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The Association Between Motor Skill Competence and Physical Fitness in Young Adults

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We examined the relationship between competence in three fundamental motor skills (throwing, kicking, and jumping) and six measures of health-related physical fitness in young adults (ages 18–25). We assessed motor skill competence using product scores of maximum kicking and throwing speed and maximum jumping distance. A factor analysis indicated the 12-min run/walk, percent body fat, curl-ups, grip strength, and maximum leg press strength all loaded on one factor defining the construct of "overall fitness." Multiple regression analyses indicated that the product scores for jumping (74%), kicking (58%), and throwing (59%) predicted 79% of the variance in overall fitness. Gender was not a significant predictor of fitness. Results suggest that developing motor skill competence may be fundamental in developing and maintaining adequate physical fitness into adulthood. These data represent the strongest to date on the relationship between motor skill competence and physical fitness.

Key words: motor development, physical activity, product scores, skill acquisition

Developing healthy lifestyles includes maintaining appropriate levels of health-related physical fitness (e.g., muscular strength/endurance, cardiorespiratory endurance, body composition, and flexibility) and physical activity. Maintaining physical fitness levels may reduce mortality risk and incidence of chronic diseases (Blair et al., 1995; CDC, 2001; Freedman, Dietz, Srinivasan, & Berenson 1999; Centers for Disease Control and Prevention, 2001) and muscular strength and endurance the functional limitations that lead to dependent care in the elderly (Brill, Macera, Davis, Blair, & Gordon, 2000; Buchner, Beresford, Larson, Lacroix, & Wagner, 1992).

While physical fitness in children, adolescents, and adults has been promoted (Blair et al., 1995; McKenzie et al., 2003; Okely, Booth, & Patterson, 2001; Sallis et al., 1997), relatively little is known about the effects of maintaining motor skills on physical fitness throughout the lifespan. Intermediate to high levels of competence in fundamental motor skills (FMS) required for successful participation in many sports and physical activities may be associated with higher levels of performance and health-related physical fitness. Many FMS (e.g., throwing, kicking, jumping, striking) involve ballistic actions that pit body mass against gravity, resulting in an increased demand for higher power outputs (Enoka, 2002; Fleisig, Barrentine, Zheng, Escamilla, & Andrews, 1999; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). FMS also may demand high levels of muscular and cardiorespiratory endurance to persist in these activities. In addition to body composition (level of obesity), these performance criteria are, in fact, foundational aspects of health-related physical fitness.

Although no formula exists for promoting sustained physical fitness and activity levels throughout the lifespan, identifying causal mechanisms and predictors of health-related physical fitness and activity is a crucial step toward developing strategies to promote and maintain a healthy lifestyle. Increasing physical fitness and activity during adolescence might mitigate the decline in these levels observed in some adults, as attitudes and habits regarding physical activity are developed primarily during the preadolescent years (Malina, 1996).

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Malina (1996) speculated that sports participation during childhood and adolescence might form the foundation for continued activity into adulthood. Tammelin, Nayha, Hills, and Jarvelin (2003) showed that children's participation in sports-related activities could be an indicator of their physical activity levels into adulthood. Children who participate in sports at least twice a week, join sports clubs, and achieve high grades in school sports are likely to maintain high levels of physical activity in adulthood. High-endurance sports and those that require or encourage diversified skills are the most beneficial to enhancing adult physical activity and physical fitness. Therefore, we believe the development of motor skill competence in childhood may serve as a mechanism for adequate health-related physical fitness and activity in adulthood.

Overall, research on the relationship between motor skill competence and aspects of physical fitness are scanty. Beunen et al. (1988) reported that strength measures and motor performance correlated moderately in Belgian boys and were the strongest between 13 and 16 years of age, but they did not provide sample correlations. Years earlier, Espenschade (1940) reported that correlations between grip strength and various motor performance tests were higher for adolescent boys (jump and reach = .27, distance throw = .71) than for girls' (jump and reach = .00, distance throw = .60). Correlations of overall upper body strength and motor performance was also higher for boys (jump and reach = .29–.71, distance throw = .47–.67, broad jump = .43–.57, and 50-yard [45.72 m] dash = 34–.49) than for girls. The highest correlations for adolescent girls were .48 (distance throw) and .32 (50-yard dash). Malina and Brouchard (1991) found generally low correlations (0–.35) between strength and motor performance during childhood. Endomorphy tended to be negatively correlated with jumping, running, and agility and positively correlated with throwing; however, mesomorphy and ectomorphy were not related to motor performance. During adolescence, correlations remained low to moderate for boys between 12–17 years of age. Obese children tended to show negative correlations with skill product scores.

Method

Participants

We recruited men (n = 79) and women (n = 109) 18–25 years of age from Bowling Green University (see Table 1 for participant data). Prior to their participation, we obtained permission to conduct the study from the university's Human Subjects Review Board and obtained informed consent from all participants. Individuals also completed a health questionnaire prior to participation.

Procedures

We evaluated participants on three FMS and six health-related physical fitness tests. Individuals did a general and/or specific warm-up routine before participation, depending on the tasks to be completed during each testing session. General warm-up activities included 3–5 min of jogging as well as static and dynamic stretching exercises. Specific warm-ups included up to five practice attempts of each specific motor skill. In general, participants completed most of the physical fitness tests during one testing session and completed the skills tests during a second testing session. Participants performed motor skills in a JUGS batting cage (JUGS Co., Tualatin, OR.) in the university's Biomechanics/Motor Behavior Laboratory. Physical fitness tests also were performed in the laboratory or in a gymnasium in the same building complex.

Motor Skills Competence Measures. We measured throwing and kicking maximum ball speed and maximum jumping distance. The highest ball speed of three throwing and kicking trials was used for data analysis. Ball speeds were measured with a JUGS radar gun. The radar gun was accurate to ± .22 m/s (.5 mph). The longest distance jumped during three trials was used for data analysis.

Health-Related Physical Fitness Measures. Fitness measures included: 12-min run/walk, body fat percentage, curl-ups, grip strength, flexibility, and maximum leg press strength. We assessed body composition using skinfold measures taken at three sites (tricep, suprailiac, and thigh for women; chest, abdomen, and thigh for men). Assessment procedures followed the American College of Sports Medicine (ACSM) recommended guidelines (ACSM, 2006). Estimations of body fat were calculated using Jackson and Pollack's (1985) equations.

We examined lower body flexibility via a sit-and-reach box (Lafayette Instrument, Lafayette, IN). Participants had three trials, the best of which was recorded (ACSM, 2006). We assessed grip strength using a handgrip dynamometer (Lafayette Instrument, Lafayette, IN) and recorded the highest of three trials using the dominant hand (in kg). We examined lower body muscle strength with an estimated three-repetition maximum unilateral leg press (dominant leg) on a universal weight

Table 1. Participant characteristics

	Total (n = 188)		Men (n = 79)		Women (n = 109)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age (years)	20.4	1.7	20.5	1.8	20.3	1.7
Height (cm)	170.2	9.8	178.0	8.1	164.3	6.4
Weight (kg)	72.8	16.1	82.1	15.2	65.8	12.9

Note. M = mean; *SD* = standard deviation.

machine (Body Masters®, Rayne, LA). Dominance was determined subjectively by asking participants which leg was stronger or was used to kick a ball. We used estimated repetition maximum assessment procedures, recommended by the National Strength and Conditioning Association (Baechle & Earle, 2000). We used a curl-up test to examine trunk muscular endurance (Baechle & Earle, 2000), which consisted of completing as many curl-ups as possible in 1 min. We assessed cardiovascular endurance using a 12-min walk/run test (Cooper, 1968), during which participants covered the maximum distance possible in 12 min of walking, running, or a combination of both. We recorded the distances to the nearest meter.

Data Analysis

Because the concept of health-related physical fitness is a combination of five specific physical domains (muscular strength, muscular endurance, flexibility, cardiovascular endurance, and body composition), we examined the global construct of physical fitness, as assessed by six fitness measures. To glean the most parsimonious construct of physical fitness, we used a factor analysis to examine the relationships among the six fitness measures. The statistical procedures for factor analysis automatically normalized the measures before running the analysis. That is, for each measure, the mean was subtracted from the observation and the difference was divided by the standard deviation. Thus, each measure had a mean of 0 and standard deviation of 1. We then ran the factor analysis on the normalized measures.

The factor analysis separated the six fitness measures into two specific factors. One factor included five of the six measures: (a) body composition, (b) leg strength, (c) grip strength, (d) curl-ups, and (e) 12-min run/walk. Pearson's bivariate correlations were moderate to strong among all five of these measures (r = .34–.71; see Table 2). All measures were positively correlated to each other, with the exception of body composition, which was negatively correlated to the other four fitness measures. We also examined construct reliability of these measures using Cronbach's alpha (.82), which indicated that all five measures significantly added to the factor. Removing any of the measures significantly reduced Cronbach's alpha.

The second factor included only the sit-and-reach flexibility measure. Pearson's bivariate correlations among sit-and-reach flexibility and the other five fitness measures were substantially lower (r = .01–.19; see Table 2) than correlations among the other fitness measures. Factor 1 predicted approximately three times the variance (relative score) in fitness (2.98) compared to Factor 2 (1.04). Because the flexibility measure was not significantly correlated to the other fitness measures and the variance explained in fitness by the measures contributing to Factor 1 was significantly higher, we used Factor 1 as our global construct of physical fitness.

We then used multiple regression analysis and regressed the construct of health-related physical fitness (i.e., the Factor 1 score) as one dependent measure on the three product scores. We used gender as an additional independent factor to assess its contribution to the overall relationship between the motor skill product scores and the construct of physical fitness (Factor 1). We also analyzed the relationships among product scores and physical fitness (Factor 1) by gender. An alpha level set at $\alpha = .05$ was implemented to determine significance. SAS Version 9.1 was used for all analyses.

Results

Normal probability and residual plots of the participant data and gender-specific data indicated that the data were normally distributed and linear with respect to the three product scores (see Table 3 for descriptive data on all measures by gender). We evaluated overall fitness of men and women using normative data (ACSM, 2006; Baechle & Earle, 2000) that were available on four of the six physical fitness measures.

Table 2. Pearson's bivariate correlations among fitness measures (N = 188)

	Body composition	Grip	Leg press	Sit-and-reach	Curl-up	Run
Body composition	1.00	-.51**	-.44**	.18*	-.53**	-.60**
Grip		1.00	.71**	-.19**	.35**	.42**
Leg press	-.44**		1.00	.01	.44**	.34**
Sit-and-reach	.18*	-.19**		1.00	-.03	-.18*
Curl-up	-.53**	.35**	.44**		1.00	.50**
Run	-.60**	.42**	.34**	-.18*		1.00

*p < .05.
**p <.01.

Our data indicated 77% of men and 45% of women were at or above the 50th percentile for body composition (higher percentile = lower % body fat); 67% of men and 48% of women were at or above the 50th percentile for curl-ups; 77% of men and 66% of women were equal to or greater than average on the 12-min run/walk for distance, and 51% of men and 61% of women were equal to or greater than average on sit-and-reach flexibility. Overall, the men demonstrated higher overall physical fitness than women (relative to normative data), with the exception of sit-and-reach flexibility. In general, our sample population was above average in fitness with respect to normative data.

Initial Pearson's bivariate correlational data indicated that motor skill product scores were moderately to highly correlated to five of the fitness measures (r = .48–.74; see Table 4), with flexibility the only fitness score not significantly correlated to the product scores ($r \leq .166$). All fitness measures were positively correlated to product scores, with the exception of body composition and flexibility, which were negatively correlated to all three motor skill product scores (see Table 4). Product scores also were highly correlated to each other, ranging from r = .77–.78; however, variance inflation factors indicated that multicolinearity was not evident and that scores from each motor skill significantly added to the model.

Table 3. Descriptive data on motor skill and fitness measures by gender

	Men (n = 79)		Women (n = 109)	
	M	*SD*	*M*	*SD*
Body composition (%)	12.2	4.6	23.1	5.6
Grip strength (kg)	49.2	9.3	30.9	5.0
Leg press (kg)	110.0	24.8	73.9	17.8
Sit-and-reach (cm)	28.5	13.0	34.8	12.6
Curl-ups	42.8	9.6	35.1	9.2
12-min run (m)	2,454	460	2,004	430
Throw velocity (m/s)	30.8	4.6	20.0	4.0
Kick velocity (m/s)	24.6	2.7	18.6	2.3
Jump distance (m)	2.24	.31	1.61	.23

Note. M = mean; *SD* = standard deviation.

Total Sample Analyses

Regression analyses for all participants indicated the product scores accounted for 79% of the physical fitness variance; each skill accounted for a significant amount of variance to the model, $F(5, 182) = 141.6$, $p < .0001$. With the exception of throwing, gender was not a significant predictor in the model. Women generally demonstrated lower levels of physical fitness and product scores. However, the overall regression slopes of men and women for the product scores were approximately equal (see Figure 1), with the exception of women in throwing, which did not significantly add to the overall model fit.

The overall regression equation including all three motor skill scores and gender was: Factor 1 = -3.84 + Kick (.014) + Jump (.013) + Throw (.015) + Throw x Gender (-.015). Regression equations (see Table 5) for each individual motor skill among all participants indicated that kicking (58%), jumping (74%), and throwing (59%) each explained substantial amounts of the variance in physical fitness (Factor 1).

Gender-Specific Analyses

The regression equation for men indicated that the product scores for jumping and throwing explained 50% of the variance in the fitness factor, $F(2,76) = 27.15$, $p <$ .0001. Kicking was not significant in the model containing all three motor skills; however, when entered into the model alone, it became a significant predictor for the fitness factor, $F(1, 77) = 13.52$, $p = .0004$, accounting for 14% of the variance in overall fitness. Individually, jumping (45%) and throwing (24%) predicted higher amounts of variance in fitness for men.

For women, the product scores for jumping and kicking predicted 43% of the variance in the fitness factor, $F(2, 106) = 28.13$, $p < .0001$. Throwing was not a significant predictor in the model containing all three motor skills, yet when entered into the model alone, it became a significant predictor for the fitness factor, $F(1, 107) = 11.15$, $p = .0012$, explaining 9% of the variance in overall fitness. Individually, jumping (41%) and kicking (19%) predicted higher amounts of variance in fitness for women.

Table 4. Pearson's bivariate correlations among fitness measures (N = 188)

	Body composition	Grip	Leg press	Sit-and-reach	Curl-up	Run
Throw	-.56**	.74*	.67*	-.17*	.48**	.50**
Kick	-.60**	.68**	.63**	-.12	.49**	.49**
Jump	-.73**	.72**	.70**	-.08	.59**	.54**

*$p < .05$.
**$p < .01$.

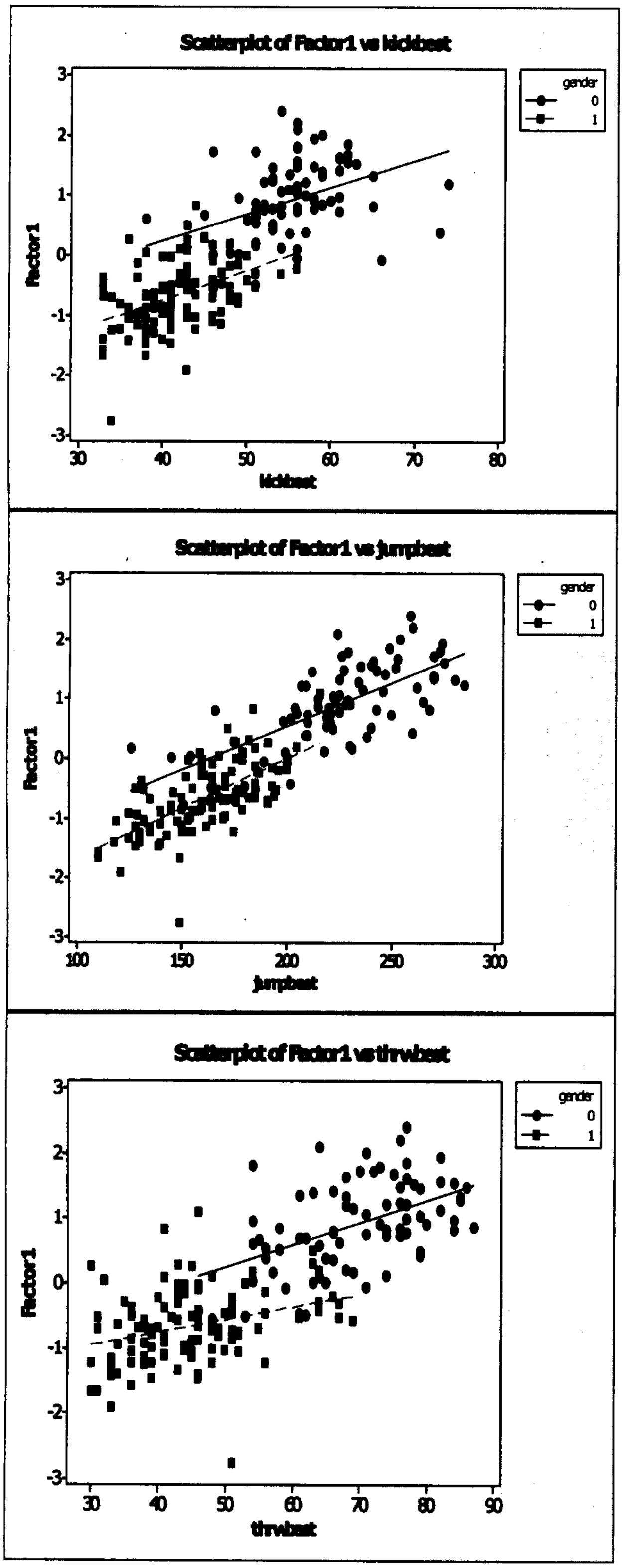

Figure 1. Distribution plots of men (circles) and women (squares) for (a) maximum kicking ball speed, (b) jumping distance, and (c) throwing ball speed; ordinate = construct of health-related fitness measures (Factor 1); abscissa = kicking and throwing speed measured in miles per hour; jumping measured in centimeters.

Discussion

Our results provided the strongest evidence to date on the relationship between motor skill competence and health-related aspects of physical fitness. The notion that performance in only three motor skills can account for 79% of the variance in physical fitness seems surprising when compared to previous results, although data from Espenschade (1940) and Beunen et al. (1988) indicated some moderate to high correlations between motor skill competence and certain fitness measures. When added to the limited existing literature, our data seem to provide a compelling argument that motor skill competence is highly related to physical fitness.

Overall, men tended to have higher overall fitness than women; however, the regression slopes for each individual motor skill plotted against the fitness factor indicated the slopes were similar, with the exception of women in throwing (see Figure 1). Thus, regardless of gender, motor skill product scores explained a significant amount of variance in the health-related fitness factor, which included measures of muscular strength (upper and lower extremities), trunk muscular endurance, and cardiorespiratory endurance. The nonsignificant relationship of throwing for women in the overall model indicated that the level of fitness in women was related to factors other than throwing. Overall, when comparing the regression equation and the data distribution plots for fitness and throwing in women, the data indicated that womens' fitness was higher than what was predicted from their throwing data.

Jumping explained the most variance out of the three motor skills overall and for both genders, but correlations among all fitness scores and jumping were between .54 and .73. These data support our argument that individuals who are skilled in jumping might participate in activities that promote not only leg strength, but also other aspects of fitness. Moderate to high correlations for throwing and kicking and fitness measures (r = .48-.74) also suggest that individuals who are highly skilled in these two areas also participate in activities that foster improvements in muscular strength, muscular endurance, cardiorespiratory endurance, and body composition in the fitness factor. Thus, ballistic FMS provides a window to understand the effects of developing motor skill competence on all aspects of health-related fitness. However, this importance may not be fully realized until adolescence or adulthood.

Emerging Relationship Between Motor Skill Competence and Health-Related Fitness

Does increased motor skill competence cause increased fitness? We believe the answer to this question depends on where in the lifespan an individual's motor skill competence and physical fitness are examined (Stodden et al., in press). For instance, acquiring motor skill competence in FMS such as throwing, kicking, and jumping in early childhood (2–5 years of age) promotes physical fitness, as time spent initially developing these skills promotes increased physical activity and neuromotor development. Acquiring higher levels of these skills demands more effective manipulation of an individual's entire body mass against gravity and higher strength and power outputs (Fleisig et al., 1999; Enoka, 2002). Additionally, the development of ballistic FMS involves multisegment movements, which places an increased demand on the neuromuscular system to generate and transfer energy optimally through the kinetic link system (i.e., optimizing control and coordination). Individuals must develop and also repeatedly produce adequate levels of muscular strength and coordination to effectively manipulate their body mass in a gravity-based environment, which promotes increased muscular endurance. In addition, these types of skills are generally associated with cardiorespiratory development activity, which are integral for many sports and games (e.g., soccer, basketball, softball, baseball, and free play).

As children move into adolescence and adulthood, we believe this relationship is more synergistic in nature. High levels of motor skill competence and increased physical fitness allow individuals to persist and succeed in activities that require greater levels of motor competency and provide more opportunities to further develop these skills. The strength of the relationship between motor skill competence and health-related physical fitness will not be as strong in childhood, but will strengthen over time through adolescence and adulthood. Data from our adult population, Espenschade (1940), Beunen et al. (1988) and Malina and Brouchard (1991), support this concept; however, these relationships need to be further examined in both younger and older populations.

Although we did not assess participant physical activity levels, we believe the relationship between physical activity and motor skill competence should also follow this pattern in adults. Demonstrating more skillful movement may result in participation in more varied physical activities, thus leading to greater amounts and higher intensities of activity (Wrotniak et al., 2006). Additionally, increased fitness levels increase the time spent in the activity (Blair et al., 1995; Blair et al., 1989; Young & Steinhardt, 1993). Individuals who demonstrate low-to-moderate skill levels might gravitate toward more repetitive, steady-state fitness activities (e.g., walking, jogging, or using cardiovascular equipment), while highly skilled individuals may participate in more diverse (e.g., sports and games) and repetitive fitness-oriented activities. Thus, high skilled individuals may increase their time spent in physical activity and persist in activities that maintain higher levels of muscular strength, power outputs, and muscular endurance.

If motor skill competence is foundational to promoting increased fitness and physical activity, then focusing on the development of motor skills should continue to be promoted. FMS development generally begins early in life, but Clark (2005) indicated that around age 7 there is a shift from this fundamental pattern period to a more context-specific period. Clark also indicated this context-specific period occurs within the same time frame as a qualitative shift to higher cognitive development, when the relationship between motor skill competence and physical fitness/activity increases. Children who attain a certain level of proficiency in FMS and continue to become skillful during middle childhood and adolescence have more options to participate and be successful in activities requiring adequate FMS as adults. These individuals will, correspondingly, demonstrate higher levels of health-related physical fitness and activity. Conversely, individuals who do not attain proficiency in FMS as children and adolescents will not participate in diverse activities as adults because they understand they are not as competent as their peers and, because they have fewer skill options and movement opportunities, will be less motivated to participate and enjoy activities.

A minimum level of motor skill competence necessary for promoting adequate fitness and activity has not been defined; however, this idea relates to Seefeldt's (1980) notion of a proficiency barrier. Seefeldt indicated there might be a critical threshold of motor skill competence, above which children will be active and successfully apply FMS competence to sports and games. If children do not reach this threshold, they will be less successful and ultimately drop out of physical activities at higher rates. The "proficiency barrier," which emerges in middle childhood and adolescents, will be more clearly defined in young adults.

References

American College of Sports Medicine. (2006). *ACSM's guidelines for exercise testing and prescription.* (7th ed.). Baltimore: Lippincott Williams & Wilkins.

Baechle, T. R., & Earle, R. W. (2000). *Essentials of strength training and conditioning,* (2nd ed.). Champaign, IL: Human Kinetics.

Beunen, G. P., Malina, R., Van't Hof, M., Simons, J., Ostyn, M., Renson, R., et al. (1988). *Adolescent growth and motor performance: A longitudinal study of Belgian boys.* Champaign, IL: Human Kinetics.

Blair, S. N., Kohl, H. W., III, Barlow, C. E., Paffenbarger, R. S., Jr., Gibbons, L. W., Macera, C. A. (1995). Changes in physical fitness and all-cause mortality. A prospective study of healthy and unhealthy men. *Journal of the American Medical Association, 273,* 1093–1098.

Brill, P. A., Macera, C. A., Davis, D. R., Blair, S. N., & Gordon, N. (2000). Muscular strength and physical function. *Medicine & Science in Sports & Exercise, 32,* 412–416.

Buchner, D. M., Beresford, S. A., Larson, E. B., LaCroix, A. Z., Wagner, E. H. (1992). *Annual Review of Public Health, 13,* 469–488.

Centers for Disease Control and Prevention (2000). *Healthy People 2010: Understanding and improving health.* Washington, DC: Government Printing Office.

Centers for Disease Control and Prevention. (2001). *The Surgeon General's call to action to prevent and decrease overweight and obesity.* Rockville, MD: U.S. Department of Health and Human Services.

Clark, J. E. (2005). From the beginning: A developmental perspective on movement and mobility. *Quest, 57,* 37–45.

Cooper, K. H. (1968). A means of assessing maximal oxygen uptake. *Journal of the American Medical Association, 203,* 201–204.

Enoka, R. M. (2002). *Neuromechanics of human movement* (3rd ed.) Champaign, IL: Human Kinetics.

Espenschade, A. (1940). Motor performance in adolescence. *Monographs of the Society for Research in Child Development, V* (1), Whole Serial No. 24.

Freedman, D. S., Dietz, W. H., Srinivasan, S. R., & Berenson, G. S. (1999). Relationship of childhood obesity to coronary heart disease risk factors in adulthood: The Bogalusa Heart Study. *Pediatrics, 103,* 1175–1182.

Fleisig, G. S., Barrentine, S. W., Zheng, N., Escamilla, R. F., & Andrews, J. R. (1999). Kinematic and kinetic comparison of baseball pitching among various levels of development. *Journal of Biomechanics, 32,* 1371–1375.

Jackson, A. S., & Pollack, M. L. (1985). Practical assessment of body composition. *Physician and Sports Medicine, 13,* 76–90.

Malina, R. M. (1996). Tracking of physical activity and physical fitness across the lifespan. *Research Quarterly for Exercise and Sport, 67*(Suppl. 1), 48–57.

Malina, R., & Bouchard, C. (1991). *Growth, maturation, and physical activity.* Champaign, IL: Human Kinetics.

McKenzie, T. L., Li, D., Derby, C., Webber, L., Luepker, R. V., & Cribb, P. (2003). Maintenance of effects of the CATCH physical education program: Results from the CATCH:ON study. *Health Education & Behavior, 30,* 447–462.

Okely, A., Booth, M. L., & Patterson, J. (2001). Relationship of cardiorespiratory endurance to fundamental movement skill proficiency among adolescents. *Pediatric Exercise Science, 13,* 380–391.

Sallis, J. F., McKenzie, T. L., Alcaraz, J. E., Kolody, B., Faucette, N., & Hovell, M. F. (1997). The effects of a 2-year physical education program (SPARK) on physical activity and fitness in elementary school students. *American Journal of Public Health, 87,* 1328–1334.

Seefeldt, V. (1980). Developmental motor patterns: Implications for elementary school physical education. In C. Nadeau, W. Holliwell, K. Newell, & G. Roberts (Eds.), *Psychology of motor behavior and sport* (pp. 314–323). Champaign, IL: Human Kinetics.

Stodden, D. F., Goodway, J., Langendorfer, S. J., Roberton, M. A., Rudisill, M. E., Garcia, C., et al. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest, 60,* 290–306.

Tammelin, T., Nayha, S., Hills, A. P., Jarvelin, M.-R. (2003). Adolescent participation in sports and adult physical activity. *American Journal of Preventive Medicine, 24,* 22–28.

Wrotniak, B. H., Epstein, L. H., Dorn, J. M., Jones, K. E., & Kondilis, V. A., (2006). The relationship between motor proficiency and physical activity in children. *Pediatrics, 118,* 1758–1765.

Young, D. R., & Steinhardt, M. A. (1993). The importance of physical fitness versus physical activity for coronary artery disease risk factors: A cross-sectional analysis. *Research Quarterly for Exercise and Sport, 64,* 377–384,

Authors' Notes

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