

Original article

Age-Related Change in Physical Activity in Adolescent Girls

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Abstract

Purpose: To determine the annual rate at which physical activity changes in girls during middle school using both objective and self-report measures of physical activity.

Methods: Participants were sixth- and eighth-grade girls from the control schools in the Trial of Activity for Adolescent Girls (TAAG). Random cross-sectional samples initially were drawn from sixth-grade girls ($n = 786$) and 2 years later from eighth-grade girls ($n = 1545$). A cohort of 501 girls was in both the sixth- and the eighth-grade samples. The girls wore an accelerometer for 6 days and completed the 3-Day Physical Activity Recall. Data were summarized using 3.0-, 4.6-, and 6.5-metabolic equivalent cutpoints for accelerometry and self-reported physical activity. Analyses were performed using repeated-measures analysis of variance in PROC MIXED.

Results: More than 40% of the girls were white, approximately 20% were African American, and 20% were Hispanic. The annual percent decrease in physical activity in the cross-sectional sample was approximately 4% (-1.76 min moderate-to-vigorous physical activity/day), using accelerometer data. The percent decrease in physical activity based on self-report data was higher, 6% to 13%, depending on the physical activity variable. Declines tended to be larger in African American girls, but the ethnic differences were not statistically significant.

Conclusions: Based on comparisons of cross-sectional samples of sixth- and eighth-grade girls, objectively measured physical activity declined at a rate of 4% per year. © 2009 Society for Adolescent Medicine. All rights reserved.

Keywords: Physical activity; Adolescents; Girls; Middle school; Accelerometry

Numerous secular changes in the industrialized societies of the world have made common a lifestyle that is characterized by little demand for physical activity and easy access to enjoyable sedentary behaviors [1]. In adults, low levels of physical activity are associated with high levels of risk for premature mortality and increased chronic disease morbidity [2]. In youth, habitual low physical activity is linked

to increased risk for development of overweight [3–5] and to adverse chronic disease risk factor profiles [6–8]. Among U.S. adolescents physical activity levels are lower in girls than boys [2,9,10], and they are particularly low in African American and Hispanic girls [9,11]. Not surprisingly, population studies of adolescents typically show that rates of overweight are highest in those demographic groups [12,13].

Many previous studies have shown that physical activity levels tend to decline with increasing age during adolescence; however, the observed rates of age-related decline in physical

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activity have varied markedly across studies [9,14–16]. Kimm et al [9] observed that between ages 9 and 19, girls' leisure-time physical activity levels declined 83%, or approximately 8% per year. McMurray and colleagues [16] found that physical activity in boys and girls ages 8 to 16 decreased 6.8% to 7.6% per year over a 7-year period. In contrast, Duncan et al [17] found that physical activity in boys and girls ages 12 to 17 decreased only approximately 3% per year over 5 years. Most studies have used questionnaires that ask children or adolescents to report their physical activity; Kimm et al [17], for example, asked girls about their extracurricular sports and physical activities during the past 12 months. Very few previous investigations of age-related change in physical activity used objective measurements, and most of those used heart rate monitoring. In recent years, accelerometry has become the method of choice for objective assessment of physical activity [18–21], but no previous study has applied accelerometry to large samples of youth for the purpose of assessing age-related change in physical activity.

The Trial of Activity for Adolescent Girls (TAAG) is a multicenter group-randomized field trial designed to test the effects of a school–community-linked intervention on physical activity in middle school girls [22,23]. In TAAG, baseline physical activity data were collected in a diverse, randomly selected sample of sixth-grade girls attending 36 middle schools in six states. Follow-up data were collected 2 years later in a second random sample of eighth-grade girls attending the same schools. Embedded in these two cross-sectional samples was a sizeable adventitious cohort. Both objective and self-report measures of physical activity were collected in TAAG participants at both the sixth-grade and eighth-grade measurement points. The major purpose of this study was to determine the rate at which objectively measured physical activity changes in girls during middle school. In addition, we observed age-related change in activity using a self-report procedure. Further, using both objective and self-report methods, we examined age-related change in physical activity using expressions of total physical activity as well as moderate-to-vigorous and vigorous intensity physical activity.

Methods

Study design

TAAG is a cross-sectional and longitudinal examination of physical activity in sixth- and eighth-grade girls recruited from six communities in the United States. University-based field centers are located in and around the cities of Tucson, Arizona; San Diego, California; New Orleans, Louisiana; Washington, DC/Baltimore, Maryland; Minneapolis, Minnesota; and Columbia, South Carolina. Six middle schools in each community were recruited for the study. To be eligible, schools had to have a minimum of 90 girls in the eighth grade and offer physical education at all grade levels. Schools were

selected by convenience, but with ethnic diversity as a goal. Within each school, girls were selected by random sampling of all eligible sixth-grade girls. Girls were considered eligible unless they had a health problem that contraindicated physical activity or if a school administrator requested that the girl not be included in the study. To exclude effects of the intervention on physical activity, only girls in the control schools (three schools per community) were included in the analyses reported in this manuscript. Study coordination was provided by the University of North Carolina at Chapel Hill and the NHLBI Project Office.

Two random cross-sectional samples were drawn, the first among sixth graders at the beginning of the study and the second among eighth graders at the end of the study, following the 2-year implementation of the intervention. Random lists of girls were generated from school enrollment data, and girls were recruited from these lists. To limit costs, the sample size at baseline was approximately half as large ($n = 60$ per school) as the sample size at the eighth-grade measurement ($n = 120$ per school). Although the two samples of girls were cross-sectional, the analysis of change was longitudinal, with a cohort of 18 schools sampled over time. In addition, an adventitious cohort was created that included girls who were by chance included in the random cross-sectional samples at both the sixth- and eighth-grade time points, and thus were measured twice.

The study was approved by the participating universities' institutional review boards. Each participant's parent or guardian provided written informed consent, and all participants assented to participation. Consent for measurement was obtained for 80% of the random sample. The cross-sectional analysis included 786 sixth-grade girls and 1545 eighth-grade girls in the control schools, and the adventitious cohort analysis included 501 girls, also in the control schools.

Accelerometer data

The girls wore an ActiGraph accelerometer (Manufacturing Technologies Inc. Health Systems, Model 7164, Shalimar, FL) for 7 consecutive days. The ActiGraph is a uniaxial accelerometer that measures acceleration in the vertical plane; it is small ($2.0 \times 1.6 \times 0.6$ inches), light (1.5 ounces), and unobtrusive. Its acceleration signal is filtered by an analog band-pass filter (0.1–3.6 Hz) and digitized by an 8-bit A/D converter rate of 10 samples per second, storing data in user-defined intervals. TAAG staff distributed the accelerometers and provided detailed verbal and written instructions on how and when to wear them. Accelerometers were initialized prior to data collection and set to begin collecting data at 5:00 a.m. on the day after they were distributed to participants; thus, data for 6 complete days were available for analysis. Data were collected and stored in 30-second increments. Girls wore the accelerometers on their right hip, attached to a belt, and were asked to take it off only when sleeping, bathing, or swimming. After 6 days of recording, data collectors

Table 1
Descriptive characteristics of the TAAG girls

Sample	Variable	n	Mean	SD	Min	Max	Race	Frequency	Percent
6th Grade (N = 786) Cross-sectional	Age	780	11.98	0.54	10.46	14.59	White	338	43.00
	BMI	782	21.00	5.02	13.31	44.75	Black	163	20.74
							Hispanic	185	23.54
							Other	100	12.72
8th Grade (N = 1545) Cross-sectional	Age	1545	13.98	0.52	12.81	16.60	White	708	45.83
	BMI	1545	22.87	5.44	13.35	55.11	Black	309	20.00
							Hispanic	338	21.88
							Other	190	12.30
Cohort (N = 501)	Age 6th	499	11.90	0.43	10.71	14.33	White	247	49.30
	BMI 6th	498	20.70	4.88	13.31	44.75	Black	89	17.76
	Age 8th	501	13.92	0.43	13.07	16.47	Hispanic	112	22.36
	BMI 8th	501	22.69	5.47	13.35	50.74	Other	53	10.58

BMI = body mass index; TAAG = Trial of Activity for Adolescent Girls.

retrieved the monitors, downloaded the data, and sent it to the coordinating center.

Data from the accelerometers were downloaded to the same laptop computer that was used to initialize them. Accelerometer readings were processed using methods similar to those of Puyau et al [24]. Readings at or above 1500 counts per 30 seconds were treated as moderate-to-vigorous physical activity (MVPA, 4.6 metabolic equivalents [METs]), and counts above 2600 per 30 seconds were treated as vigorous physical activity (VPA, 6.5 METs) [25]. Occasional missing data within a girl's 6-day record were replaced via imputation based on the Expectation Maximization (EM) algorithm [26]. On average, approximately 12 hours of data (about 11%) per girl were imputed over the 6 days of data collection. Counts above 1500 per 30 seconds were converted into METs using a regression equation [27]. One MET-minute represents the metabolic equivalent of energy expended while sitting at rest for 1 minute, and MET-weighted minutes of MVPA (MW-MVPA) were computed.

Self-reported physical activity

Self-reported physical activity was obtained with a modified version of the 3-Day Physical Activity Recall (3DPAR) [28,29]. The 3DPAR required participants to recall PA behavior from the previous 3 days, beginning with the most recent day, using a script and graphic figures to explain the intensity of common activities. Light activities were described as requiring little or no movement with slow breathing, moderate activities as requiring some movement and normal breathing, hard activities as requiring moderate movement and increased breathing, and very hard activities as requiring quick movements and hard breathing.

Participants were asked to complete a grid divided into 30-minute time blocks, beginning at 6 a.m. and ending at 12 midnight. A list of 71 activities grouped in categories of eating, after school/spare time/hobbies, sleep/bathing, school, transportation, work, and physical activity was provided. Girls were asked to enter their predominant activity in each

30-minute block and an intensity code for nonsedentary activities. Extra activities were added to the original 3DPAR to reflect the different activities that can be performed in various climates. MET values were obtained from the Compendium of Physical Activities [30]. Four summary variables were created to be similar to the ActiGraph variables. These included the number of average daily blocks of MVPA, with 4.6 METs as the cutpoint; average daily blocks of VPA, with 6.5 METs as the cutpoint; number of average daily blocks of PA, with 3.0 METs as the cutpoint; and average total daily METs. Although collection of the 3DPAR and accelerometer data was scheduled to overlap, occasionally it did not (e.g., if a girl was absent when she initially was scheduled to complete the 3DPAR).

Other measures

Girls classified themselves in one of five race/ethnicity categories: Asian, African American, Hispanic, white, or other. Girls were categorized as Hispanic if they indicated Hispanic ethnicity on the questionnaire. Otherwise, girls who indicated more than one race group or who selected "Native Hawaiian or other Pacific Islanders" were classified as "other." Parents reported girls' date of birth on the consent form. Age was calculated as time between the date of birth and the questionnaire completion date. Height and weight were measured using standardized procedures. Body mass index (BMI) was calculated by dividing weight in kilograms by height in meters squared.

Statistical methods

Descriptive statistics were calculated for girls included in the cross-sectional and longitudinal samples. All analyses were conducted with SAS Version 9.1.3 (SAS Institute, Cary, NC).

Repeated-measures analysis of covariances (ANCOVAs) were fit using SAS PROC MIXED [31]. For the cross-sectional samples, the models included time and race as fixed effects with field center and school within field center as

random effects; for analyses of accelerometry data, wave of data collection was included as an additional random effect. For the longitudinal sample, the models included time and race as fixed effects and field center, school within field center, and girl within school as random effects; for analyses of accelerometry data, week of data collection was included as an additional random effect. From these repeated-measures ANCOVAs, we calculated the absolute difference between sixth and eighth grades, and expressed it as the percent change per year between sixth and eighth grade for each physical activity variable for each sample. Significance levels were assessed based on the mixed models, taking into account the positive intraclass correlation expected in these data [32]. These analyses were repeated after stratifying on race to explore differences between racial and ethnic groups in their absolute and relative change between sixth and eighth grades for each physical activity variable.

Results

Cross-sectional samples

In the control schools, a total of 856 (79.2%) of the 1080 sixth-grade girls eligible at baseline consented and participated in the measurement protocol. Also in the control schools, 2038 eighth-grade girls were eligible for the student-level measurements during Spring 2005, and 1713 (84.1%) consented and participated in the measurement protocol. After exclusions for missing physical activity data, 786 sixth-grade girls and 1545 eighth-grade girls were available from the control schools for the cross-sectional analyses. The mean age, mean BMI, and racial composition of each

of the cross-sectional samples (sixth and eighth grades) are presented in Table 1. The racial/ethnic composition of the two cross-sectional samples was similar.

Cohort sample

In the control schools, 614 of the 856 girls measured in sixth grade were still enrolled in the participating schools in eighth grade. Of that number, 563 (91.7%) consented to measurement at eighth grade, and 501 provided data for the cohort analyses. The mean age, mean BMI, and racial composition of the cohort are presented in Table 1. The racial/ethnic composition of the cohort differed slightly from the two cross-sectional samples, with a greater percentage of white girls and a lower percentage of African American and Hispanic girls.

Change in physical activity

Table 2 shows the physical activity levels among sixth- and eighth-grade girls, as well as absolute and percent change in mean physical activity levels between sixth and eighth grade, for both the cross-sectional sample and the cohort sample. In the cross-sectional sample, there was a decrease in physical activity, as measured by the 3DPAR and accelerometry. The decline in the number of average daily blocks of MVPA and VPA measured by the 3DPAR was larger, 11% and 13% per year, respectively, than the decline as measured by accelerometry (3% and 4%, respectively). This also was apparent in the cohort. Metrics of physical activity that were based on a self-report instrument produced estimates of age-related change that were much more variable than those based on accelerometry.

Table 2

Physical activity means (SEs), absolute changes and percent change per year among sixth- and eighth-grade girls from the TAAG cross-sectional and cohort samples

	Cross-sectional samples				Cohort sample			
	(n = 2331)		Absolute change 6th to 8th	Percent change per year	(n = 501)		Absolute change 6th to 8th	Percent change per year
6th (n = 786)	8th (n = 1545)	6th			8th			
Accelerometer								
Mean minutes daily MVPA (4.6 METS)	24.27 (1.33)	22.51 (1.30)	-1.76***	-3.63%	24.03 (1.56)	23.01 (1.55)	-1.01	-2.11%
Mean MET-weighted minutes MVPA (4.6 METS)	151.16 (8.34)	138.41 (8.08)	-12.76***	-4.22%	151.19 (10.07)	141.97 (10.02)	-9.22*	-3.05%
Mean minutes daily VPA (6.5 METS)	5.86 (0.41)	5.41 (0.39)	-0.44*	-3.80%	5.95 (0.49)	5.54 (0.49)	-0.40	-3.38%
Mean MET-weighted minutes daily of >50 counts/30 sec	1052.01 (19.52)	939.09 (18.90)	-112.93***	-5.37%	1062.20 (23.35)	936.47 (23.26)	-125.74***	-5.92%
3DPAR								
Mean blocks daily MVPA (4.6 METS)	1.88 (0.096)	1.47 (0.08)	-0.42***	-11.02%	1.95 (0.10)	1.42 (0.09)	-0.53***	-13.68%
Mean blocks daily VPA (6.5 METS)	1.24 (0.06)	0.92 (0.05)	-0.32***	-12.86%	1.29 (0.06)	0.90 (0.06)	-0.39***	-14.33%
Mean blocks daily PA (3 METS)	4.01 (0.19)	3.55 (0.18)	-0.46***	-5.74%	4.19 (0.19)	3.44 (0.18)	-0.75***	-8.97%
Avg. daily METs from 3DPAR	68.08 (0.78)	67.00 (0.71)	-1.08	-0.80%	68.53 (0.75)	66.76 (0.74)	-1.77*	-1.29%

MVPA = moderate-to-vigorous physical activity; VPA = vigorous physical activity; MET = metabolic equivalent total.; TAAG = Trial of Activity for Adolescent Girls; 3DPAR = 3-day physical activity recall.

p-Value = based on 1 df *F* test for time.

p* < .05; *p* < .01; ****p* < .001.

Table 3
Physical activity means (SEs), absolute changes (ABS), and relative percent change per year among sixth- and eighth-grade girls from the TAAG cross-sectional sample by race–ethnicity (N = 2041) (other race groups not shown)

	White (n = 1046)				Black (n = 472)				Hispanic (n = 523)				Omnibus P- value [#]
	6th (n = 338)	8th (n = 708)	8th–6th ABS	Percent change per year	6th (n = 163)	8th (n = 309)	8th–6th ABS	Percent change per year	6th (n = 185)	8th (n = 338)	8th–6th ABS	Percent change per year	
Accelerometer													
Mean minutes daily MVPA (4.6 METS)	25.42 (1.41)	23.74 (1.34)	−1.68*	−3.31%	24.74 (1.56)	21.59 (1.44)	−3.15**	−6.37%	21.81 (1.52)	21.78 (1.42)	−0.03	−0.07%	.15
Mean MET-weighted minutes MVPA (4.6 METS)	160.55 (8.91)	146.04 (8.37)	−14.51**	−4.52%	153.70 (10.01)	131.61 (9.15)	−22.09**	−7.19%	132.95 (9.75)	133.86 (8.97)	0.91	0.34%	.13
Mean minutes daily VPA (6.5 METS)	6.28 (0.45)	5.83 (0.41)	−0.45	−3.60%	6.15 (0.52)	5.02 (0.46)	−1.12*	−9.12%	4.80 (0.50)	5.01 (0.45)	0.20	2.13%	.17
Mean MET-weighted minutes daily of >50 counts/30 sec 3DPAR	1056.22 (21.23)	939.89 (19.87)	−116.33***	−5.51%	1066.77 (24.15)	953.13 (21.90)	−113.64***	−5.33%	1030.86 (23.45)	937.53 (21.53)	−93.32***	−4.53%	.52
Mean blocks daily MVPA (4.6 METS)	2.00 (0.13)	1.66 (0.10)	−0.34**	−8.48%	1.73 (0.17)	1.30 (0.14)	−0.43*	−12.52%	1.62 (0.16)	1.35 (0.13)	−0.27	−8.34%	.14
Mean blocks daily VPA (6.5 METS)	1.36 (0.09)	1.02 (0.07)	−0.34***	−12.51%	1.12 (0.12)	0.89 (0.09)	−0.23	−10.31%	1.01 (0.11)	0.84 (0.09)	−0.16	−8.11%	.12
Mean blocks daily PA (3 METS)	4.07 (0.22)	3.71 (0.20)	−0.36*	−4.45%	3.83 (0.28)	3.24 (0.24)	−0.60*	−7.78%	3.82 (0.26)	3.57 (0.23)	−0.25	−3.32%	.33
Avg. daily METs from 3DPAR	68.20 (0.95)	67.87 (0.81)	−0.33	−0.24%	67.87 (1.21)	65.67 (1.00)	−2.21	−1.63%	66.97 (1.15)	66.53 (0.96)	−0.43	−0.32%	.31

METS = metabolic equivalent totals; TAAG = Trial of Activity for Adolescent Girls; 3DPAR = 3-day physical activity recall.

ABS = 8th–6th.

#p-Value = based on 2 df *F* test for time x race.

p* < .05; *p* < .01; ****p* < .00.

Table 3 shows the physical activity data for the cross-sectional samples of sixth and eighth graders for each of the three race/ethnicity groups, excluding the “other” category. With the exception of average daily MET-weighted minutes of accelerometer >50 counts per 30 seconds and mean blocks of daily PA (3 METS), African American girls had a greater decrease in physical activity compared to white girls and Hispanic girls, although the differences were not statistically significant.

Discussion

In a large and diverse sample of sixth- and eighth-grade girls, we found that physical activity measured using accelerometers declined at a rate of approximately 4% per year. Moderate and/or vigorous intensity physical activity declined at rates between 3.6% and 4.2% per year. Total physical activity (mean MET-weighted daily min of >50 counts/30 sec), regardless of intensity, declined at a slightly higher annual rate of 5.4%. Previous studies of age-related change in physical activity in youth have provided varying estimates, and comparisons with the findings of the present study are difficult because of differences in methodologies [9,14–16]. In addition, changes in activity levels previously have not been assessed in adolescents using accelerometry. Hence, the findings of the present study are unique and constitute the strongest evidence to date regarding the rate at which activity changes with age in adolescent girls.

Most previous studies of physical activity in youth have used self-report instruments, and studies using such instruments have yielded varying estimates of age-related change. For example, Kimm et al [9] reported that self-reported physical activity declined at an annual rate of 8.3% among girls ages 9 to 19 observed in the National Growth and Health Study (and approximately 10.2% per year in girls ages 11/12 to 13/14), whereas Janz et al [33] found no change in self-reported vigorous physical activity in girls between ages 10 and 15 years in the Muscatine Study.

In the present study, both objective and self-report methodologies were employed and, therefore, the findings for the two methods can be compared. Average daily blocks of MVPA from the 3DPAR, using a 3-MET cutpoint for MVPA, showed a 5.7% annual decrease in activity; this is quite similar to the 5.4% decline found for the corresponding accelerometry metric. In contrast, the 3DPAR metrics that were defined with higher cutpoints (4.6 METS for MVPA; 6.5 METS for VPA) yielded much higher annual rates of decrease in physical activity compared to accelerometry. It seems likely that these higher rates of decline are a function of the relative insensitivity of the 3DPAR. It is also possible that girls respond to a question about vigorous physical activity differently at different ages. Girls in the sixth grade reported an average of only 1.88 blocks per day for MVPA and 1.24 blocks per day for VPA. So the observed decreases with these metrics represented rather large percentages of the baseline values. Nonetheless, it provides credibility to the

utility of self-report measures that the more inclusive 3DPAR metric yielded an annual rate of change that was quite similar to that observed with accelerometry-based metrics.

The annual percent change in objectively measured physical activity tended to be smaller in the cohort than in the cross-sectional samples for MVPA, MET-weighted MVPA, and VPA. However, the total physical activity metric fell at a rate of 5.9% per year in the cohort, which was about the same as the 5.4% decline seen in the cross-sectional samples. In contrast, percent annual changes assessed by the 3DPAR tended to be slightly higher compared to the cross-sectional samples. Although these trends were relatively consistent, the differences were not very large. The cohort and cross-sectional samples were essentially identical at the sixth-grade measurement, but higher values were seen in the cohort at the eighth-grade observation. It is possible that the cohort was biased by the fact that those girls were measured twice, but it is also possible that the data simply reflect normal sampling variability. To our knowledge, no previous study has reported on age-related change in physical activity for both cross-sectional samples and an associated adventitious cohort.

The TAAG sample included substantial numbers of African American, Hispanic, and white girls. Physical activity declined with increasing age in all three groups, but the rate of decline tended to be larger in African American girls than the other two races/ethnicities. This is consistent with the findings of Kimm et al [9], who reported a much larger rate of decline in African American girls than their white counterparts. In the present study, Hispanic girls in the sixth grade tended to be less active than their African American and white counterparts, but age-related change tended to be smaller in Hispanic girls than the other two groups. This suggests that the Hispanic girls may have experienced a pronounced decline in physical activity prior to the sixth grade, or were generally less active from an early age. As eighth graders, physical activity levels were about the same in African American and Hispanic girls, but lower in both of those groups than in whites. It is possible that the trend toward race/ethnicity differences in age-related change in physical activity seen in this study is explained by developmental factors, such as age at menarche. That explanation cannot be examined in the TAAG data, but future studies should consider this possibility.

This study has important strengths, and some limitations that should be noted. The sample of participants is relatively large, racially diverse, and geographically dispersed across the United States. Both objective and self-report measures of physical activity were used. Rigorous procedures had been used in validating and calibrating the objective measure of physical activity, and the psychometric properties of the self-report method had been described extensively. The pool of participants included both cross-sectional and cohort samples. However, the sample included only girls, and age-related change in physical activity was observed only across

a 2-year period. Despite these limitations, we believe that this study provides the most comprehensive examination to date of age-related change in physical activity in a specified group.

In summary, age-related change in physical activity was observed in a sample of middle-school girls. Based on comparisons of cross-sectional samples of sixth- and eighth-grade girls, objectively measured physical activity declined at a rate of approximately 4% per year. This finding carries considerable significance for public health. Previous studies have shown that most adolescent youth, including those in the TAAG investigation, fail to meet the current physical activity guideline, which calls for them to be active for at least 60 minutes per day. Our findings suggest that girls fall well short of that goal at sixth grade, reporting an average of only 24.3 minutes of MVPA per day, which is only 40% of the goal. Our observation that physical activity declined at the rate of 4% per year between sixth and eighth grade meant the girls were moving even further away from the goal and heightens the need to understand the factors that explain this decline and to develop interventions to prevent it.

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