ORIGINAL ARTICLE

Longitudinal Progression of Movement Abnormalities in Relation to Psychotic Symptoms in Adolescents at High Risk of Schizophrenia

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Context: Because recent findings suggest that early treatment may ameliorate the course or even prevent the onset of schizophrenia and other psychotic disorders, longitudinal high-risk research on biological markers of risk has become a priority. Within this context, premorbid movement abnormalities are of particular interest because the neurocircuitry hypothesized to give rise to dyskinetic movements has also been implicated in psychotic symptoms. To date, there have been no published longitudinal studies examining the progression of movement abnormalities and their relation with symptom progression in at-risk youth.

Objective: To examine the progression of movement abnormalities in relation to positive and negative symptoms in adolescents at high risk of developing psychotic disorders.

Design: Naturalistic, prospective, longitudinal design.

Setting: Participants recruited through announcements directed at parents of adolescents showing schizotypal symptoms.

Participants: One hundred twenty-one adolescents (mean baseline age, 14.26 years), 32 with schizotypal personality disorder, 49 nonclinical controls, and 40 with other personality disorders.

Main Outcome Measures: Participating adolescents were evaluated for personality disorders (Structured Interview for *DSM-IV* Personality Disorders), prodromal symptoms (Structured Interview for Prodromal Symptoms), and movement abnormalities (Dyskinesia Identification System Condensed User Scale) at 3 annual assessments.

Results: The schizotypal group exhibited significantly elevated movement abnormalities in comparison with controls across all 3 time points. Further, the schizotypal personality disorder group alone showed significant increases in movement abnormalities over time. Movement abnormalities were correlated with prodromal symptoms at each time period, and for several body regions, the magnitude of this relationship significantly increased over time.

Conclusions: The results are consistent with the hypothesis of shared neural circuitry for movement abnormalities and psychotic symptoms and suggest the potential value of including an assessment of motor signs in screening for psychosis risk.

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ABNORMAL MOVEMENTS, particularly oral-facial and upper limb dyskinesias that are independent of medication, have been observed in individuals with schizophrenia spectrum disorders.[1,2] Movement abnormalities have also been documented throughout the premorbid period, including infancy,[3] childhood,[4] and adolescence.[5] Further, they are observable in both medicated[6] and medication-naive individuals who have converted to Axis I psychosis.[7] It has been proposed that movement abnormalities are an external marker of an underlying neural process that is linked with the etiology of psychotic disorders.[8]

Recent research suggests the possibility that early pharmacological and psychosocial interventions with high-risk individuals (eg, individuals with schizotypal or prodromal signs) might have the potential to ameliorate the course or even prevent onset of psychosis.[9-11] It is important to note that this research is in a nascent stage of development and that future carefully controlled studies are necessary before any stronger conclusions can be drawn. However, if there are indeed beneficial effects of early treatment or intervention, because of the problematic adverse effects of antipsychotics and the relatively high costs of psychosocial intervention, blanket intervention with all individuals who manifest risk indicators is not practical. For example, only about 35% of youth who meet current criteria for the prodrome eventually develop an Axis I psychosis (eg, schizophrenia, schizoaffective disorder, bipolar and unipolar depression with psychotic features).[12,13]

Table 1. Demographic Characteristics by Diagnostic Group Over 3 Time Points

	Baseline				Follow-up 1				Follow-up 2			
	NC	SPD	OPD	Total	NC	SPD	OPD	Total	NC	SPD	OPD	Total
Total, No.	**49**	**42**	**30**	**121**	**33**	**26**	**22**	**81**	**25**	**17**	**18**	**60**
Sex, No.												
Male	27	29	13	66	17	16	10	43	12	11	8	31
Female	22	13	17	55	16	10	12	38	13	6	10	29
Age, mean (SD), y	14.14 (1.97)	14.16 (1.66)	14.72 (1.70)	14.26 (1.73)	15.16 (1.77)	15.30 (1.56)	15.40 (1.68)	15.26 (1.70)	16.16 (1.94)	16.12 (1.60)	16.30 (1.59)	16.26 (1.76)
Ethnicity, No.												
White	24	32	16	72	17	19	11	47	12	13	9	34
African American	24	9	11	44	16	6	6	28	13	3	6	22
Asian American	0	1	2	3	0	1	2	3	0	1	2	3
Hispanic	1	0	1	2	0	0	1	1	0	0	1	1

Abbreviations: NC, nonclinical controls; OPD, controls with other personality disorder; SPD, schizotypal personality disorder.

Among high-risk indicators, movement abnormalities may have potential for enhancing prediction of those at greatest risk for psychosis. Adolescents with schizotypal personality disorder (SPD) show elevated movement abnormalities when compared with both nonclinical controls (NC) and controls with other personality disorders (OPD).[14,15] Recent, longitudinal studies of the same sample revealed that, when controlling for baseline symptoms, baseline movement abnormalities predicted the severity of prodromal symptoms 1 year later, and those who converted to an Axis I psychotic disorder at follow-up (within 3-4 years of baseline) exhibited significantly elevated baseline movement abnormalities when compared with those who did not convert.[15,16]

Evidence suggests that prodromal or prepsychotic symptoms increase in severity and frequency throughout adolescence among a subgroup of high-risk individuals.[17,18] In light of theories proposing common neural circuitry in movement abnormalities and psychotic symptoms,[5] it was predicted that movement abnormalities will increase in frequency and severity as high-risk individuals progress through the adolescence. More specifically, we predicted that in comparison with those from the NC and OPD groups, high-risk adolescents with SPD will show a longitudinal increase in movement abnormalities. Further, it was hypothesized that there would be a general increase in the magnitude of the relationship between symptoms and movement abnormalities over time.

METHODS

RECRUITMENT

Recruitment was conducted through announcements directed at parents of youth aged 12 through 18 years who were manifesting schizotypal signs. A nonpsychiatric comparison group was recruited through the Emory University research participant pool. This report presents data on 121 children ranging in age from 12 to 18 years (mean [SD] age, 14.26 [1.73] years) who underwent an initial assessment and 2 subsequent annual follow-ups.

Written consent was obtained from all participants and a parent in accordance with the guidelines of the Emory University human subjects review committee. Demographic characteristics of the sample are presented in **Table 1**. Exclusion criteria at baseline were neurological disorder, mental retardation, substance abuse/addiction, and current Axis I disorder with the exception of learning disorders, attention-deficit disorder, and other disruptive behavior disorders as the latter disorders show a high rate of comorbidity with psychosis.[19]

Because of the potential confound of neurological and tic disorders that might interfere with movement coding, special attention was given to screening any history of these disorders. Furthermore, each participant was observed prior to inclusion in the study by a psychologist with expertise in neuromotor disorders and an experienced child psychiatrist. Any participants suspected of having a neurological disorder were referred to a pediatric neurologist; as a function of the careful prestudy screening procedure, none of the participants had any prior or current neurological disorders.

The NC and OPD groups were selected to be comparable with the SPD group in mean age, educational level, ethnicity, and sex ratio. The final sample of SPD subjects comprised those who met *DSM-IV-TR* diagnostic criteria for SPD but no Axis I disorder. Cluster A personality disorders other than SPD (ie, schizoid, avoidant) were not included in the high-risk (ie, SPD) group because behavioral genetic research indicates that the SPD syndrome is uniquely elevated in relatives of probands with schizophrenia.[20] The OPD group comprised subjects who meet criteria for 1 or more of the other Axis II diagnoses or conduct disorder (schizoid = 1, avoidant = 3, conduct disorder = 10, narcissistic = 4, borderline = 6, histrionic = 3, obsessive-compulsive personality disorder = 3). The NC group consisted of those who did not meet criteria for any Axis I or II diagnoses.

Assessments were conducted on 81 children (33 NC, 26 SPD, 22 OPD) at follow-up 1 and 60 children (25 NC, 17 SPD, 18 OPD) at follow-up 2. Of the 61 participants who did not complete the entire study, the reasons for nonparticipation were loss of contact (ie, moved with no forwarding information, 43%), relocation to another city/state (20%), parent disinterest (16%), child refusal (11%), or child institutionalization (10%).

Although priority was given to the recruitment of participants who had never received a psychotropic drug, 29% of the participants were receiving 1 or more psychotropic drugs at baseline. The most common was stimulants (baseline, SPD = 28%,

OPD=20%, NC=10%; follow-up 1, SPD=23%, OPD=9%, NC=6%; follow-up 2, SPD=18%, OPD=6%, NC=4%) followed by antidepressants (baseline, SPD=28%, OPD=7%, NC=6%; follow-up 1, SPD=12%, OPD=13%, NC=3%; follow-up 2, SPD=12%, OPD=17%, NC=4%) and antipsychotics (baseline, SPD=14%, OPD=3%, NC=8%; follow-up 1, SPD=12%, OPD=5%, NC=3%; follow-up 2, SPD=12%, OPD=6%, NC=4%).

DIAGNOSTIC MEASURES

A battery of diagnostic measures was administered, including the Structured Interview for *DSM-IV* Personality Disorders (SIDP-IV),[21] the Structured Clinical Interview for Axis I *DSM-IV* Disorders (SCID),[22] an interview with the parent, and the Structured Interview for Prodromal Symptoms (SIPS).[17] Previous research has shown that personality disorders can be reliably assessed during the adolescent period, although they are less stable than in adulthood.[23-25]

To obtain data on prodromal signs, we administered the Scale of Prodromal Symptoms (SOPS), which rates the severity of prodromal symptoms. The SOPS comprises 5 symptom domains that are classified as positive (unusual thoughts/ideas, suspiciousness, grandiosity, perceptual abnormalities, conceptual disorganization), negative (social isolation, avolition, decreased expression of emotion, decreased experience of emotion, decreased ideational richness, deteriorated role function), disorganized (odd behavior, bizarre thinking, trouble with focus and attention, impairment in personal hygiene or social attention), and general (sleep disturbance, dysphoric mood, motor disturbance, impaired stress tolerance). (The motor disturbance item was omitted in the present study to prevent overlap.)

Training of interviewers was conducted over a 2-month period, and interrater diagnostic reliabilities exceeded the minimum study criterion of $\kappa \geq 0.80$. Interrater reliabilities (Pearson correlation) for the SOPS symptom ratings all exceeded 0.75.

CODING OF MOVEMENT ABNORMALITIES

Following the procedures used in previous research, motor behavior was coded from videotapes of subjects made during the clinical interview.[14] Interviews were conducted in private rooms and the participant was videotaped while seated in a chair facing a wall-mounted camera behind the interviewer. The chair was positioned so that the entire body was visible on tape. A total of 45 minutes of each videotape was coded with the audio turned off to keep raters blind to the participants' clinical status.

The Dyskinesia Identification System Condensed User Scale (DISCUS) was used to code movements. The DISCUS was empirically developed and contains 15 items that are rated on a 0-to-4 (absent to severe) scale.[26] It yields high interrater reliability (>0.90) for mentally ill and nonpsychiatric subjects.[27,28] The measure also provides separate indexes for 3 different body regions: facial (eg, tics, grimace, blinking, tongue thrusts), upper body (eg, shoulder/hip torsion, writhing extensions of the fingers or wrist), and lower body (eg, ankle flexion, foot tapping).

Another benefit of the DISCUS is the sensitivity to delineating specific abnormalities from general movements; because each item is described with a very specific movement type (eg, tongue thrust) in a specific region (eg, oral region), the DISCUS enables trained raters to endorse items relating to hyperkinetic movements while filtering out general movements that often occur during an interview (eg, twirling hair, adjusting/readjusting clothing, changing seating position, twiddling thumbs). Further, the movements evaluated and endorsed on the DISCUS are distinct from more subtle neurological soft signs (eg, integrative sensory function, motor coordination, and motor sequencing), as well as drug-induced hypokinetic movement, such as Parkinsonian-type rigidity and bradykinesia.

The DISCUS was chosen because the nature of the instrument lends well to a video observation methodology. More specifically, when using the DISCUS, an evaluator is required to take a sample of behavior and apply the rating to this sample. This procedure can be successfully accomplished via videotape observation, which holds several advantages over a live structured movement interview (eg, a reviewer can rewind or slow down the tape, which can ensure blind rater status).

Coders were blind to time point, patient status, and clinical ratings when coding tapes for movements. Coding of the subject tapes began after all pairs of raters had achieved a minimum interrater reliability of 0.80 for coding independently each body region and movement type. The mean reliability at the end of the training period was 0.86 and ranged from 0.72 to 0.95 across body regions.

STATISTICAL ANALYSES

Analyses of covariance (ANCOVA) were conducted to test for group differences for movements at each time point. Dummy-coded classes of psychotropic medication were the covariates at each time point. Post hoc analyses were conducted to determine specific group differences. To test for changes in movement abnormality over time, we conducted a series of three 3×3 (time $\times$ diagnostic group) mixed repeated-measures ANCOVA, controlling for baseline psychotropic medications. Assessment time (baseline vs follow-up 1 vs follow-up 2) was the within-subject factor and diagnostic group was the between-subjects factor. Partial correlations, controlling for medications at each time point, were conducted by diagnostic group to examine associations between movement abnormality and SOPS total, positive, and negative symptoms at each assessment. Analyses were conducted to compare the magnitude of correlations across and within groups using the Fisher z transformation.

RESULTS

PRELIMINARY ANALYSES

Preliminary analyses were conducted to test for demographic differences among the diagnostic groups. χ^2 tests revealed no significant diagnostic group differences in sex ratio, and a 1-way analysis of variance indicated no diagnostic group differences in age (the P values for these comparisons did not approach significance). Screening the data using Kolmogorov-Smirnov tests revealed that distributions of symptom composites and movement abnormality variables were normal and met the assumptions for parametric statistics.

Independent means t tests were used to test for baseline symptom and movement differences between the participants with data for the 3 time points (n=60) and those who did not participate in the 2 follow-ups (n=61), and no significant differences were detected.

Group comparison analyses were conducted to determine whether the inclusion/exclusion of participants with cluster A disorders other than SPD (ie, avoidant, schizoid; n=4) from the high-risk group would affect the outcome of results. This did not alter the pattern of results or levels of significance from the findings reported here in any case. Further, analyses were conducted with and without the 4 individuals in the NC group who were being treated with antipsychotic medications. As with the

Table 2. Changes in Movement Abnormalities Represented by DISCUS Scores Over Time

	NC	SPD	OPD	Total	Group Differences
			Baseline		
Face score, mean (SD)	0.18 (0.52)	1.04 (1.37)	0.43 (1.52)	0.54 (1.21)	SPD > NC,OPD[a] NC = OPD
Upper body score, mean (SD)	1.16 (1.17)	2.76 (2.49)	1.20 (1.54)	1.72 (2.01)	SPD > NC,OPD[a] NC = OPD
Lower body score, mean (SD)	1.02 (1.07)	1.48 (1.26)	1.60 (1.03)	1.32 (1.15)	NC = SPD = OPD
			Follow-up 1		
Face score, mean (SD)	0.15 (0.50)	1.23 (1.33)	0.35 (0.81)	0.55 (1.03)	SPD > NC,OPD[a] NC = OPD
Upper body score, mean (SD)	0.27 (0.71)	4.89 (2.28)	0.85 (1.13)	2.01 (2.60)	SPD > NC,OPD[a] NC < OPD
Lower body score, mean (SD)	0.69 (0.80)	1.46 (1.10)	0.60 (0.82)	0.93 (0.99)	SPD > NC,OPD[a] NC = OPD
			Follow-up 2		
Face score, mean (SD)	0.36 (1.07)	2.88 (3.99)	0.27 (0.95)	1.05 (2.53)	SPD > NC,OPD[a] NC = OPD
Upper body score, mean (SD)	1.04 (1.24)	4.91 (2.49)	2.00 (0.70)	2.26 (2.44)	SPD > NC,OPD[a] NC < OPD
Lower body score, mean (SD)	0.76 (0.83)	1.82 (1.28)	0.77 (0.87)	1.06 (1.08)	SPD > NC,OPD[a] NC = OPD

Abbreviations: DISCUS, Dyskinesia Identification System Condensed User Scale; NC, nonclinical controls; OPD, controls with other personality disorder; SPD, schizotypal personality disorder.
[a] $P \leq .01$.

previous series of analyses, this did not alter the pattern of results or levels of significance from the findings reported here in any case.

GROUP DIFFERENCES IN MOVEMENT OVER TIME

At baseline, there were significant group differences for movement abnormalities of the face region ($F_{2,120}=4.53$, $P \leq .01$, $\eta^2=0.19$) and the upper-body region ($F_{2,120}=3.63$, $P \leq .01$, $\eta^2=0.16$). Post hoc comparisons revealed the SPD group showed more severe face and upper-body movement abnormalities than both control groups. The analyses did not find significant group differences for the lower-body region.

For the face region, both stimulants ($F_{1,120}=5.95$, $P=.01$) and antipsychotics ($F_{1,120}=5.22$, $P=.02$) were significant covariates, but antidepressants were not ($F_{1,120}=0.57$, $P=.44$). Stimulant medication was associated with a higher DISCUS score, whereas antipsychotics were associated with a lower score. For the upper-body region, covariates for stimulants ($F_{1,120}=1.62$, $P=.20$), antipsychotics ($F_{1,120}=0.13$, $P=.71$), and antidepressants ($F_{1,120}=0.55$, $P=.45$) were not significant. Similarly, for the lower-body region, covariates for stimulants ($F_{1,120}=0.00$, $P=.99$), antipsychotics ($F_{1,120}=0.32$, $P=.57$), and antidepressants ($F_{1,120}=0.79$, $P=.37$) were not significant.

At follow-up 1, there were significant group differences for movement abnormalities of the face region ($F_{2,81}=4.00$, $P \leq .01$, $\eta^2=0.25$); the upper-body region ($F_{2,81}=27.67$, $P \leq .01$, $\eta^2=0.69$); and, divergent from the findings in baseline, the lower-body region ($F_{2,81}=3.02$, $P \leq .01$, $\eta^2=0.20$). For the face region, covariates for stimulants ($F_{1,81}=2.27$, $P=.13$), antipsychotics ($F_{1,81}=0.04$, $P=.83$), and antidepressants ($F_{1,81}=0.98$, $P=.32$) were not significant. For the upper-body region, covariates for stimulants ($F_{1,81}=0.80$, $P=.37$), antipsychotics ($F_{1,81}=2.14$, $P=.14$), and antidepressants ($F_{1,81}=0.71$, $P=.40$) were not significant. Similarly, for the lower-body region, covariates for stimulants ($F_{1,81}=1.09$, $P=.30$), antipsychotics ($F_{1,81}=1.53$, $P=.21$), and antidepressants ($F_{1,81}=0.55$, $P=.45$) were not significant.

At follow-up 2, there were significant group differences for movement abnormalities of the face region ($F_{2,120}=3.39$, $P \leq .01$, $\eta^2=0.27$), the upper-body region ($F_{2,60}=5.25$, $P \leq .01$, $\eta^2=0.37$), and the lower-body region ($F_{2,60}=3.06$, $P \leq .01$, $\eta^2=0.25$). For the face region, covariates for stimulants ($F_{1,60}=0.001$, $P=.98$), antipsychotics ($F_{1,81}=0.03$, $P=.86$), and antidepressants ($F_{1,81}=1.23$, $P=.27$) were not significant. For the upper-body region, covariates for stimulants ($F_{1,60}=0.37$, $P=.54$), antipsychotics ($F_{1,81}=0.49$, $P=.48$), and antidepressants ($F_{1,81}=1.31$, $P=.25$) were not significant. For the lower-body region, covariates for stimulants ($F_{1,60}=2.45$, $P=.12$), antipsychotics ($F_{1,81}=1.74$, $P=.19$), and antidepressants ($F_{1,81}=0.01$, $P=.89$) were not significant. The means and standard deviations are presented in **Table 2**.

TEMPORAL PROGRESSION OF MOVEMENT ABNORMALITIES

Analyses of the facial region revealed that the SPD group remained significantly elevated in comparison with both comparison groups for each of the 3 time points (Table 2), and the changes in DISCUS score between the 3 time points were highly significant (Wilks $\Lambda=0.88$, $F_{3,57}=3.17$, $P \leq .05$). Post hoc paired sample t tests indicated that the SPD was unique in that it showed a significant rise in abnormal movements between baseline and follow-up 2 ($t_{17}=-1.76$, $P \leq .05$) and between follow-up 1 and follow-up 2 ($t_{17}=-1.76$, $P \leq .05$) while movement abnor-

Table 3. Correlations Between Movement Abnormality and Psychotic Symptoms for the Total Sample by Assessment Time

	Baseline (n=121)			Follow-up 1 (n=81)			Follow-up 2 (n=60)		
	Positive	Negative	Total	Positive	Negative	Total	Positive	Negative	Total
Face	0.24[a]	0.37[b]	0.33[b]	0.23[a]	0.22[a]	0.25[a]	0.22[a]	0.21	0.21
Upper body	0.25[a]	0.37[b]	0.29[b]	0.43[b]	0.42[b]	0.47[b]	0.44[b]	0.45[b]	0.49[b]
Lower body	0.10	0.09	0.06	0.24[a]	0.25[a]	0.23[a]	0.35[b]	0.34[b]	0.30[a]

[a] $P<.05$.
[b] $P<.001$.

malities in both comparison groups remained constant across time. Antipsychotic medications were a significant covariate in this analysis (Wilks $\Lambda=0.85$, $F_{2,58}=4.25$, $P=.03$) (associated with a longitudinal decrease in movement abnormalities). Stimulants (Wilks $\Lambda=0.97$, $F_{2,58}=0.55$, $P=.57$) and antidepressants (Wilks $\Lambda=0.94$, $F_{2,58}=1.65$, $P=.20$) were not significant covariates.

Analyses of the upper-body region revealed that the SPD group remained significantly elevated in comparison with both controls for each of the 3 time points (Table 2), and the changes in DISCUS score between the 3 time points were highly significant (Wilks $\Lambda=0.92$, $F_{3,57}=2.20$, $P\leq.05$). Post hoc paired sample *t* tests indicated that the SPD group was unique in that it showed a significant rise in abnormal movements between baseline and follow-up 1 ($t_{28}=2.74$, $P\leq.01$). However, the movement abnormalities for this group between follow-up 1 and follow-up 2 remained relatively constant. Movement abnormalities significantly decreased for the normal control group between baseline and follow-up 1 ($t_{32}=-3.87$, $P\leq.01$) but returned to baseline levels at follow-up 2 ($t_{23}=-2.04$, $P=.05$). There were no significant changes across time for the OPD group. In this series of analyses, stimulants (Wilks $\Lambda=0.91$, $F_{2,58}=2.36$, $P=.10$), antipsychotics (Wilks $\Lambda=0.98$, $F_{2,58}=0.38$, $P=.68$), and antidepressants (Wilks $\Lambda=0.96$, $F_{2,58}=1.09$, $P=.34$) were not significant covariates.

Analyses of the lower-body region revealed that the SPD group was not different from controls at baseline but became significantly elevated in comparison with both comparison groups at follow-up 2 (Table 2). Although movement abnormalities were elevated for the SPD group at follow-up 2, results did not indicate a statistically significant longitudinal change for this group (Wilks $\Lambda=0.94$, $F_{3,57}=1.60$, $P=.11$). Movement abnormalities remained constant for the NC group across time periods. For the OPD group, there was an initial decline between baseline and follow-up 1 ($t_{21}=-2.72$, $P\leq.01$) but no change between follow-up 1 and follow-up 2. Covariates were not significant for stimulants (Wilks $\Lambda=0.98$, $F_{2,58}=0.49$, $P=.61$), antipsychotics (Wilks $\Lambda=0.90$, $F_{2,58}=0.29$, $P=.07$), and antidepressants (Wilks $\Lambda=0.99$, $F_{2,58}=0.19$, $P=.82$).

ASSOCIATION BETWEEN MOVEMENT ABNORMALITIES AND PRODROMAL SYMPTOMS OVER TIME

Movement abnormalities are rated on a continuous scale, and both NC and OPD groups in the present study exhibited some, albeit low, levels of abnormal movements. Because prodromal symptoms were assessed in each participant on a continuous scale, it was possible for individuals in the NC and OD groups to endorse some items yet still remain at subthreshold levels for prodromal or SPD status. Correlational analyses to test the relation between movement and symptom scores were therefore conducted on the entire sample (**Table 3**).

Movement abnormalities in the facial region were positively associated with prodromal symptomatology at baseline, but the strength of this relationship appeared to diminish as a function of time. Correlations were significant for the upper body for each of the 3 assessments, and increased in magnitude at subsequent time points. Finally, associations for the lower-body region were not significant for baseline, but the magnitude of the correlations subsequently increased and were significant at follow-up 1 and follow-up 2.

Fisher *z* transformations were used to test the hypothesis that the strength of the relation between movement abnormalities and symptoms would increase over time. For the facial region, the correlations between movement abnormalities and positive symptoms were not significantly different across time points. For negative symptoms and facial movements, a decrease in magnitude between baseline and follow-up 1 ($z=1.18$, $P=.12$) and between baseline and follow-up 2 ($z=1.13$, $P=.12$) approached statistical significance. Correlations for the facial region and total symptoms showed a similar downward pattern although the differences in magnitude across time points did not approach significance.

For movement abnormalities in the upper-body region, the magnitude of the relationship with positive symptoms significantly increased from baseline to follow-up 1 ($z=-1.50$, $P=.05$) and showed a moderate trend for increase from baseline to follow-up 2 ($z=-1.4$, $P=.08$). For negative symptoms, there was a slight increase in magnitude, but it did not approach statistical significance. For total symptoms, there was a significant increase in magnitude between baseline and follow-up 1 ($z=-1.64$, $P=.04$) and between baseline and follow-up 2 ($z=-1.60$, $P=.05$).

For lower-body movements, there was a marginal increase in the strength of the relation with positive symptoms between baseline and follow-up 1 ($z=-1.04$, $P=.12$) and a significant change between baseline and follow-up 2 ($z=-1.71$, $P=.04$). The same held for negative symptoms and movement abnormalities in the lower-body region, where there was an increase in magnitude

between baseline and follow-up 1 that approached significance ($z=-1.18$, $P=.11$) and a significant increase in magnitude between baseline and follow-up 2 ($z=-1.71$, $P=.04$). Finally, for total symptoms, there was a trend for an increase between baseline and follow-up 1 ($z=-1.25$, $P=.10$) and a significant change between baseline and follow-up 2 ($z=-1.61$, $P=.05$).

MEDICATION-FREE ANALYSES

The reported analyses used a statistical control for the use of psychotropic medications. It was also of interest to determine whether the general pattern of findings held true when the analyses listed here were conducted on the 71% medication-free proportion of the sample. Each of the series of analyses was conducted on the medication-free sample. In each case, the pattern of findings held consistent with the results comprising the entire sample listed here. Exceptions to this trend (ie, when a direction of a finding changed, when a significant finding was no longer significant) are listed here. There were several cases in which the medication-free analyses results increased in magnitude; at baseline the relationship between total symptoms and lower-body abnormal movements ($r=.21$, $P\leq.05$) and positive symptoms and lower-body movements ($r=.23$, $P\leq.05$) became significant. Further, at follow-up 2, the relationship between upper-body movements and negative symptoms became significant ($r=.36$, $P\leq.01$). However, longitudinal changes in magnitude held the same as the analyses that included the whole sample.

COMMENT

To our knowledge, the present investigation represents the first longitudinal study of the progression of movement abnormalities in conjunction with psychotic symptoms through the adolescent prodromal period. Consistent with prediction, for the SPD group, movement abnormalities of the face and upper body were significantly elevated at all 3 time points and also increased over time. These findings suggest that as high-risk children progress through adolescence toward the mean age at onset for psychosis (men, 21 years; women, 27 years),[29] the occurrence of movement abnormalities increases. Further, results from the present investigation suggest that the magnitude of the associations between movement abnormalities and psychotic symptoms increases as a function of time.

These relationships may reflect the overlapping circuitry responsible for movement and symptoms. More specifically, hyperkinetic movements are assumed to be a reflection of overactivation of ascending dopamine pathways, specifically the striatal pathway mediated by the D2 receptor subtype.[30] Striatal D2 receptor overactivation has been implicated in Axis I psychosis.[31,32] Given this overlap, some have suggested that cortico-striato-pallido-thalamic circuit malfunction, mediated by dopamine activity,[33] is responsible for the deficits in motivation and cognitive functioning associated with psychotic disorders as well as both positive and negative psychotic symptoms.[8,34]

The present findings are consistent with research examining individuals with recent onset or first episode schizophrenia[7,35]; the results from studies with these populations also indicate that movement abnormalities are elevated. Thus, the pattern of findings suggests that for high-risk individuals, movement abnormalities increase in adolescence and then continue after onset. The longitudinal course of movement abnormalities after onset is uncertain, and medication poses a challenge to studies of the natural progression of motor signs. Nonetheless, there is some evidence that although movement abnormalities remain present in individuals with schizophrenia throughout the lifetime, they do not continue to exacerbate with late age.[36]

Because movements in the face regions are represented in the ventral medial area of the putamen,[8] results from the present study suggest that an exacerbating neuropathology in this region is associated with psychotic disorder. This theory is further supported by other studies of movement that have reported elevated orofacial dyskinesia in drug-naive individuals with schizophrenia.[7]

One interpretation of the overall pattern of findings is that vulnerability for psychosis involves striatal abnormalities that can be initially manifested as movement abnormalities during childhood and adolescence, then, as frontal-striatal circuitry matures through late adolescence, striatal dysfunction is manifested as prodromal and eventually psychotic symptoms.[8] Thus the same striatal dopamine receptor abnormality could result in 2 distinct manifestations: movement abnormality and psychotic symptoms.

CONCLUSIONS

There are several limitations in the present study. Although medications were statistically controlled in the present analyses (eg, group comparisons were conducted with and without covariates), this does not eliminate the potential confound of medication effects. A second limitation concerns the coding procedure, which was applied to videos of seated participants and may have masked movement abnormalities in the lower limbs; future research using different observation methodologies such as observing behavior during ambulation will help elucidate this matter. A noteworthy limitation is that state anxiety experienced by the participants may have influenced the general level of movement.

Another potential limitation is a possibility that differential attrition across the study was not detected. Specifically, although baseline comparisons indicated no significant differences in motor function between those who remained in the study and those lost to attrition, it is possible that differences between these 2 groups emerged after the baseline assessment or the first follow-up. For example, those whose symptoms or motor signs improved may have been less inclined to continue participation. Although postbaseline attrition is plausible, the present study would not detect it.

In the present study, we observed an SPD-specific relationship between movements and symptoms that generally increased in magnitude throughout the progression of prodromal illness. Because these data are a product of an ongoing longitudinal study at Emory University[5,15,16] designed to follow up high-risk individuals through the adolescent risk period, it will be possible to follow up the same partici-

pants and answer several other important theoretical and empirical questions. The next step will be to analyze conversion data from the ongoing longitudinal study, available in the next several years, and address a key issue: the value of longitudinal measures of movement abnormalities in predicting conversion to schizophrenia. At the present time, follow-up assessments are being conducted to determine psychiatric outcome, particularly conversion to an Axis I psychotic disorder. At this writing, there have been some conversions, and more are anticipated, given that the participants are still in the mid point of the modal risk period for the onset of psychosis. When the final follow-up assessments are completed, the longitudinal relation of movement abnormalities with conversion will be examined.

It will be fruitful for future research to examine movement abnormalities using other methodologies. For example, it may be useful to combine a questionnaire that assesses movement disorders that may not be readily observable (eg, akathisia) with the observation-type assessment used in this present research. It will also be of interest to examine the relationship among these variables in other types of high-risk populations; although the present study used a model focusing on adolescents with SPD, determining the pattern of findings when using other sampling methodologies, such as following up individuals with a close family history of psychotic disorders, will expand our understanding of this phenomenon. Finally, it will be informative to study how other types of movements observed in individuals with schizophrenia (eg, hypokinetic movements associated with low dopamine activity) fit into the present framework.

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