Age and Gender Differences in Youth Physical Activity: Does Physical Maturity Matter?

LAUREN B. SHERAR[1], DALE W. ESLIGER[1], ADAM D. G. BAXTER-JONES[1], and MARK S. TREMBLAY[1,2]

[1]*College of Kinesiology, University of Saskatchewan, Saskatoon, Saskatchewan, CANADA; and* [2]*Statistics Canada, Ottawa, Ontario, CANADA*

BASIC SCIENCES

ABSTRACT

SHERAR, L. B., D. W. ESLIGER, A. D. G. BAXTER-JONES, and M. S. TREMBLAY. Age and Gender Differences in Youth Physical Activity: Does Physical Maturity Matter? *Med. Sci. Sports Exerc.*, Vol. 39, No. 5, pp. 830–835, 2007. **Purpose:** To investigate whether observed gender differences in objectively measured physical activity (PA) in children (8–13 yr) are confounded by physical maturity differences. **Methods:** Four hundred and one children (194 boys and 207 girls) volunteered for this study. An Actigraph accelerometer was used to obtain seven consecutive days of minute-by-minute PA data for each participant. Minutes of moderate to vigorous PA per day (MVPA), continuous minutes of MVPA per day (CMVPA), and minutes of vigorous PA per day (VPA) were derived from the accelerometer data. Age at peak height velocity (APHV), an indicator of somatic maturity, was predicted in all individuals. Gender differences in the PA variables were analyzed using a two-way (gender × age) ANOVA. **Results:** Levels of PA decreased with increasing chronological age in both genders ($P < 0.05$). When aligned on chronological age, boys had a higher MVPA at 10–13 yr, a higher CMVPA at 9–12 yr, and a higher VPA at 9–13 yr ($P < 0.05$). When aligned on biological age, PA declined with increasing maturity ($P < 0.05$); however, gender differences between biological age groups disappeared. **Conclusion:** The observed age-related decline in adolescent boys and girls PA is antithetical to public health goals; as such, it is an important area of research. To fully understand gender disparities in PA, consideration must be given to the confounding effects of physical maturity.
Key Words: ACCELEROMETRY, ADOLESCENCE, MEASUREMENT, PEAK HEIGHT VELOCITY

One of the most pervasive findings in epidemiological studies of physical activity (PA) is the decline in PA with age. Although PA has been shown to decline throughout the lifespan (2,3,21), cross-sectional and longitudinal studies have shown that the decline in self-reported PA is greatest during the adolescent years. For example, a Finnish longitudinal study has shown that in boys, the greatest overall decline in PA was between 12 and 18 yr, and in girls, it was between 12 and 15 yr. Additionally, data from the Amsterdam Longitudinal Growth and Health Study (32) document the greatest decline in PA between 13 and 16 yr of age. Lastly, in a cross-sectional U.S. sample, Caspersen and colleagues (4) found that the greatest reduction in self-report PA occurred between 15 and 18 yr of age.

In addition to the consistent documentation of an age-related decline in PA in both boys and girls, it is also well established that boys are more active than girls at all ages (7,9,16,18,19,26,30). For example, an investigation of accelerometer-assessed PA in 375 students (grades 1–12) has shown that boys participated in more minutes of daily moderate to vigorous PA (MVPA) (with the exception of grades 1–3) and more minutes of daily vigorous PA (VPA) (30). Further evidence using a large sample (N = 2185) from the European Youth Heart Study has shown that 9- and 15-yr-old boys spent 20 and 36% more time than girls in daily moderate PA (16). In a Canadian study of 1057 normal-weight children, it was again found that boys spent more time in PA than girls. Specifically, boys in grades 3, 7, and 11, respectively, spent 9, 22, and 27% more time in MVPA than girls (27).

The observation that at a given age, boys are more active than girls may be well established, but at least one group believes the finding to be confounded. A longitudinal study by Thompson et al. (26) has found that during adolescence, the gender differences in self-reported PA disappeared when differences in physical maturity were controlled (26). The main concern regarding confounding is that, on average, girls mature approximately 2 yr before boys (14,24). For example, on average, boys reach peak height velocity, a somatic indicator of physical maturity, at approximately 14 yr of age, whereas girls, on average, reach the same maturity milestone at approximately 12 yr of age. Adolescence is recognized as a period of great physical, psychosocial, cognitive, and emotional change.

Address for correspondence: Lauren B. Sherar, 87 Campus Drive, Physical Activity Complex, Saskatoon, Saskatchewan, S7H 1P1; E-mail: lauren.sherar@usask.ca.
Submitted for publication July 2006.
Accepted for publication January 2007.

0195-9131/07/3905-0830/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/mss.0b013e3180335c3c

Each of these changes (which may be linked to physical maturity) influences adolescent participation in PA (20). Therefore, the consistent observation that boys are more active than girls during adolescence may purely be an artifact of boys maturing later than girls and, as a result, altering their PA behavior later.

Thompson et al. (26) have determined that gender differences in PA disappear when aligned on maturational age, suggesting that physical maturity may be intricately involved in the adolescent decline in PA. This has important public health implications. For example, adolescent PA interventions may need to target biological maturity groups rather than chronological age groups (i.e., grades in school) to effect positive change. However, to the authors' knowledge, the study by Thompson et al. (26) is the only one to date to consider biological maturation in the study of adolescent PA and has yet to be replicated using an objective assessment of PA. Therefore, the purpose of the present study was to investigate whether observed gender differences in objectively measured PA in children (8–13 yr) are confounded by physical maturity differences.

METHODS

Participants. Data from 194 boys and 207 girls, aged 8–13.9 yr, were included in this study. Participants between the ages of 8.0 and 13.9 yr were chosen because they are likely to be predominantly pre-PHV (on average, boys reach PHV at 14 yr of age, and girls reach PHV at 12 yr of age). This age group is important to study because most of the variation in physical maturity occurs during the years approaching PHV (14,24). Participants comprised four groups of children residing in Canada: 1) rural-living children from Saskatchewan (N = 127), 2) urban-living children from Saskatchewan (N = 91), 3) Old Order Mennonite children from southwestern Ontario (N = 119), and 4) Old Order Amish children from southwestern Ontario (N = 64). Information on the recruitment of participants can be found elsewhere (1,28). Each child gave written assent, and parental consent was also obtained. All procedures were approved by the institutional research ethics board.

Chronological age. Decimal age was calculated by subtracting date of birth from the measurement date. Chronological age categories were constructed using 1-yr intervals, for example, individuals between 8.00 and 8.99 yr of age were grouped in the 8-yr-old category. These age categories are consistent with the age-specific accelerometer cut points (30). The decision to use whole-year age categories in truncated format (e.g., 8.00–8.99 = 8) rather than centered on whole-year age midpoint (e.g., 7.50–8.49 = 8) was taken out of necessity. Because the physical activity data were calculated using whole-year age categories in truncated format according to the age-specific cut-points described by Trost et al. (30), we were obligated to present the data in this format. This is important because it ensures that children grouped in the same age category are held to the same count-intensity standard when determining how many minutes of physical activity they accumulate.

Anthropometry. Measurements were taken for stature, sitting height, and body mass. All measurements were performed by a professional fitness and lifestyle consultant certified by the Canadian Society for Exercise Physiology. Leg length was calculated by subtracting sitting height from stature.

Physical maturity (biological age). A common maturity-assessment technique in longitudinal studies is the determination of years from attainment of peak height velocity (PHV) (13). PHV is an indicator of somatic maturity and reflects the age at maximum growth rate in stature during adolescence (age at PHV, APHV). In the present cross-sectional study, each individual's years from APHV were predicted using a gender-specific multiple-regression equation that included height, sitting height, leg length, chronological age, and their interactions (15). The prediction of years from APHV results in a continuous measure of biological age. Biological age categories were constructed using 1-yr intervals, such that the −1 APHV age group included observations between −0.49 and −1.50 yr from (i.e., before) APHV.

Physical activity. Physical activity levels were directly measured for seven consecutive days, using the Actigraph 7164 accelerometer (Actigraph, LLC, Fort Walton Beach, FL). The Actigraph is a uniaxial accelerometer that detects vertical acceleration in the magnitude of 0.05–2.00g with a frequency response of 0.25–2.50 Hz (31). All accelerometers underwent a calibration check on a hydraulic shaker plate at varying accelerations and frequencies before being used in the study (6). Only accelerometers with intra- and interinstrument reliability values below 5% coefficient variation were used. Participants wore the Actigraph over the right hip using a waist-mounted nylon belt. Participants were asked to record when the monitor was put on in the morning and when it was removed in the evening before bed, for the purpose of distinguishing between activity time and sleep time. On completion of the data collection, the data were electronically downloaded, resulting in a file containing minute-by-minute movement counts for each child. After data were scanned for spurious measures, sleep time was determined from the log sheets, and activity counts were added to the data file for unworn daytime periods for which the activity was included on the log sheet (using the compendium of physical activities and MET-to-count conversion values derived via regression equations published by Trost et al. (29)). Files with minimal levels of incomplete data underwent imputation procedures to ensure that 7 d of data were available for analysis. A more complete description of the data-reduction procedures can be found elsewhere (5,28).

TABLE 1. Subject characteristics by gender, chronological age (CA), and biological age (BA).

CA Group (yr)	*N*	Stature (cm)	Body Mass (kg)	BA Group (yr)	*N*	Stature (cm)	Body Mass (kg)
Boys							
8	11	129.2 (7.8)	26.8 (4.7)	−5	12	127.1 (4.4)	25.3 (2.2)
9	39	137.8 (7.2)	34.6 (7.2)	−4	23	134.6 (5.6)	31.0 (5.8)
10	42	142.8 (7.2)	37.4 (7.2)	−3	62	141.7 (5.8)*	36.7 (4.2)*
11	43	148.0 (7.2)	44.0 (8.7)	−2	55	149.5 (4.8)*	43.3 (5.9)*
12	43	153.8 (8.0)	44.8 (8.3)*	−1	36	158.1 (5.6)*	50.7 (8.5)*
13	16	157.9 (8.5)	48.3 (8.0)				
Girls							
8	8	127.2 (5.2)	25.3 (3.6)	−3	15	130.3 (4.1)	27.7 (1.8)
9	32	135.8 (6.4)	33.0 (6.6)	−2	39	138.2 (6.7)	33.4 (5.9)
10	56	143.3 (6.3)	38.9 (8.3)	−1	64	145.4 (4.4)	40.6 (6.4)
11	46	149.0 (7.1)	43.2 (9.6)	0	47	151.6 (5.4)	45.6 (8.7)
12	56	155.8 (6.6)	49.6 (9.6)	1	36	160.2 (4.6)	54.3 (7.1)
13	9	159.9 (4.2)	52.5 (6.2)				

Means (SD). Biological age was calculated in years from estimated age at peak height velocity (APHV). * Significantly ($P < 0.05$) greater than girls. Observations that fell outside −5 to −1 for girls and −3 to 1 for boys were excluded because of the small number; thus, $N = 401$ when aligned by CA and $N = 389$ when aligned by BA.

The average number of minutes of moderate to vigorous PA (MVPA; accumulated minutes ≥ 3 METs), continuous minutes of MVPA (CMPVA; accumulated minutes ≥ 3 METs clustered in bouts ≥ 10 min), and minutes of vigorous PA (VPA; accumulated minutes ≥ 6 METs) per day were calculated using age-specific cut points (30).

Statistical analysis. Independent *t*-tests were used to investigate the gender difference in stature and body mass at each chronological and biological age. Gender and age (chronological and biological) differences in PA were tested using a two-way ANOVA. Included in each model were the main effects for age category and gender, and the interaction of gender and age. Physical activity data were log transformed because of the positive skewedness of MVPA, VPA, and CMVPA. The alpha level was set at 0.05. SPSS (version 11.5) was used to analyze the data.

RESULTS

The subjects' physical characteristics, by chronological and biological age category, are shown in Table 1. There were no significant differences between boys and girls in body mass or stature, except for age 12, where girls were significantly ($P < 0.05$) heavier than boys. When the data were aligned on biological age, boys were significantly taller and heavier than girls at all ages before PHV that were common between the groups.

For ease of interpretation, Figure 1 shows the arithmetic means and standard deviations (i.e., nontransformed) for MVPA, CMPVA, and VPA. When aligned on chronological age, PA showed the characteristic decrease with increasing age; however, not all decreases between age categories were significant ($P > 0.05$) (Fig. 1A, C, E). The boys were found to have a higher MVPA at 10–13 yr, a higher CMVPA at 9–12 yr, and a higher VPA at 9–13 yr compared with the girls ($P < 0.05$). For MVPA, the gender difference was the smallest at 8 yr of age (9.7%) and the greatest at 13 yr of age (30.5%). For CMPVA, the gender difference ranged from 20.9% at 9 yr to 52.1% at 11 yr. For VPA, the gender difference ranged from 20.8% at 9 yr to 46.3% at 11 yr.

When aligned on biological age, PA decreases with increasing biological age; however, not all decreases between biological age categories were significant ($P > 0.05$) (Fig. 1B, D, F). There were no significant differences in MVPA, CMVPA, or VPA between girls and boys at each biological age ($P < 0.05$).

Among the boys, the largest chronological age difference (relative to the previous chronological age category) in MVPA, CMVPA, and VPA occurred between 8 and 9 yr of age and was 28.4, 38.8, and 49.5%, respectively. Among the girls, the largest chronological age difference in MVPA, CMVPA, and VPA also occurred between 8 and 9 yr of age and was 23.6, 47.9, and 37.1%, respectively. Among the boys, the largest biological age difference (relative to the previous biological age category) in MVPA, CMVPA, and VPA occurred between −5 and −4 yr from APHV and was 28.4, 41.3, and 55.4%, respectively. Among the girls, the largest biological age difference in MVPA, CMVPA, and VPA occurred between −3 and −2 yr from APHV and was 23.0, 39.8, and 40.8%, respectively.

DISCUSSION

The present finding that accelerometer-assessed PA declines in both genders with increasing chronological age from 8 to 13 yr supports previous research (10,16,30). As expected, when boys and girls were compared on the basis of chronological age, boys accumulated significantly more MVPA, CMVPA, and VPA at most ages between 8 and 13 yr. The fact that boys are more active than girls is a fairly consistent finding; however, the magnitude of the gender differences seems to depend on the type and intensity of the activity (25,29). For example, Trost and colleagues (29) have shown that for VPA, the average gender gap was substantial at 45%, whereas the average gender gap for MVPA was only 11%. Results from the present study also demonstrate that the gender difference is greater for VPA than for MVPA. The greatest decrease in MVPA, VPA, and CMVPA occurred between 8 and 9 yr of age in boys as well as girls.

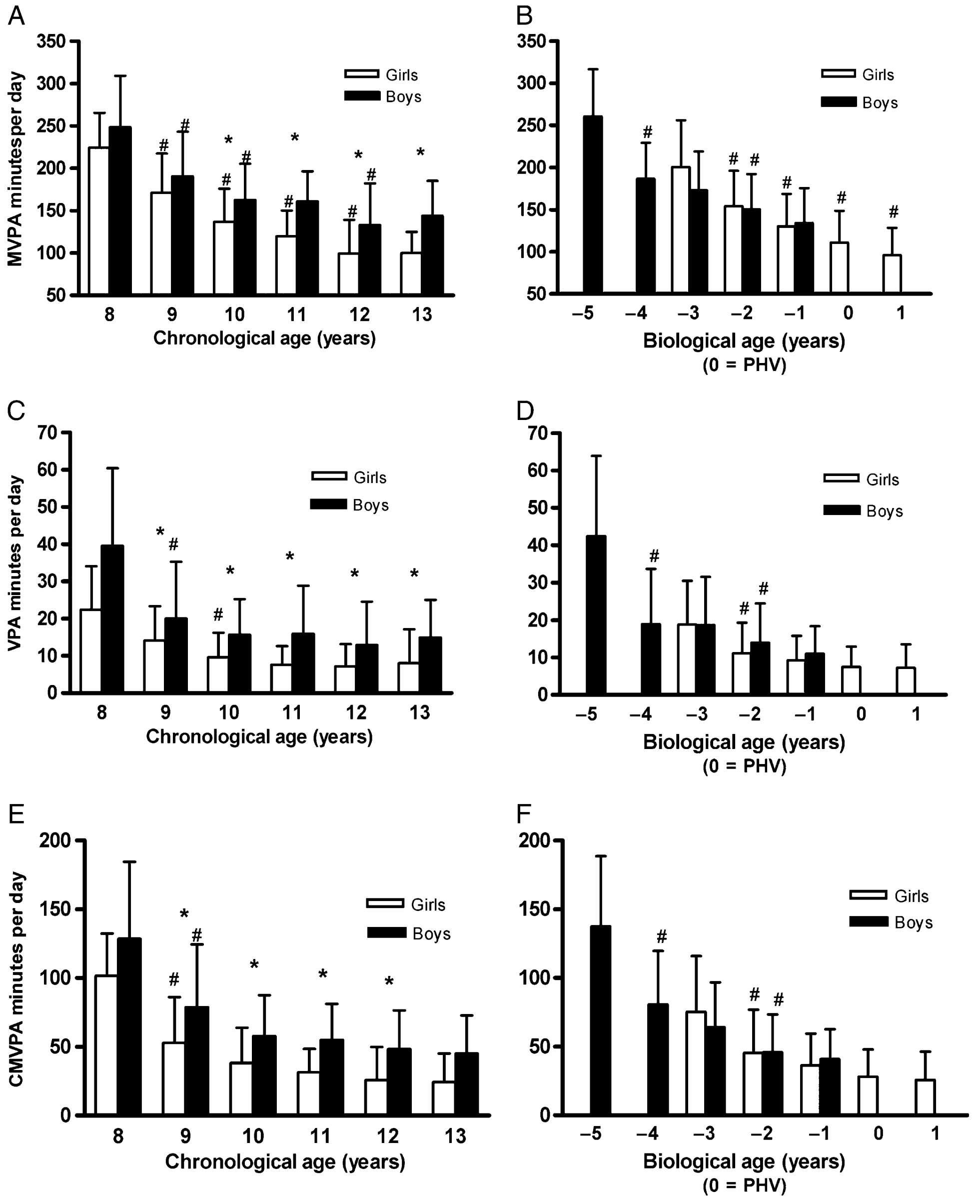

FIGURE 1—Objectively measured physical activity (PA) variables (mean ± SD) of boys and girls by chronological age (*A*, minutes of moderate to vigorous PA (MVPA); *C*, minutes of vigorous PA (VPA); *E*, continuous minutes of MVPA (CMVPA)) and biological age (years from age at peak height velocity (APHV)) (*B*, MVPA; *D*, VPA; *F*, CMVPA). * Significant gender difference within age category (P < 0.05); # significant difference from previous age category (P < 0.05).

The results from this study also support the findings of Thompson and colleagues (26) demonstrating that the gender differences in PA disappeared when aligned on physical maturity. This finding supports the notion that maturity differences between genders (i.e., on average, girls mature earlier than boys) may be one reason why research consistently shows that girls are less active than boys of the same chronological age. To the authors' knowledge, this is the first study to demonstrate this phenomenon using accelerometer-assessed PA.

Acknowledging the potential role of biological maturity in adolescent PA may help explain findings from previously published work. For example, Klasson-Haggebo and Anderssen (10) note that the rate of longitudinal decline in PA was similar for both boys and girls (25.9 and 27.2%, respectively) but that the age at which PA levels began to decline was younger for girls than boys. The authors provide no explanation for this finding; however, we speculate that the earlier decline in PA shown in girls is attributable to their earlier age of maturation because, on average, girls reach every maturity milestone earlier than boys (14). Consistent with previous research (14,22), the average APHV in the present study was 1.65 yr younger in girls compared with boys. The average APHV for boys (13.54 ± 0.81 yr) and girls (11.89 ± 0.58 yr) falls within the range of ages reported in previous literature (14,22).

The age-related decline in PA is well accepted but is not well understood (12). The present study provides evidence

BASIC SCIENCES

to suggest that, at least in 8.0- to 13.9-yr-olds, the decline in PA is associated with biological maturity. Further supporting the importance of biological maturity, Finnish studies have shown that the beginning of the decline in PA is associated with puberty, with early-maturing girls being slightly less active than late-maturing girls (11). Furthermore, there is much evidence, from both cross sectional and longitudinal studies to suggest that the annual rate of decline in PA is much greater during adolescence than during late childhood and adulthood (4,9,25,32). However, most research exploring the age-related decline has not included children younger than 9 yr. The inclusion of younger children in the present study shows that the greatest decrease in MVPA, VPA, and CMVPA was between 8 and 9 yr (preadolescence) in boys as well as girls. However, longitudinal PA data including young children is required to make a definitive determination of the age at which the marked decline in PA occurs.

The consistent finding of an age-related decline in PA, with boys being more active than girls, provides the primary rationale for many interventions targeting adolescent girls. Three examples are the Trial of Activity in Adolescent Girls (TAAG) (23), Project FAB (8), and Girls on the Move (17). Because controlling for biological maturity seems to nullify gender differences in PA, it may be erroneous or misguided to target adolescent females over males when designing interventions. However, research does support gender-targeted PA interventions, because adolescent boys and girls prefer different activities, participate in PA for dissimilar reasons, and may face different barriers to PA (33). Interventions may also need to target girls at an earlier chronological age than boys, considering that, on average, girls mature 2 yr earlier than boys.

Previous research has explored barriers (and correlates) to adolescent PA in an effort to reduce the decline in PA over time. However, the relationship between barriers to PA and biological maturity has not yet been addressed. Identifying maturity-related barriers to PA during adolescence may provide valuable information that can be used to design interventions to help boys and girls of varying maturation overcome these barriers. In the future, the consideration of biological maturity may also cause us to rethink the implementation of adolescent PA interventions. The majority of interventions are based on chronological age groups (i.e., grades) in schools. Within one grade, there is considerable variation in biological age and in the level of biological maturity attained. For example, some 12-yr-old girls are already sexually mature, others are in the process of maturing, and others will not begin the process for several more years. Yet, all the girls have the same chronological age and are typically in the same grade in school. This wide variation in physical maturity was evident in the present sample of adolescents, with boys' APHV spanning 4.78 yr and girls' APHV spanning 4.84 yr. Therefore, in the design and implementation of school-based PA interventions, there may be a need to consider the variation in physical maturity within gender and grades. That said, one must acknowledge the potential hurdles in conducting a PA intervention based on maturity. For example, adolescents may be more comfortable participating in interventions with their peers in the same grade. Also, considering that most school scheduling is based on chronological age grades, organizing maturity-based interventions that span many grades may be problematic.

The present sample of boys and girls spanned 8.0–13.9 yr of age; therefore, some of the participants (especially the boys) were likely prepubertal. To completely document the confounding effects of biological maturity on age and gender differences in adolescent PA, there is a need for an objective assessment of PA and for an assessment of biological maturity on children older then 13.9 yr of age. The present sample is also cross-sectional; APHV was predicted, and as such, it is likely less accurate than when observed in a longitudinal study.

CONCLUSION

The observed age-related decline in adolescent boys and girls PA is antithetical to public health goals, and as such, it is an important area of research. To fully understand gender disparities in PA, consideration must be given to the confounding effects of biological age.

This research was supported by a grant from the Canadian Population Health Initiative of the Canadian Institute for Health Information, and by the Community and Population Health Research (CPHR) Training Program delivered by the Saskatchewan Population Health and Evaluation Research Unit (SPHERU).

REFERENCES

1. Bassett, D., M. S. Tremblay, D. W. Esliger, J. L. Copeland, J. D. Barnes, and G. E. Huntington. Physical activity levels in children of an Old Order Amish community. *Med Sci Sports Exerc.* 38(5 Suppl.):S81–S82, 2006.
2. Bijnen, F. C., E. J. Feskens, C. J. Caspersen, W. L. Mosterd, and D. Kromhout. Age, period, and cohort effects on physical activity among elderly men during 10 years of follow-up: the Zutphen Elderly Study. *J. Gerontol. A Biol. Sci. Med. Sci.* 53:M235–M241, 1998.
3. Caspersen, C. J., and R. K. Merritt. Physical activity trends among 26 states, 1986–1990. *Med. Sci. Sports Exerc.* 27:713–720, 1995.
4. Caspersen, C. J., M. A. Pereira, and K. M. Curran. Changes in physical activity patterns in the United States, by sex and cross-sectional age. *Med. Sci. Sports Exerc.* 32:1601–1609, 2000.
5. Esliger, D. W., J. L. Copeland, J. D. Barnes, and M. S. Tremblay. Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring. *J. Phys. Act. Health* 3:366–383, 2005.

6. Esliger, D. W., and M. S. Tremblay. Technical reliability assessment of three accelerometer models in a mechanical setup. *Med. Sci. Sports Exerc.* 38:2173–2181, 2006.
7. Jago, R., C. B. Anderson, T. Baranowski, and K. Watson. Adolescent patterns of physical activity differences by gender, day, and time of day. *Am. J. Prev. Med.* 28:447–452, 2005.
8. Jamner, M. S., D. Spruijt-Metz, S. Bassin, and D. M. Cooper. A controlled evaluation of a school-based intervention to promote physical activity among sedentary adolescent females: project FAB. *J. Adolesc. Health* 34:279–289, 2004.
9. Kimm, S. Y., N. W. Glynn, A. M. Kriska, et al. Longitudinal changes in physical activity in a biracial cohort during adolescence. *Med. Sci. Sports Exerc.* 32:1445–1454, 2000.
10. Klasson-Heggebo, L., and A. Anderssen. Gender and age differences in relation to the recommendations of physical activity among Norwegian children and youth. *Scand. J. Med. Sci. Sports* 13:293–298, 2003.
11. Laakso, R., and R. Telama. (1981) Sport participation of Finnish youth as a function of age and schooling. In: Telama, R. and X. Yang. Decline of physical activity from youth to young adulthood in Finland. *Med. Sci. Sports Exerc.* 32:1617–1622, 2000.
12. Livingstone, M. B., P. J. Robson, J. M. Wallace, and M. C. McKinley. How active are we? Levels of routine physical activity in children and adults. *Proc. Nutr. Soc.* 62:681–701, 2003.
13. Malina, R. M. Adolescent growth and maturation: selected aspects of current research. *Yearb. Phys. Anthropol.* 21:63–94, 1978.
14. Malina, R. M., C. Bouchard, and O. Bar-Or. *Growth, Maturation and Physical Activity*, Champaign, IL: Human Kinetics, pp. 307–333, 2004.
15. Mirwald, R. L., A. D. Baxter-Jones, D. A. Bailey, and G. P. Beunen. An assessment of maturity from anthropometric measurements. *Med. Sci. Sports Exerc.* 34:689–694, 2002.
16. Riddoch, C. J., L. B. Andersen, N. Wedderkopp, et al. Physical activity levels and patterns of 9- and 15-yr-old European children. *Med. Sci. Sports Exerc.* 36:86–92, 2004.
17. Robbins, L. B., K. A. Gretebeck, A. S. Kazanis, and N. J. Pender. Girls on the move program to increase physical activity participation. *Nurs. Res.* 55:206–216, 2006.
18. Sallis, J. F. Epidemiology of physical activity and fitness in children and adolescents. *Crit. Rev. Food Sci. Nutr.* 33:403–408, 1993.
19. Sallis, J. F., J. E. Alcaraz, T. L. McKenzie, and M. F. Hovell. Predictors of change in children's physical activity over 20 months. Variations by gender and level of adiposity. *Am. J. Prev. Med.* 16:222–229, 1999.
20. Sallis, J. F., J. J. Prochaska, and W. C. Taylor. A review of correlates of physical activity of children and adolescents. *Med. Sci. Sports Exerc.* 32:963–975, 2000.
21. Schoenbornf, C. A. Health habits of U.S. adults, 1985: the "Alameda 7" revisited. *Public Health Rep.* 101:571–580, 1986.
22. Sherar, L. B., A. D. Baxter-Jones, and R. L. Mirwald. Limitations to the use of secondary sex characteristics for gender comparisons. *Ann. Hum. Biol.* 31:586–593, 2004.
23. Stevens, J., D. M. Murray, and D. J. Catellier. Design of the Trial of Activity in Adolescent Girls (TAAG). *Contemp. Clin. Trials* 26:223–233, 2005.
24. Tanner, J. M. *Foetus Into Man. Physical Growth From Conception to Maturity*. London, UK: Castlemead Publications, pp. 6–23, 1989.
25. Telama, R., and X. Yang. Decline of physical activity from youth to young adulthood in Finland. *Med. Sci. Sports Exerc.* 32: 1617–1622, 2000.
26. Thompson, A. M., A. D. Baxter-Jones, R. L. Mirwald, and D. A. Bailey. Comparison of physical activity in male and female children: does maturation matter? *Med. Sci. Sports Exerc.* 35:1684–1690, 2003.
27. Thompson, A. M., P. D. Campagna, L. A. Rehman, R. J. Murphy, R. L. Rasmussen, and G. W. Ness. Physical activity and body mass index in grade 3, 7, and 11 Nova Scotia students. *Med. Sci. Sports Exerc.* 37:1902–1908, 2005.
28. Tremblay, M. S., J. D. Barnes, J. L. Copeland, and D. W. Esliger. Conquering childhood inactivity: is the answer in the past? *Med. Sci. Sports Exerc.* 37:1187–1194, 2005.
29. Trost, S. G., R. R. Pate, P. S. Freedson, J. F. Sallis, and W. C. Taylor. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med. Sci. Sports Exerc.* 32:426–431, 2000.
30. Trost, S. G., R. R. Pate, J. F. Sallis, et al. Age and gender differences in objectively measured physical activity in youth. *Med. Sci. Sports Exerc.* 34:350–355, 2002.
31. Tyron, W. W., and R. Williams. Fully proportional actigraphy: a new instrument. *Behav. Res. Methods Instrum. Comput.* 28: 392–403, 1996.
32. Van Mechelen, W., J. W. Twisk, G. B. Post, J. Snel, and H. C. Kemper. Physical activity of young people: the Amsterdam Longitudinal Growth and Health Study. *Med. Sci. Sports Exerc.* 32:1610–1616, 2000.
33. Vu, M. B., D. Murrie, V. Gonzalez, and J. B. Jobe. Listening to girls and boys talk about girls' physical activity behaviors. *Health Educ. Behav.* 33:81–96, 2006.