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Factorial Validity and Invariance of a Self-Report Measure of Physical Activity Among Adolescent Girls

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*We examined the factorial validity and factorial invariance of the 3-day physical activity recall (3DPAR) using confirmatory factor analysis. Adolescent girls from two cohorts (*N = 955, N = 1,797*) completed the 3DPAR in the eighth grade; participants in Cohort 2 (*N = 1,658*) completed the 3DPAR again 1 year later in the ninth grade. The 3DPAR was best represented by two uncorrelated factors in Cohort 1. The two-factor, uncorrelated measurement model exhibited evidence of cross-validity between Cohorts 1 and 2. This model also exhibited configural and partial metric invariance between race and across time. Hence, the 3DPAR consisted of two uncorrelated factors underlying three indicators of both moderate and vigorous physical activity in this sample of Black and White girls across a 1-year period. The 3DPAR can be used in cross-sectional, prospective cohort and intervention studies that examine mediators and moderators of physical activity among Black and White adolescent girls.*

Key words: African American, confirmatory factor analysis, measurement

National health objectives for promoting physical activity among youth (Centers for Disease Control and Prevention, 1998) and the need to understand patterns and predictors of physical activity among youth (Sallis, Prochaska, & Taylor, 2000) underscore the importance of measuring physical activity, especially among adolescent girls who are less active than boys (Caspersen, Pereira, & Curran, 2000; Centers for Disease Control and Prevention, 1998). Physical activity can be measured by self-report instruments, direct observation, mechanical or electronic monitoring, direct or indirect calorimetry, and physiological markers (LaPorte, Montoye, & Caspersen, 1985). Among those types of measures, self-report instruments are most practical and cost-effective for population-based studies (Dishman, Washburn, & Schoeller, 2001).

Studies that have examined the validity of inferences from scores on self-report measures of physical activity among youth focused on the relations between self-report scores and objective measures of physical activity (Pereira et al., 1997; Sirard & Pate, 2001). We are not aware of any studies that directly tested the factorial validity and factorial invariance of self-report measures of physical activity, although we know of three studies that used principal components analysis to examine the latent structure underlying physical activity and sedentary behaviors among adults (Baecke, Burema, & Frijters, 1982; Prochaska, Sallis, Sarkin, & Calfas, 2000) and youth (Pate, Dowda, & Ross, 1990). Principal components analysis is a variance extraction technique that assumes no measurement error in the underlying physical activity indexes and is, thus, not a preferred approach to examine the factorial validity of a self-report measure of physical activity (Comrey & Lee, 1992; Gorsuch, 1983).

Factorial or structural validity is the degree to which the measure of a construct conforms to the theoretical definition of the construct (Hoyle & Smith, 1994; Loevinger, 1957; Messick, 1995) and is considered an important component of establishing evidence for the validity of inferences from test scores (Loevinger, 1957;

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Messick, 1989, 1995). Factorial validity is established by testing the fit of a theoretically based measurement model for describing the variances and covariances underlying items on a scale using confirmatory factor analysis (Bollen, 1989; Hoyle & Smith, 1994). The measurement model specifies the exact mapping of indicators on a measure that has an underlying latent structure. Evidence of factorial validity provides a rationale for weighted and unweighted linear combinations of the indicators to form composite measures of latent variables (i.e., fidelity of the scoring structure; Loevinger, 1957; Messick, 1989, 1995). Such evidence is needed before the construct validity of inferences from scores on an instrument can be established, because the combination of indicators to form composite measures of latent variables is indefensible without first providing an empirical justification for the scheme used to score an instrument. This logic is based on the argument that the structure of the construct being measured must be understood before its meaning can be examined (Anderson & Gerbing, 1988). Factorial invariance concerns the degree to which a construct is measured similarly between groups or across time (Hoyle & Smith, 1994). Factorial invariance is established by testing the comparability of the form and values of parameters within a measurement model between groups or across time (Hoyle & Smith, 1994; Motl & DiStefano, 2002; Vandenberg & Lance, 2000).

There are at least three important reasons for establishing the latent structure and measurement equivalence of a physical activity self-report measure between Black and White girls and across time. First, population-based estimates have indicated that Black and White adolescent girls differ in their reported levels (Centers for Disease Control and Prevention, 1998; Kimm et al., 2002) and modes (Dowda et al., 1999) of physical activity. These differences might reflect variability in the measurement properties of the self-report instrument to assess physical activity rather than true differences in the latent variable of physical activity. Second, the age-related decline in physical activity levels among adolescent girls (Caspersen et al., 2000; Centers for Disease Control and Prevention, 1998; Kimm et al., 2002) could reflect variability in the measurement properties of a self-report instrument across time rather than true age-related differences in the latent variable of physical activity. Third, public health calls for more research on mediators of change in physical activity, and interventions to increase physical activity among Black and White girls (Stone, McKenzie, Welk, & Booth, 1998) cannot be successfully addressed without a physical activity measure with evidence of factorial validity and factorial invariance, which can be established by multigroup and longitudinal analyses of factorial invariance (Bollen, 1989).

Herein, we report on factorial validity and invariance tests of the 3-day physical activity recall (3DPAR; Pate, Ross, Dowda, Trost, & Sirard, 2003) among Black and White adolescent girls. The 3DPAR was designed to be a measure of *usual* moderate and vigorous physical activity among adolescents. This is accomplished by prompting a recall of specific physical activities and their relative intensities across 3 days of the previous week in a single reporting session. Hence, the implied measurement model underlying the 3DPAR consists of two correlated factors (moderate and vigorous physical activity) with three indicators per factor (the 3 days of recall). To date, no studies have directly tested the factorial validity and invariance of the presumed measurement model for the 3DPAR, although the construct validity from the 3DPAR scores has been partially established. The initial evidence of construct validity has been based on comparisons of scores between athletes and nonathletes (Pires et al., 2001) and correlations with a self-report measure of team sport involvement during the previous 12 months (Motl, Dishman, Felton, & Pate, 2003) and an objective measure of physical activity derived from accelerometry (Pate et al., 2003). For example, in a study of 70 girls in the eighth and ninth grades, correlations between 3DPAR and accelerometer counts were stronger when recorded over periods of 7 and 3 days, respectively, for estimates of vigorous ($r = .45$ and .41, respectively) and moderate-to-vigorous ($r = .35$ and .27, respectively) physical activity (Pate et al., 2003). Those results provided initial evidence that the 3DPAR gives independent estimates of usual participation in moderate and vigorous physical activity. The present study was designed to extend that evidence by testing the factorial validity and multigroup and longitudinal invariance of a measurement model for the 3DPAR consisting of two correlated factors with three indicators per latent variable.

Method

Participants

Participants were eighth and ninth grade girls from 31 middle schools and their associated 24 high schools in South Carolina who were participating in a study designed to examine the effects of a school-based intervention on physical activity and fitness. Some of the measurement procedures of the study were reported previously (Dishman et al., 2002; Motl et al., 2000, 2002, 2003). The girls in Cohort 1 ($N = 955$) had a mean age of 13.7 years ($SD = 0.7$), with racial proportions of 46.7% Black, 48.8% White, and 4.5% other. The girls in Cohort 2 ($N = 1{,}797$) had a mean age of 13.6 years ($SD = 0.6$), with racial proportions of 49.9% Black, 45.8% White, and 3.6% other; 0.7% of the girls in Cohort 2 did not report race. The majority of girls ($N = 1{,}658$) from Cohort 2 also completed assessments 1 year later in the ninth grade. There

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was a statistically significant but trivial difference between cohorts in age, $t(2{,}733) = 5.71$, $p < .001$, $\omega^2 = .01$. There was no statistically significant difference in the distribution of race, χ^2 (2, $N = 2{,}740$) = 3.52, $p = 0.17$.

Measure

Physical activity was assessed using the 3DPAR (Pate et al., 2003), which is a modification of the previous day physical activity recall (Weston, Petosa, & Pate, 1997). The 3DPAR required participants to recall physical activity behavior from 3 previous days of the week (first Tuesday, then Monday, then Sunday); the instrument was always completed on Wednesday. Those 3 days were selected to capture physical activity on 1 weekend day and 2 weekdays. To improve the accuracy of physical activity recall, the 3 days were segmented into thirty-four 30-min time blocks, beginning at 7:00 a.m. and continuing through to 12:00 midnight. To further aid recall, the 30-min blocks were grouped into broader time periods (i.e., before school, during school, lunchtime, after school, supper time, and evening). The 3DPAR included a list of 55 commonly performed activities grouped into broad categories (i.e., eating, work, after school/spare time/hobbies, transportation, sleeping/bathing, school, and physical activities and sports) to improve activity recall; this was not a checklist but rather a mnemonic device. For each of the 30-min time blocks, students reported the main activity performed and rated the relative intensity of the activity as light, moderate, hard, or very hard. To help students select a relative intensity, the instrument included illustrations depicting activities representative of the various intensities. The data then were converted into the number of 30-min blocks per day in which the main activity was between three and six METs (i.e., moderate physical activity [MPA]) and six or more METs (i.e., vigorous physical activity [VPA]). Hence, the unit of analysis was the number of 30-min blocks per day of MPA and VPA for each of the 3 previous days. The number of 30-min blocks per day served as the three indicators of MPA and VPA.

Procedure

The procedures were approved by the University of South Carolina Institutional Review Board. All participants and the parent or guardian provided written informed consent. Baseline testing was conducted with Cohorts 1 and 2 in the 1998 and 1999 spring semesters, when students were in the eighth grade. Follow-up testing was conducted with Cohort 2 in spring 2000, when students were in the ninth grade. Trained data collectors administered the 3DPAR to small groups of 6–10 participants. The data collectors underwent 3 months of extensive training and used standardized protocols and scripts when collecting responses to the 3DPAR.

Data Analysis

The factor structure of the 3DPAR was initially tested using confirmatory factor analysis (CFA) with baseline data from Cohort 1. The factor structure was then cross-validated using a multigroup analysis of factorial invariance, with baseline data from Cohorts 1 and 2. The factor structure also was tested for multigroup factorial invariance between Black and White girls using baseline data from Cohort 2 and longitudinal factorial invariance across a 1-year period, using baseline and follow-up data from Cohort 2.

Confirmatory Factor Analysis

The analyses were performed using full information maximum likelihood (FIML) estimation in AMOS 4.0 (Arbuckle & Wothke, 1999). FIML was selected because it is a theoretically based method for treating missing data in covariance modeling that has resulted in more accurate fit indexes and parameter estimates than listwise and pairwise case deletion and mean imputation of missing values (Arbuckle, 1996; Arbuckle & Wothke, 1999; Enders & Bandalos, 2001). The sample size of Cohorts 1 and 2 was adequate to estimate the models based on two criteria: sample size larger than 800 and ratio of sample size to number of estimated parameters exceeding 10:1 (Bollen, 1989; Jackson, 2001; Jöreskog & Sörbom, 1996).

Model Specification. The measurement model underlying the 3DPAR is displayed in Figure 1. It consisted

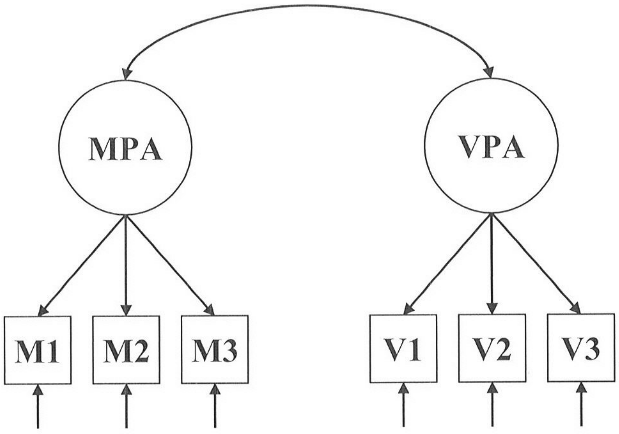

Figure 1. Two-factor, correlated measurement model underlying the three indicators of moderate physical activity and the three indicators of vigorous physical activity tested using confirmatory factor analysis. M1 = Tuesday, moderate physical activity; V1 = Tuesday, vigorous physical activity; M2 = Monday, moderate physical activity; V2 = Monday, vigorous physical activity; M3 = Sunday, moderate physical activity; V3 = Sunday, vigorous physical activity; MPA = moderate physical activity; VPA = vigorous physical activity.

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of two correlated factors underlying the three MPA and three VPA indicators. The matrix of factor loadings was specified to reflect simple structure such that indicators were specified to load on a single factor. The loading for the first indicator on each factor was set to 1.0 to establish the metric of the latent variable. The matrix of factor variances and covariances was symmetric (i.e., there were variances along the diagonal and covariances below the diagonal). The matrix of item uniquenesses was diagonal (i.e., there were no correlated uniquenesses).

Model Fit. Model fit was assessed by the chi-square statistic (Bollen, 1989; Jöreskog, 1993), the root mean square error of approximation (RMSEA; Browne & Cudeck, 1993), comparative fit index (CFI; Bentler, 1990), and nonnormed fit index (NNFI; Bentler & Bonett, 1980). The chi-square statistic assessed absolute model fit to the data, but it is sensitive to sample size (Bollen, 1989; Jöreskog, 1993). No restrictive model with positive degrees of freedom is able to fit real data, and often a formal test of significance with a sufficiently large sample size will reject such models (Cudeck & Browne, 1983; Marsh, 1996). Accordingly, other subjective indexes of fit were used to judge the model fit. The RMSEA represents closeness of fit or an estimate of error per degree of freedom (Browne & Cudeck, 1993). RMSEA values approximating 0.06 and zero demonstrated close and exact model fit, respectively (Browne & Cudeck, 1993; Hu & Bentler, 1999). The 90% confidence interval (CI) around the RMSEA point estimate should contain 0.06 to indicate the possibility of close model-data fit (Browne & Cudeck, 1993). Both CFI and NNFI are incremental fit indexes, and both test the proportionate improvement in fit by comparing the target model to a baseline model with no correlations among observed variables (Bentler, 1990; Bentler & Bonett, 1980). CFI and NNFI values approximating 0.90 (Bentler, 1990; Bentler & Bonett, 1980; Bollen, 1989) and 0.95 (Hu & Bentler, 1999) indicated minimally acceptable and good model fit, respectively. The factor loadings, uniquenesses, standard errors, *z* statistics (i.e., parameter estimate divided by its standard error), and squared multiple correlations (SMC) were inspected for appropriate sign and magnitude (Bollen, 1989). Parameters with nonsignificant *z* statistics and a sign opposite of expected direction should be removed, because no substantively meaningful interpretation can be provided for the parameter estimates (Jöreskog, 1993). Large standard errors indicate that the parameter estimate is not reliable (Raykov & Marcoulides, 2000).

Cross-Validation. The factor structure was cross-validated, because any modifications performed with a single sample might capitalize on chance features of the data (MacCallum, Roznowski, & Necowitz, 1992). Cross-validity was examined using an analysis of multigroup factorial invariance (Bollen, 1989; Jöreskog & Sörbom, 1996), because it provides information about the model robustness and its parameters across independent samples (MacCallum, Roznowski, Mar, & Reith, 1994; Motl et al., 2000). The comparison of nested models was based on chi-square difference tests and changes in the RMSEA, CFI, and NNFI values. The criterion of -0.01 for a change in the CFI ($CFI_{\text{constrained model}} - CFI_{\text{unconstrained model}}$), for example, was reported to be robust for testing the multigroup invariance (Cheung & Rensvold, 2002) and used in a recent test of the longitudinal invariance of a measure of self-esteem (Motl & DiStefano, 2002).

Multigroup Factorial Invariance. The multigroup factorial invariance of the final factor structure was tested between Black and White girls. The invariance analysis was performed with the same multistep procedure used for cross-validation (Bollen, 1989; Jöreskog & Sörbom, 1996).

Longitudinal Factorial Invariance. The longitudinal factorial invariance of the final factor structure was tested across a 1-year period. The analysis of longitudinal factorial invariance was performed using a standard procedure (Motl & DiStefano, 2002; Motl et al., 2000).

Results

Descriptive Statistics

Table 1 contains the means, standard deviations, and estimates of skewness and kurtosis for the indicators of MPA and VPA from the 3DPAR using baseline data from Cohorts 1 and 2. Table 2 contains the same descriptive information but for Black and White girls in Cohort 2 across time. Consistent with other population-based estimates of physical activity rates among adolescents (Centers for Disease Control and Prevention, 1998), MPA and VPA were positively skewed and leptokurtic. Although the data might violate the assumption of multivariate normality underlying maximum likelihood estimation, recent simulation studies found that maximum likelihood estimation results in minimally biased fit indexes and parameter estimates with highly skewed or kurtotic data (Hutchinson & Olmos, 1998; Olsson, Foss, Troye, & Howell, 2000). The covariance matrices are provided in the Appendix. The matrices were computed using the saturated model in AMOS 4.0 with FIML estimation, and when used as input into another program they will yield similar but not identical, fit indexes, parameter estimates, and standard errors.

Factorial Validity

Cohort 1. The two-factor correlated model to the 3DPAR provided a good model-data fit, $\chi^2 = 15.91$, $df = 8$, $p = .04$, RMSEA = 0.03 (90% CI = 0.01 - 0.06), CFI = 0.99, NNFI = 0.98. Although the χ^2 was statistically sig-

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nificant, the RMSEA was below 0.06 and the CFI and NNFI exceeded 0.95. All but one of the parameters were statistically significant and of the expected direction; the parameter estimate for the covariance between MPA and VPA was not statistically significant ($\phi_{21} = -.021$, $p = .67$). Hence, we removed it and then tested the fit of a two-factor uncorrelated measurement model to the 3DPAR. The model provided a good fit, $\chi^2 = 16.10$, $df = 9$, $p = .07$, RMSEA = 0.03 (90% CI = 0.00 - 0.05), CFI = 0.99, NNFI = 0.99, and did not differ from the two-factor correlated model, $\chi^2_{\text{diff}} = .19$, $df = 1$, $p = .67$. The χ^2 was not statistically significant, the RMSEA was below 0.06, and the CFI and NNFI exceeded 0.95. The unstand-ardized and standardized factor loadings are provided in Table 3. The unstandardized factor loadings illustrate the strength of the relationship between each indicator and the latent variable based on the units in which the indicator was scaled. The standardized factor loadings illustrate the strength of the relationship between each indicator and the latent variable based on standardized or similar units. The standardized factor loadings can be directly compared for relative strength of the relationship between the indicators and the latent variable.

Table 1. Descriptive statistics for the indicators of moderate and vigorous physical activity on the 3-day physical activity recall among adolescent girls using baseline data from cohorts 1 (*N* = 955) and 2 (*N* = 1,797)

Measure	Indicator	Cohort 1				Cohort 2			
		M	*SD*	Skew (*SE*)	Kurt (*SE*)	*M*	*SD*	Skew (*SE*)	Kurt (*SE*)
MPA	Tuesday	2.62	2.59	1.46 (.09)*	2.52 (.18)*	1.91	2.06	1.33 (.06)*	1.83 (.12)*
	Monday	2.65	3.01	2.08 (.09)*	7.94 (.18)*	2.08	2.42	1.50 (.06)*	2.68 (.12)*
	Sunday	2.94	3.53	1.64 (.09)*	3.39 (.18)*	2.80	3.50	1.81 (.06)*	5.05 (.12)*
VPA	Tuesday	1.15	1.72	1.85 (.09)*	3.74 (.18)*	1.10	1.71	1.94 (.06)*	4.27 (.12)*
	Monday	1.32	1.97	1.92 (.09)*	4.18 (.18)*	1.09	1.81	2.24 (.06)*	6.78 (.12)*
	Sunday	1.31	2.43	2.87 (.09)*	12.78 (.18)*	0.97	2.14	3.69 (.06)*	19.16 (.12)*

Note. Skew = skewness; Kurt = kurtosis; *SE* = standard error; MPA = moderate physical activity (number of 30-min blocks•d^{-1}); VPA = vigorous physical activity (number of 30 min blocks•d^{-1}).
*$p < .05$.

Table 2. Descriptive statistics for the indicators of moderate and vigorous physical activity on the 3-day physical activity recall among Black (*n* = 896) and White (*n* = 823) adolescent girls using baseline and follow-up data from Cohort 2

Measure	Indicator	Black girls				White girls			
		M	*SD*	Skew (*SE*)	Kurt (*SE*)	*M*	*SD*	Skew (*SE*)	Kurt (*SE*)
Baseline									
MPA	Tuesday	1.65	1.89	1.57 (.08)*	3.14 (.17)*	2.21	2.20	1.11 (.09)*	0.92 (.18)*
	Monday	1.79	2.26	1.70 (.08)*	3.71 (.17)*	2.42	2.57	1.33 (.09)*	1.98 (.18)*
	Sunday	2.46	3.39	1.83 (.08)*	4.00 (.17)*	3.21	3.65	1.81 (.09)*	5.85 (.18)*
VPA	Tuesday	0.97	1.62	2.11 (.08)*	5.26 (.17)*	1.29	1.83	1.77 (.09)*	3.37 (.18)*
	Monday	0.85	1.50	1.95 (.08)*	3.63 (.17)*	1.32	2.05	2.21 (.09)*	6.63 (.18)*
	Sunday	0.59	1.41	3.58 (.08)*	17.53 (.17)*	1.40	2.68	3.12 (.09)*	13.02 (.18)*
Follow-up									
MPA	Tuesday	2.32	2.58	1.38 (.10)*	1.93 (.19)*	2.65	2.57	1.15 (.10)*	2.57 (.19)*
	Monday	2.34	2.54	1.41 (.10)*	2.55 (.19)*	2.71	2.87	1.57 (.10)*	3.74 (.19)*
	Sunday	2.07	3.05	2.03 (.10)*	5.23 (.19)*	2.98	3.57	1.32 (.10)*	1.41 (.19)*
VPA	Tuesday	1.09	2.00	2.37 (.10)*	6.43 (.19)*	1.31	2.04	1.85 (.10)*	3.74 (.19)*
	Monday	1.06	1.97	2.31 (.10)*	6.06 (.19)*	1.25	2.02	2.05 (.10)*	4.93 (.19)*
	Sunday	0.52	1.52	4.67 (.10)*	29.42 (.19)*	1.12	2.39	3.47 (.10)*	17.22 (.19)*

Note. Skew = skewness; Kurt = kurtosis; *SE* = standard error; MPA = moderate physical activity (30 min-blocks•d^{-1}); VPA = vigorous physical activity (30 min blocks•d^{-1}).
*$p < .05$.

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Cohort 2. The two-factor uncorrelated measurement model to the 3DPAR represented a good model-data fit, $\chi^2 = 43.27$, $df = 9$, $p < .0001$, RMSEA = 0.05 (90% CI = 0.03 - 0.06), CFI = 0.98, NNFI = 0.96. The χ^2 was statistically significant, but the RMSEA was below 0.06, and the CFI and NNFI exceeded 0.95. The unstandardized and standardized factor loadings are provided in Table 3.

Cross-Validation

The two-factor uncorrelated model to the 3DPAR was cross-validated using a multigroup analysis of factorial invariance with baseline data from Cohorts 1 and 2. The results are provided in Table 4. The test of equal sigmas, which involves a comparison of elements within the matrix of variances and covariances underlying the 3DPAR, resulted in an acceptable, but not good, fit. The χ^2 was statistically significant. Although the RMSEA was below 0.06 and the CFI exceeded 0.95, the value of the NNFI only exceeded 0.90. Hence, the variance-covariance matrix underlying the 3DPAR was not entirely invariant between cohorts. There was no difference in fit between models constraining the factor structure and factor loadings to be equal between cohorts (Model 1 vs. Model 2); the χ^2 difference test was nonsignificant, and the other fit indexes were overlapping. There were changes in fit for the models constraining the factor variances (Model 2 vs. Model 3) and item uniquenesses (Model 3 vs. Model 4) to be equal between cohorts. The χ^2 difference tests were statistically significant, and the other fit indexes were not overlapping. Hence, only the factor structure and factor loadings were invariant between cohorts.

Table 3. Unstandardized and standardized factor loadings for the indicators of moderate and vigorous physical activity on the 3-day physical activity recall; the factor loadings were generated from CFA performed on the responses from two cohorts of adolescent girls

Factor	Indicator	Cohort 1 (*N* = 955) Unstandardized Factor loading	Cohort 1 (*N* = 955) Standardized Factor loading	Cohort 2 (*N* = 1,797) Unstandardized Factor loading	Cohort 2 (*N* = 1,797) Standardized Factor loading
MPA	Tuesday	1.00	0.72	1.00	0.71
	Monday	1.38	0.85	1.18	0.71
	Sunday	0.78	0.41	0.82	0.34
VPA	Tuesday	1.00	0.70	1.00	0.70
	Monday	1.30	0.80	1.23	0.82
	Sunday	0.82	0.41	0.80	0.45

Note. MPA = moderate physical activity; VPA = vigorous physical activity.

Table 4. Confirmatory factor analysis testing the cross-validity of the two-factor, uncorrelated model to the 3-day physical activity recall using a multigroup analysis of factorial invariance with baseline data from Cohorts 1 and 2

Model	*df*	χ^2	*p* value	RMSEA (90% CI)	CFI	NNFI
Equal sigmas	21	126.46	< .0001	0.04 (0.04–0.05)	0.96	0.94
Model 1	18	59.37	< .0001	0.03 (0.02–0.04)	0.98	0.97
Model 2	22	61.41	< .0001	0.03 (0.02–0.03)	0.98	0.98
Model 3	24	112.31	< .0001	0.04 (0.03–0.04)	0.96	0.95
Model 4	30	177.45	< .0001	0.04 (0.04–0.05)	0.94	0.94

Model comparisons	*df*	χ^2_{diff}	*p* value
Model 1 versus 2	4	2.04	.73
Model 2 versus 3	2	50.90	< .0001
Model 3 versus 4	6	65.14	< .0001

Note. df = degrees of freedom; χ^2 = chi-square statistic; RMSEA = root mean square error of approximation; CI = confidence interval; CFI = comparative fit index; NNFI = non-normed fit index; χ^2_{diff} = chi-square difference test; Model 1 = equality of factor structure; Model 2 = equality of factor loadings; Model 3 = equality of factor variances; Model 4 = equality of item uniquenesses.

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Multigroup Factorial Invariance

The multigroup factorial invariance of the two-factor uncorrelated model to the 3DPAR was tested between Black ($n = 896$) and White ($n = 823$) girls using baseline data from Cohort 2. The model fit was good in the sample of Black girls, $\chi^2 = 22.63$, $df = 9$, $p = .007$, RMSEA = 0.04 (90% CI = 0.02 - 0.06), CFI = 0.98, NNFI = 0.97. The χ^2 was statistically significant, but the RMSEA was below 0.06, and the values of the CFI and NNFI exceeded 0.95. The fit of the model was minimally acceptable in the sample of White girls, $\chi^2 = 40.12$, $df = 9$, $p < .0001$, RMSEA = 0.07 (90% CI = 0.05 - 0.09), CFI = 0.95, NNFI = 0.92. The χ^2 was statistically significant, and the RMSEA exceeded 0.06; although the CFI exceeded 0.95, the NNFI only exceeded 0.90.

The results of the invariance routine are provided in Table 5. The test of equal sigmas resulted in a poor fit and indicated that the variance-covariance matrix underlying the 3DPAR was not invariant between Black and White girls. There was a difference in fit between models constraining the factor structure and factor loadings to be equal between groups (Model 1 vs. Model 2a); the χ^2 difference test was statistically significant, and the other fit indexes were not overlapping. This was expected based on the initial differences in fit when the model was tested in the samples of Black and White girls separately. Based on previous research (Dowda et al., 1999), we removed the equality constraint (Byrne, Shavelson, & Muthén, 1989) on the factor loading for the indicator of weekend vigorous physical activity (V3 in Figure 1); there was no difference in fit between the model constraining the factor structure and the model partially constraining the factor loadings (Model 1 vs. Model 2b). The χ^2 difference test was not statistically significant, and the other fit indexes were overlapping. There was not an appreciable change in fit for the model constraining the factor variances to be equal between Black and White girls (Model 2b vs. Model 3); the χ^2 difference test was statistically significant, but the RMSEA, CFI, and NNFI were overlapping. There was a substantial change in fit, with the model constraining the item uniquenesses to equality (Model 3 vs. Model 4); the χ^2 difference test was statistically significant, and the other fit indexes were not overlapping. The factor structure and variances were invariant between Black and White girls; the factor loadings were partially invariant between groups.[1]

Longitudinal Factorial Invariance

The longitudinal factorial invariance of the two-factor uncorrelated model to the 3DPAR was tested across a 1-year period, with baseline and follow-up data from Cohort 2. The results are presented in Table 6. There was a difference in fit between models constraining the factor structure (Model 1 vs. Model 2a) and factor loadings (Model 2a) to be equal across time; the χ^2 difference test was statistically significant, and the other fit indexes were not overlapping. Based on the previous set of multigroup invariance analyses, we removed the equality constraint (Byrne et al., 1989) on the factor load-

Table 5. Confirmatory factor analysis testing the multigroup invariance of the two-factor, uncorrelated model to the 3-day physical activity recall across samples of Black and White girls with baseline data from Cohort 2

Model	*df*	χ^2	*p* value	RMSEA (90% CI)	CFI	NNFI
Equal sigmas	21	506.80	< .0001	0.12 (0.11–0.13)	0.68	0.54
Model 1	18	62.75	< .0001	0.04 (0.03–0.05)	0.97	0.95
Model 2a	22	99.65	< .0001	0.05 (0.04–0.06)	0.95	0.93
Model 2b	21	65.54	< .0001	0.04 (0.03–0.05)	0.97	0.96
Model 3	23	75.77	< .0001	0.04 (0.03–0.05)	0.97	0.95
Model 4	29	514.97	< .0001	0.10 (0.09–0.11)	0.68	0.66

Model comparisons	*df*	χ^2_{diff}	*p* value
Model 1 versus 2a	4	36.90	< .0001
Model 1 versus 2b	3	2.79	.43
Model 2b versus 3	2	10.23	.006
Model 3 versus 4	6	439.17	< .0001

Note. df = degrees of freedom; χ^2 = chi-square statistic; RMSEA = root mean square error of approximation; CI = confidence interval; CFI = comparative fit index; NNFI = non-normed fit index; χ^2_{diff} = chi-square difference test; Model 1 = equality of factor structure; Model 2a = equality of factor loadings; Model 2b = partial equality of factor loadings; Model 3 = equality of factor variances; Model 4 = equality of item uniquenesses.

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ing for the indicator of weekend vigorous physical activity (V3 in Figure 1); there was no appreciable difference in fit between the model constraining the factor structure and the model partially constraining the factor loadings (Model 1 vs. Model 2b). Although the χ^2 difference test was statistically significant, the other fit indexes were overlapping. There were changes in fit for the models constraining the factor variances (Model 2b vs. Model 3) and item uniquenesses (Model 3 vs. Model 4) to be equal across time. The χ^2 difference tests were statistically significant, and the values of the CFI changed by more than .01, although the RMSEA 90% CIs were overlapping. The factor structure was invariant across a 1-year period, the factor loadings were partially invariant, and there was weak evidence for the invariance of the factor variances and item uniquenesses. The interfactor correlations from the model constraining the factor loadings to be partially invariant were 0.32 and 0.43 for MPA and VPA, respectively, indicating modest temporal stability of the physical activity latent variables across a 1-year period.[2]

Discussion

The 3DPAR was best described by a two-factor, uncorrelated measurement model, indicating that the latent variables representing the indicators of moderate and vigorous physical activity were uncorrelated. This agrees with previous research (Prochaska et al., 2000) that used principal components analysis to examine the structure underlying 14 indexes of physical activity and 1 index of sedentary behavior among young adults, reporting that variables measuring moderate and vigorous physical activity loaded on different, orthogonal (Comrey & Lee, 1992; Gorsuch, 1983) principal components. Hence, our present results derived from confirmatory factor analysis further support the relative independence of moderate and vigorous physical activity measures. This finding is important, because moderate and vigorous physical activity likely represent different behaviors, exhibit different patterns of correlations with determinants of physical activity (Dishman & Sallis, 1994; Motl et al., 2002; Sallis et al., 1992), and have different health-related outcomes (Bouchard, 2001). Interventions might need to target different theoretically based social-cognitive and environmental variables to alter moderate and vigorous physical activity, while including a measure that can differentially assess the intensity dimension of physical activity.

The two-factor uncorrelated measurement model to the 3DPAR demonstrated configural and partial metric invariance between groups and across time. Configural invariance indicates the same pattern of fixed and freed elements in the matrices containing factor loadings, factor variances-covariances, and item uniqueness. Evidence of configural invariance demonstrates that the same conceptual frame of reference was used when Black and White girls responded to the 3DPAR across time (Steenkamp & Baumgartner, 1998; Vandenberg & Lance, 2000). Partial metric invariance indicates the equivalence of most, but not all, of the factor loadings for like indicators between groups and across time. As long as the analysis of partial metric invariance includes three or more

Table 6. Confirmatory factor analysis testing the longitudinal invariance of the two-factor, uncorrelated model to the 3-day physical activity recall across a 1-year period with baseline and follow-up data from Cohort 2

Model	*df*	χ^2	*p* value	RMSEA (90% CI)	CFI	NNFI
Model 1	46	209.31	< .0001	0.04 (0.04–0.05)	0.95	0.94
Model 2a	50	257.08	< .0001	0.04 (0.04–0.05)	0.94	0.92
Model 2b	49	221.24	< .0001	0.04 (0.04–0.05)	0.95	0.94
Model 3	51	292.19	< .0001	0.05 (0.04–0.05)	0.93	0.91
Model 4	57	378.12	< .0001	0.05 (0.05–0.06)	0.91	0.90

Model comparisons	*df*	χ^2_{diff}	*p* value
Model 1 versus 2a	4	47.77	< .0001
Model 1 versus 2b	3	11.93	.008
Model 2b versus 3	2	70.95	< .0001
Model 3 versus 4	6	85.93	< .0001

Note. df = degrees of freedom; χ^2 = chi-square statistic; RMSEA = root mean square error of approximation; CI = confidence interval; CFI = comparative fit index; NNFI = non-normed fit index; χ^2_{diff} = chi-square difference test; Model 1 = equality of factor structure; Model 2a = equality of factor loadings; Model 2b = partial equality of factor loadings; Model 3 = equality of factor variances; Model 4 = equality of item uniquenesses.

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indicators per construct and one of the indicators (other than the indicator fixed to 1.00 for the purpose of identification) is invariant, comparisons of mean scores can be made (Byrne et al., 1989). Thus, evidence of partial metric invariance demonstrates that the indicators of moderate and vigorous physical activity from the 3DPAR can be summed to yield accurate comparisons between Black and White girls across time in regard to the underlying physical activity construct (Steenkamp & Baumgartner, 1998; Vandenberg & Lance, 2000). Hence, scores on the 3DPAR equally represent the constructs of moderate and vigorous physical activity for Black and White girls across time.

The invariance analyses demonstrated that the indicator for weekend vigorous physical activity was not fully invariant between Black and White girls or across a 1-year period. The variation across race likely was related to the types of physical and sedentary activities Black and White girls performed on the weekend (Dowda et al., 1999). White girls have reported more roller blading and softball than Black girls on the weekend. Black girls have reported more basketball and church attendance than White girls on the weekend (Dowda et al., 1999). That variation in types of physical and sedentary activities could account for the lack of invariance of the indicator for weekend vigorous physical activity. Thus, although scores from the 3DPAR equally represent moderate and vigorous physical activity between Black and White girls, the accumulation of different types of physical activity on the weekend likely comprise those scores.

The lack of invariance for the indicator of weekend vigorous physical activity across time is more difficult to explain. Weekend vigorous physical activity may be more variable than weekday vigorous physical activity across time. On the weekend, youth have less structure across most of the day compared to weekdays, when school consumes a large portion of the day. This difference in structure across the day may make weekend vigorous physical activity more variable and less consistent than weekday vigorous physical activity. The inconsistency of weekend vigorous physical activity could have contributed to the invariance of the indicator. Nonetheless, we observed evidence of partial metric invariance across time, indicating the mean comparisons on composite 3DPAR scores are still viable. Moreover, the interfactor correlations across the 1-year period for MPA and VPA were 0.32 and 0.43, respectively, indicating modest stability of the physical activity latent variables across time.

We used CFA to examine the factorial validity and factorial invariance of the 3DPAR. There might be some added value in using item response theory (IRT) for addressing those questions. Both CFA and IRT provide information about the invariance of the relationship between an indicator and the latent variable. This is provided by factor loadings or λs in CFA and α coefficients in IRT. Yet, classical CFA does not include the category threshold or difficulty parameters that are part of IRT. The difficulty parameters identify items that are biased or functioning differently between groups. Although previous researchers identified relative strengths and weaknesses of both CFA and IRT for exploring measurement invariance (Maurer, Raju, & Collins, 1998; Raju, Laffitte, & Byrne, 2002; Reise, Widaman, & Pugh, 1993), we await future examinations of the factorial validity and invariance of physical activity self-report measures that compare the value of these two approaches.

The availability of a physical activity measure that has established evidence of the factorial validity and invariance of its scoring structure will permit researchers to pursue several important questions. An established latent structure underlying responses to the indicators will permit researchers to further examine the construct validity of scores from the 3DPAR using accelerometry, pedometry, diaries, or logs. The 3DPAR has an evidentiary basis for the formation and comparison of composite scores for moderate and vigorous physical activity among adolescent Black and White girls across time. Similar information has not been provided for other self-report measures of physical activity among adolescents. Also, the 3DPAR can be used in studies examining the applicability of general psychological theories to understanding physical activity behavior among adolescent girls. Furthermore, the 3DPAR can be used in research on moderators and mediators of physical activity and interventions to increase physical activity among adolescent Black and White girls, areas of research that have been recognized as important but understudied (Stone et al., 1998).

References

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103,* 411–423.

Arbuckle, J. L. (1996). Full information estimation in the presence of incomplete data. In G. A. Marcoulides & R. E. Schumacker (Eds.), *Advanced structural equation modeling: Issues and techniques* (pp. 243–277). Mahwah, NJ: Lawrence Erlbaum.

Arbuckle, J. L., & Wothke, W. (1999). *Amos 4.0 user's guide.* Chicago: SmallWaters Corporation.

Baecke, J. A. H., Burema, J., & Frijters, J. E. R. (1982). A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *American Journal of Clinical Nutrition, 36,* 936–942.

Bentler, P. M. (1990). Comparative fit indices in structural models. *Psychological Bulletin, 107,* 238–246.

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin, 88,* 588–606.

Bollen, K. A. (1989). *Structural equations with latent variables.* New York: John Wiley & Sons, Inc.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

Bouchard, C. (2001). Physical activity and health: Introduction to the dose-response symposium. *Medicine & Science in Sports & Exercise, 33,* S347.

Browne, M. W., & Cudeck. R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equation models* (pp. 136–162). Newbury Park, CA: Sage Publications, Inc.

Byrne, B. M., Shavelson, R. J., & Muthén, B. (1989). Testing for the equivalence of factor covariance and mean structures: The issue of partial measurement invariance. *Psychological Bulletin, 105,* 456–466.

Caspersen, C. J., Pereira, M. A., & Curran, K. M. (2000). Changes in physical activity patterns in the United States, by sex and cross-sectional age. *Medicine & Science in Sports & Exercise, 32,* 1601–1609.

Centers for Disease Control and Prevention (1998). Youth risk behavior surveillance—United States, 1997. *Morbidity and Mortality Weekly Report, 47*(SS-3), 1–89.

Cheung, G. W., & Rensvold, R. B. (2002). Evaluating goodness-of-fit indices for testing measurement invariance. *Structured Equation Modeling, 9,* 233–255.

Comrey, A. L., & Lee, H. B. (1992). *A first course in factor analysis* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Dishman, R. K., Motl, R. W., Saunders, R. P., Dowda, M., Felton, G., Ward, D. S., et al. (2002). Factorial invariance and latent mean structure of questionnaires measuring social-cognitive determinants of physical activity among Black and White adolescent girls. *Preventive Medicine, 34,* 100–108.

Dishman, R. K., & Sallis, J. F. (1994). Determinants and interventions for physical activity and exercise. In C. Bouchard, R. J. Shephard, & T. Stephens (Eds.), *Physical activity, fitness, and health: International proceedings and consensus statement* (pp. 214–238). Champaign, IL: Human Kinetics.

Dishman, R. K., Washburn, R. A., & Schoeller, D. A. (2001). Measurement of physical activity. *Quest, 53,* 295–309.

Dowda, M., Pate, R. R., Ward, D. S., Saunders, R., Felton, G., & Dishman, R. K. (1999). Physical activity choices of African American and White eighth grade girls [Abstract]. *Medicine & Science in Sports & Exercise, 31,* S176.

Enders, C. K., & Bandalos, D. L. (2001). The relative performance of full information maximum likelihood estimation for missing data in structural equation models. *Structural Equation Modeling, 8,* 430–457.

Gorsuch, R. (1983). *Factor analysis* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Hoyle, R. H., & Smith, G. T. (1994). Formulating clinical research hypotheses as structural equation models: A conceptual overview. *Journal of Consulting and Clinical Psychology, 62,* 429–440.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indices in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6,* 1–55.

Hutchinson, S. R., & Olmos, A. (1998). Behavior of descriptive fit indices in confirmatory factor analysis using ordered categorical data. *Structural Equation Modeling,* 5, 344–364.

Jackson, D. L. (2001). Sample size and number of parameter estimates in maximum likelihood confirmatory factor analysis: A Monte Carlo investigation. *Structural Equation Modeling, 8,* 205–223.

Jöreskog, K. G. (1993). Testing structural equation models. In K. A. Bollen & J. S. Long (Eds.), *Testing structural equation models* (pp. 294–316). Newbury Park, CA: Sage.

Jöreskog, K. G., & Sörbom, D. (1996). *LISREL® 8: User's reference guide.* Chicago: Scientific Software International, Inc.

Kimm, S. Y., Glynn, N. W., Kriska, A. M., Barton, B. A., Kronsberg, S. S., Daniels, S. R., et al. (2002). Decline in physical activity in black girls and White girls during adolescence. *New England Journal of Medicine, 347,* 709–715.

LaPorte, R. E., Montoye, H. J., & Caspersen, C. J. (1985). Assessment of physical activity in epidemiologic research. *Public Health Reports, 100,* 131–146.

Loevinger, J. (1957). Objective tests as instruments of psychological theory [Monograph No. 9]. *Psychological Reports, 3,* 635–694.

MacCallum, R. C., Roznowski, M., Mar, C. M., & Reith, J. V. (1994). Alternative strategies for cross-validation of covariance structural models. *Multivariate Behavior Research, 29,* 1–32.

MacCallum, R. C., Roznowski, M., & Necowitz, L. B. (1992). Model modifications in covariance structure analysis: The problem of capitalization on chance. *Psychological Bulletin, 111,* 490–504.

Marsh, H. W. (1996). Positive and negative global self-esteem: A substantively meaningful distinction or artifactors? *Journal of Personality and Social Psychology, 70,* 810–819.

Maurer, T. J., Raju, N. S., & Collins, W. C. (1998). Peer and subordinate performance appraisal measurement equivalence. *Journal of Applied Psychology, 83,* 693–702.

Messick, S. (1989). Validity. In R. L. Linn (Ed.), *Educational measurement* (3rd ed., pp. 13–103). New York: Macmillin.

Messick, S. (1995). Validity of psychological assessment. Validation of inferences from persons' responses and performances as scientific inquiry into score meaning. *American Psychologist, 50,* 741–749.

Motl, R. W., & DiStefano, C. (2002). Longitudinal invariance of self-esteem and method effects associated with negatively worded items. *Structural Equation Modeling, 9,* 562–578.

Motl, R. W., Dishman, R. K., Felton, G., & Pate, R. R. (2003). Self-motivation and physical activity among Black and White adolescent girls. *Medicine & Science in Sports & Exercise, 35,* 128–136.

Motl, R. W., Dishman, R. K., Saunders, R. P., Dowda, M., Felton, G., Ward, D. S., et al. (2002). Examining social-cognitive determinants of intention and physical activity among Black and White adolescent girls using structural equation modeling. *Health Psychology, 21,* 459–467.

Motl, R. W., Dishman, R. K., Trost, S. G., Saunders, R. P., Dowda, M., Felton, G., et al. (2000). Factorial validity and invariance of questionnaires measuring social-cognitive determinants of physical activity in adolescent girls. *Preventive Medicine, 31,* 584–594.

Olsson, U. H., Foss, T., Troye, S. V., & Howell, R. D. (2000). The performance of ML, GLS, and WLS estimation in structural equation modeling under conditions of misspecification and nonnormality. *Structural Equation Modeling, 7,* 557–595.

Pate, R. R., Dowda, M., & Ross, J. G. (1990). Associations between physical activity and physical fitness in American children. *American Journal of Diseases of Children, 144,* 1123–1129.

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Pate, R. R., Ross, R., Dowda, M., Trost, S. G., & Sirard, J. (2003). Validation of a three-day physical activity recall instrument in female youth. *Pediatric Exercise Science, 15,* 257–265.

Pereira, M. A., FitzGerald, S. J., Gregg, E. W., Joswiak, M. L., Ryan, W. J., Suminski, R. R., et al. (1997). A collection of physical activity questionnaires for health-related research. *Medicine & Science in Sports & Exercise, 29*(Suppl.), S149–S152.

Pires, E. A. G., De Bem, M. F. L., Pires, M. C., Barros, M. V. G., da Silva Duarte, M. F., & Nanas, M. V. (2001). Reproducibility and validity of the 3 DPAR physical activity questionnaire in a sample of Brazilian adolescents [Abstract]. *Medicine & Science in Sports & Exercise,* 33, S144.

Prochaska, J. J., Sallis, J. F., Sarkin, J. A., & Calfas, K. J. (2000). Examination of the factor structure of physical activity behaviors. *Journal of Clinical Epidemiology, 53,* 866–874.

Raju, N. S., Laffitte, L. J., & Byrne, B. M. (2002). Measurement equivalence: A comparison of methods based on confirmatory factor analysis and item response theory. *Journal of Applied Psychology, 87,* 517–529.

Raykov, T., & Marcoulides, G. A. (2000). *A first course in structural equation modeling.* Mahwah, NJ: Lawrence Erlbaum Associates.

Reise, S. P., Widaman, K. F., & Pugh, R. H. (1993). Confirmatory factor analysis and item response theory: Two approaches for exploring measurement invariance. *Psychological Bulletin, 114,* 552–566.

Sallis, J. F., Prochaska, J. J., & Taylor, W. C. (2000). A review of correlates of physical activity of children and adolescents. *Medicine & Science in Sports & Exercise, 32,* 963–975.

Sallis, J. F., Simons-Morton, B. G., Stone, E. J., Corbin, C. B., Epstein, L. H., Faucette, N., et al. (1992). Determinants of physical activity and interventions in youth. *Medicine & Science in Sports & Exercise, 24,* S248–S257.

Sirard, J. R., & Pate, R. R. (2001). Physical activity assessment in children and adolescents. *Sports Medicine, 31,* 439–454.

Steenkamp, J. E. M., & Baumgartner, H. (1998). Assessing measurement invariance in cross-national consumer research. *Journal of Consumer Research, 25,* 78–90.

Stone, E. J., McKenzie, T. L., Welk, G. J., & Booth, M. L. (1998). Effects of physical activity interventions in youth: Review and synthesis. *American Journal of Preventive Medicine, 15,* 298–315.

Vandenberg, R. J., & Lance, C. E. (2000). A review and synthesis of the management invariance literature: Suggestions, practices, and recommendations for organizational research. *Organizational Research Methods, 3,* 4–69.

Weston, A. T., Petosa, R., & Pate, R. R. (1997). Validity of an instrument for measurement of physical activity in youth. *Medicine & Science in Sports & Exercise, 29,* 138–143.

Notes

1. The analysis of multigroup factorial invariance was performed using data from both cohorts, but only the analyses with Cohort 2 were included in the present report. The results from Cohort 1, which included 446 Black and 466 White girls, and Cohort 2 were nearly identical and, therefore, represent redundant tests.
2. As done for the multigroup comparison, the analysis of longitudinal factorial invariance was performed using data from both cohorts, but again only the analyses with Cohort 2 were included in the present report. The results from Cohort 1, which included 845 of the original 955 girls, and Cohort 2 were nearly identical and, therefore, represent redundant tests.

Authors' Notes

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Appendix A. Variance-covariance matrices for the three indicators of modertae and vigorous physical activity on the 3-day physical activity recall

Table A1. Variance-covariance matrix for the three indicators of moderate and vigorous physical activity on the 3-day physical activity recall using baseline data from Cohorts 1 and 2

Variable	1	2	3	4	5	6
Cohort 1						
1. Tuesday MPA	6.69					
2. Monday MPA	4.76	9.07				
3. Sunday MPA	2.70	3.73	12.41			
4. Tuesday VPA	-0.13	-0.08	0.39	2.97		
5. Monday VPA	-0.05	-0.28	0.64	1.90	3.87	
6. Sunday VPA	0.29	0.27	0.52	1.19	1.55	5.91
Cohort 2						
1. Tuesday MPA	4.24					
2. Monday MPA	2.45	5.85				
3. Sunday MPA	1.74	2.05	12.27			
4. Tuesday VPA	-0.18	-0.05	0.21	2.94		
5. Monday VPA	-0.01	-0.18	0.28	1.79	3.26	
6. Sunday VPA	0.26	0.40	-0.10	1.15	1.42	4.57

Note. MPA = moderate physical activity; VPA = vigorous physical activity.

Table A2. Variance-covariance matrix for the three indicators of moderate and vigorous physical activity on the 3-day physical activity recall for the Black and White girls using baseline data from Cohort 2

Variable	1	2	3	4	5	6
Black girls						
1. Tuesday MPA	3.59					
2. Monday MPA	2.18	5.08				
3. Sunday MPA	1.48	1.84	11.54			
4. Tuesday VPA	0.05	0.17	0.46	2.62		
5. Monday VPA	0.15	0.09	0.58	1.55	2.23	
6. Sunday VPA	0.08	0.31	0.21	0.63	0.64	2.00
White girls						
1. Tuesday MPA	4.85					
2. Monday MPA	2.66	6.59				
3. Sunday MPA	1.85	2.13	13.27			
4. Tuesday VPA	-0.55	-0.41	-0.17	3.34		
5. Monday VPA	-0.31	-0.60	-0.19	2.01	4.21	
6. Sunday VPA	0.25	0.27	-0.79	1.65	2.10	7.16

Note. MPA = moderate physical activity; VPA = vigorous physical activity.

Appendix A cont. on p. 271.

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Appendix A cont. from p. 270.

Table A3. Variance-covariance matrix for the three indicators of moderate and vigorous physical activity on the 3-day physical activity recall for baseline (Variables 1–6) and follow-up (Variables 7–12) data from Cohort 2

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. Tuesday MPA	4.24											
2. Monday MPA	2.51	5.87										
3. Sunday MPA	1.75	2.07	12.29									
4. Tuesday VPA	-0.17	-0.04	0.21	2.94								
5. Monday VPA	-0.01	-0.18	0.29	1.79	3.26							
6. Sunday VPA	0.27	0.41	-0.10	1.16	1.42	4.57						
7. Tuesday MPA	0.86	1.27	1.11	0.20	0.19	0.39	6.70					
8. Monday MPA	0.71	1.00	1.11	0.21	0.24	0.41	4.07	7.57				
9. Sunday MPA	0.80	1.22	2.17	0.48	0.45	0.83	2.24	2.26	11.70			
10. Tuesday VPA	0.09	0.28	0.03	0.99	0.74	0.70	-0.78	-0.25	0.62	4.25		
11. Monday VPA	0.14	0.31	0.21	1.02	0.76	0.87	-0.30	-0.50	0.42	2.63	4.07	
12. Sunday VPA	0.11	0.26	0.17	0.59	0.53	0.95	-0.10	-0.05	-0.10	1.01	1.10	4.15

Note. MPA = moderate physical activity; VPA = vigorous physical activity.

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