the twins' neighborhoods, and the parents' marital relationship. In doing so, we make use of several measurement strategies: parent- and child-informant reports, videotaped parent–child, family, and spousal interactions, and the assessment of an independent sample of neighborhood informants from each twin family's neighborhood. The *TBED-C* has already produced several published papers (Burt & Klump, 2012, in press-a; Burt et al., 2012; Humbad et al., 2011; Klahr et al., in press; Marceau et al., 2012; Nikolas et al., 2012, in press), with many more under review and in preparation.

Adolescent Twin Study of Behavioral Adjustment and Development (Adolescent-TSBAD)

Eating disorders rarely occur in pre-pubertal individuals (Bulik, 2002) and demonstrate a sharp rise in incidence during adolescence (Graber et al., 1994; Killen et al., 1992). Likewise, the prevalence of non-aggressive delinquency is higher in adolescence (e.g., 20–25%) than at any other point in the lifespan (Stanger et al., 1997). Both phenotypes show developmental shifts in etiologic factors from childhood to adolescence, with increasing genetic risk observed for disordered eating (Klump et al., 2000, 2007, 2010), and antisocial behavior (Burt, in press; Burt & Klump, 2009; Burt & Neiderhiser, 2009). Puberty appears to be a particularly important developmental stage, as early puberty is a risk factor for both disordered eating (Bulik, 2002) and antisocial behavior (Burt et al., 2006) and genetic risk for eating symptoms increase dramatically across pubertal development (Culbert et al., submitted; Klump et al., 2003). Understanding the etiological forces involved in the development of disordered eating and antisocial behavior during adolescence, and how they may differ from other developmental periods, is thus a fundamental part of understanding the development of these phenotypes.

The MSUTR Adolescent-TSBAD includes several sub-studies (e.g., the Twin Study of Hormones and Disordered Eating across Puberty) that examine genetic, environmental, and neurobiological risk factors for disordered eating, antisocial behavior, and related phenotypes across adolescent and pubertal development. This study is ongoing, but has already assessed 998 twins (662 from same-sex female, 206 from same-sex male, and 130 from opposite-sex pairs) between the ages of 8 and 15, and includes assessments of pubertal development, steroid hormones (e.g., estrogen, progesterone, testosterone,), candidate genes (via buccal swabs), and, in some sub-samples, gene expression (via blood samples). Papers from this sample have already con-firmed increased genetic risk for eating disorders during puberty (Culbert et al., 2009) and a role for estrogen in these developmental effects (Culbert et al., 2009; Klump et al., 2012, 2010), as well as examined genetic/environmental risk factors for other phenotypes (Culbert et al., submitted; Moore et al., 2011a, 2011b; Suisman

et al., in press). We now hope to (1) determine whether the activation of gonadal hormones accounts for the dramatic increase in incidence and heritability of disordered eating and other phenotypes during puberty, and (2) examine the extent to which gonadal hormones, gene × environment interactions, and changes in gene expression account for developmental and sex differences in eating pathology and antisocial behavior.

Adult TSBAD (Adult-TSBAD)

Although disordered eating increases in incidence from childhood to adolescence, it is most prevalent in adulthood. Antisocial behavior, in contrast, is far less common in adulthood than in adolescence. Given these developmental shifts, the MSUTR includes assessments of young adults in order to capitalize on increased numbers of individuals with disordered eating and to compare etiologic effects across developmental periods.

The MSUTR Adult-TSBAD has data on 1,190 twins (828 same-sex female, 168 same-sex male, and 194 opposite sex) between the ages of 16 and 30. The project has two primary aims. The first is to examine predictors of eating pathology and antisocial behavior and sex differences in etiologic influences on these and related phenotypes. Several papers addressing this aim have already been published (Culbert et al., 2008; Donnellan et al., 2008; Eggert et al., 2007; Gobrogge et al., 2008; Harrell et al., 2009; Hopwood et al., in press; Klump et al., 2008; Klump et al., in press; Moore et al., 2011a, 2011b; Moser et al., 2012; Racine et al., 2011, 2012; Slane et al., 2010, 2011, 2012; Spanos et al., 2010; Suisman et al., in press), with more underway.

The second primary aim is to examine the role of gonadal hormones in the etiology and genetic diathesis of disordered eating in adult female twins. These studies (e.g., the Twin Study of Hormones and Behaviors across the Menstrual Cycle) extend analyses of hormone/disordered eating associations during puberty by investigating whether natural changes in ovarian hormones predict changes in disordered eating across the menstrual cycle, and whether these associations are genetically mediated or moderated. Findings thus far show that changes in estrogen and progesterone significantly predict changes in disordered eating (Klump et al., 2008; Klump et al., submitted; Klump et al., in press; Racine et al., submitted-b; Racine et al., 2012). Twin analyses of mediation/moderation are ongoing, as are molecular gene–environment interaction models examining hormones as moderators of gene-disordered eating associations.

Study Assessments

Table 2 presents a summary of the assessments that comprise each of the individual MSUTR projects. Given the relatively low base rates of internalizing and externalizing symptoms and the correspondingly large sample sizes needed for twin biometric modeling, there is an emphasis on continuous data in all of these projects (although structured diagnostic interviews are often included as well). There is also an emphasis on the use of developmentally appropriate measures. Finally, every effort is made to ensure that MSUTR projects use the same or similar measures of core phenotypes (i.e., disordered eating and antisocial behavior). This maximizes data collection efforts and allows for comparisons of etiologic effects across datasets and developmental periods.

Zygosity was established using physical similarity questionnaires (administered to the twins and/or their parents) that show accuracies of 95% or better (Iacono et al., 1999; Lykken et al., 1990; Peeters et al., 1998). For several projects, a research assistant also independently evaluates the twins on physical similarity indices. Zygosities are then compared between the participant and research assistant reports and discrepancies are resolved through review of questionnaire data and twin photographs (when available) by one of the MSUTR principal investigators (KLK or SAB) or by DNA markers.

Future Directions

We are hopeful that the developmentally informed approach of the MSUTR will (continue to) yield data that clarifies the role of genetic, environmental, and neurobiological factors in the development of psychopathology across the lifespan. We are taking several steps to achieve this goal. First, new analyses and additional data collections are planned. For example, we recently received funding from MSU to add the recruitment of 6,000 adult twins (from 3,000 pairs), aged 35–45 years, and their children to the Michigan Twins Project, an addition we call the Children of Twins registry (COT). Once developed, it is hoped that the COT will serve as a participant bank from which researchers can identify and recruit children-of-twins samples. We also plan to extend the MSUTR by adding longitudinal follow-up assessments of existing MSUTR samples (particularly those in childhood and adolescence). We welcome collaborations with other twin researchers and registries on these new as well as existing MSUTR projects. Through such collaborations and prospective designs, we hope to further increase understanding of the etiology of disordered eating and antisocial behavior and their developmental trajectories.

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TABLE 1

A Comparison of Participating and Non-Participating Families in the TBED-C

Twin/family characteristic	Mean (*SD*) for participating twins/families	Mean (*SD*) for nonparticipating twins/families	Cohen's *d* effect size
Twin conduct problems	1.33 (1.23)	1.39 (1.30)	−0.05
Twin emotional symptoms	1.80 (1.44)	1.79 (1.48)	0.01
Twin hyperactivity	2.92 (1.96)	3.08 (1.98)	−0.08
Family income	$72,027 (43,800)	$78,319 (50,300)	−0.13~
% two parent homes	89.3 (34.0)	86.0 (36.8)	0.09
% dizygotic	51 (50.1)	55 (50.0)	−0.08
% conceived with fertility meds	20 (40.2)	22 (41.2)	−0.05
Number of twin siblings	2.1 (1.1)	2.2 (1.0)	−0.10
Paternal years of education	7.9 (2.6)	7.9 (2.6)	0.00
Maternal years of education	8.7 (2.3)	8.3 (2.4)	0.17*
Paternal age at assessment (in yrs)	40.3 (6.3)	39.7 (6.0)	0.10
Maternal age at assessment (in yrs)	38.5 (5.6)	38.1 (5.5)	0.07
% of mothers with alcohol problems	2.0 (14.1)	1.3 (11.4)	0.05
% of fathers with alcohol problems	8.7 (28.3)	8.0 (27.2)	0.03
% paternal felony convictions	5.0 (21.8)	6.9 (25.4)	−0.01
% maternal felony convictions	0.4 (6.7)	3.1 (17.5)	−0.20*
Absolute average effect size			.076

Note: Twin conduct problems, emotional symptoms, and hyperactivity were assessed using the Strengths and Difficulties Questionnaire (SDQ; Goodman & Scott, 1999). Each SDQ scale has a possible range of 0–10. National norms for mean SDQ conduct problems, emotional symptoms, and hyperactivity among 8–10 year-olds were 1.3, 1.5, and 2.9, means that are quite comparable to those reported here. Similarly according to the 2008–2010 American Community Survey, the mean family income for the state of Michigan is $73,373, an income level that is quite comparable with that seen in our families. Parental education was coded on a scale of 1–12, with 1 indicating the completion of 7th grade and 12 indicating the completion of more than 2 years of graduate school (7 and 8 correspond to the completion of 2 and 3 years of college, respectively).

*Indicates that the difference between participating and non-participating families was significant at $p < .05$. ~ indicates marginally significant difference ($p < .10$). Please note, however, that none of the means were significantly different across participation status once we Bonferroni-corrected for the number of statistical tests.

TABLE 2

Summary of Existing MSUTR Project Assessments

	Informant reports					Assessment type		
MSUTR project (current *N*)	**Twin**	**Parent(s)**	**Teacher**	**Co-twin**	**Neighborhood informant sample**	**Questionnaire**	**Interview with twin and/or parent**	**Observer ratings**
Parent twin registry (*N*= 10,000 families)								
Zygosity determination		x				x		
Antisocial behavior		x				x		
Disordered eating		x				x		
Other internalizing/externalizing symptoms		x				x		
Family history of psychopathology		x				x		
Twin pubertal development		x				x		
Twin birth complications		x				x		
Use of fertility medications		x				x		
Current height & weight		x				x		
Birth height & weight		x				x		
TBED-Children (*N*= 850 families)								
Zygosity determination		x				x		
Antisocial behavior	x	x	x			x	x	x
Disordered eating	x					x		
Other internalizing/externalizing symptoms	x	x	x			x	x	x
Parent–child relationship	x	x				x		x
Body mass index							x	
Parental personality & psychopathology		x				x		
Neighborhood characteristics	x	x			x	x	x	
Academic/verbal abilities			x				x	
Social-information processing							x	
Parent’s marital relationship	x	x				x		x
Peer deviance		x	x			x		
DNA[a]	x	x	N/A	N/A		N/A	N/A	N/A
Adolescent-TSABD: (*N*= 499 families)								

MSUTR project (current *N*)	Informant reports					Assessment type		
	Twin	Parent(s)	Teacher	Co-twin	Neighborhood informant sample	Questionnaire	Interview with twin and/or parent	Observer ratings
Zygosity determination		x				x		x
Disordered eating	x	x				x	x	
Antisocial behavior	x	x				x		
Other internalizing/externalizing symptoms	x	x				x		
Temperament	x	x				x		
Finger-length ratios	x							
Body mass index & percent body fat							x	
Maternal and/or paternal personality, psychopathology, finger-length ratios, body mass index, and percent body fat	x	x				x	x	
Parent–adolescent relationship	x	x				x		
Teasing by family and peers	x	x				x		
Parent's marital relationship		x				x		
Steroid hormones[b]	x	N/A	N/A	N/A		N/A	N/A	N/A
DNA[a]	x	N/A	N/A	N/A		N/A	N/A	N/A
Gene expression[d]	x	N/A	N/A	N/A		N/A	N/A	N/A
Adult-TSABD: (*N*= 595 families)								
Zygosity determination	x					x		x
Disordered eating	x					x	x	
Antisocial behavior	x					x	x	
Other internalizing/externalizing symptoms	x					x	x	
Personality characteristics	x			x		x		
Finger-length ratios							x	
Body mass index							x	
Family history of psychopathology	x					x		
Nonshared environmental factors	x					x		
DNA[a]	x	N/A	N/A	N/A		N/A	N/A	N/A
Twin steroid hormones[b,c]	x	N/A	N/A	N/A		N/A	N/A	N/A

Note:

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[a] DNA was collected using buccal swabs or saliva collection procedures.

[b] Steroid hormones for each twin were assayed from salivary, finger prick blood spot, and/or serum samples.

[c] Steroid hormones were collected for a subsample of female participants only.

[d] Gene expression was assessed via blood samples for a subsample of female participants only.