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MOVEMENT PROFICIENCY IN CHILDHOOD: IMPLICATIONS FOR PHYSICAL ACTIVITY AND YOUTH SPORT

GIBALNA SPRETNOST V OTROŠTVU: IMPLIKACIJE ZA TELESNO DEJAVNOST IN ŠPORT MLADIH

ABSTRACT

Development of voluntary control of movement begins in infancy and progresses into childhood as the child attains postural, locomotor and prehensile control. With the refinement of walking, control of locomotor and manipulative abilities improves so that a considerable amount of independent action is possible. These basic movement patterns are the foundation upon which other movements and combinations of movements are subsequently developed and refined. Movement is the substrate of physical activity, and there is increasing interest in relationships between proficiency in basic movement skills and habitual physical activity. Evidence indicates that motor skill instructional and physical activity interventions are associated with improvements in basic movement skills in children. By inference, improving the motor proficiency of young children has the potential to enhance levels of habitual physical activity. Motor coordination is also a predictor of physical activity during middle childhood.

The teaching of skills, rules and strategies is an objective of youth sport and talent development programs. Observations would suggest that this objective is generally achieved, but specific evidence for participants in youth sports is limited. Individual differences are considerable and are often influenced by the quality of coaching/instruction. Unfortunately, relatively more emphasis is given to the talented few in contrast to the majority of youth participants.

Key words: movement proficiency, childhood, physical education, motor learning

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IZVLEČEK

Razvoj hotenega obvladovanja gibanja se prične že v zgodnjem otroštvu in se nadaljuje v otroštvo, ko otrok že nadzoruje svojo držo, gibanje in oprijemanje. Ko postane hoja spretnejša, se izboljša tudi nadzor nad gibalnimi in manipulativnimi sposobnostmi, tako da lahko otrok izvaja veliko samostojnih gibalnih aktivnosti. Ti osnovni vzorci gibanja so podlaga, na kateri se pozneje razvijejo druga gibanja in kombinacije gibanj. Gibanje je osnova telesne dejavnosti, zato je vse večje zanimanje za odnose med dobrim obvladovanjem osnovnih gibalnih spretnosti in običajno telesno dejavnostjo. Dokazi kažejo, da je poučevanje učenja motoričnih spretnosti in usmerjanje telesne dejavnosti povezano z izboljšanjem osnovnih gibalnih spretnosti otrok. Iz tega sklepamo, da lahko izboljšanje motoričnih spretnosti majhnih otrok izboljša raven običajne telesne dejavnosti. Koordinacija gibanja je tudi eden od dejavnikov, ki napovedujejo telesno dejavnost v srednjem obdobju otroštva.

Poučevanje spretnosti, pravil in strategij je cilj športa mladih in programov za razvijanje talentov. Opažanja kažejo, da se ta cilj na splošno dosega, vendar pa je malo specifičnih dokazov za tiste, ki so aktivno vključeni v šport mladih. Razlike med posamezniki so velike in nanje pogosto vpliva kakovost treniranja/poučevanja. Žal pa se sorazmerno več pozornosti posveča nadarjenim posameznikom kot pa večini mladih udeležencev.

Ključne besede: gibalna spretnost, otroštvo, športna vzgoja, motorično učenje

INTRODUCTION

The development of proficiency in movement skills is a major development task of infancy and early childhood. Movement is also the substrate of physical activity, and there is increasing interest in relationships between proficiency in basic movement skills and habitual physical activity. Improving the motor proficiency of young children has the potential to enhance levels of habitual physical activity beyond the preschool years. Proficiency in movement skills is also central to sport, and the teaching and refinement of sport-related skills is an objective of youth sport and talent development programs. With the preceding as background, the objectives of this paper are twofold: first, to review basic concepts, age trends and correlates of motor development and physical activity in children; and second, to address implications of motor proficiency for physical activity and youth sport.

UNIVERSAL TASKS OF "GROWING UP"

"Growing up" is the universal business of children and adolescents. The path from infancy to adulthood involves three interacting processes: growth, maturation and development. The terms are often treated as synonymous, but represent three distinct processes in the daily lives of children and adolescents (Malina, Bouchard, & Bar-Or, 2004).

Growth refers to the increase in the size of the body as a whole and of its parts. As children grow, they increase in height and weight, in lean and fat tissues, in size of organs, and so on. Heart volume and mass follow a growth pattern like that for body weight, while the lungs and lung functions grow proportionally to height. Different parts of the body grow at different rates and different times, which results in changes in body proportions. The legs, for example, grow faster than the trunk during childhood; hence, the child becomes relatively longer-legged.

Maturation refers to progress towards the biologically mature state, which is an operational concept because the mature state varies with body system. All tissues, organs and systems eventually reach maturity though the definition of maturity varies for each. The process of biological maturation varies in tempo (rate) and timing (when specific maturational events occur). Timing and tempo also vary considerably among individuals. Studies of youth commonly focus on sexual and skeletal maturation and landmarks of the adolescent growth spurt in height.

Development refers to the acquisition of behavioral competence – the learning of appropriate behaviors expected by society. As children experience life at home, school, church, sports, recreation, and other community activities, they develop cognitively, socially, emotionally, morally, and so on. They are learning to behave in a culturally appropriate manner.

Growth and maturation are biological processes, while development involves several behavioral domains. The three processes occur simultaneously and interact with the environments in which children and youth are reared – the human or social, the man-made, and the natural environments. Specific environments vary in their influence on these processes. Effects of the nutritional environment are rather obvious, whereas other may be more subtle. The demands of sport at a young age, for example, are superimposed upon those associated with normal growth, maturation and development. A mismatch between demands of a sport and those of normal growth, maturation and development may be a source of stress for some young athletes and may precipitate stressful interactions with coaches and parents. Those working with children and adolescents need to be aware of these interactions. How a youngster is coping with his/her

sexual maturation or adolescent growth spurt, for example, may influence his/her behaviors, including sport-related behaviors and performance.

MOTOR BEHAVIOR

The development and refinement of movement patterns and skills straddles the biological and behavioral domains. Motor development is manifest in a variety of movement behaviors which are physically performed by children. *Movement is the substrate of physical activity,* "…any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen, Powell, & Christenson 1985, p. 126). Although commonly viewed in the context of health-related benefits associated with energy expenditure, mechanical forces and physical fitness, it must be emphasized that *physical activity is a behavior,* or more appropriately a complex set of movement behaviors that has associated meanings for the individual and that is influenced by many environmental factors.

The physical education and sport sciences tend to focus on the development of movement proficiency and physical activity. What is often overlooked is the important role of movement per se and movement proficiency of young children as a source of enjoyment and as a medium for learning and exploration, social interactions (siblings, peers, and parents) and environmental interactions (indoor and outdoor, man-made and natural).

An issue that needs further exploration is the meaning of movement for children. What meanings or values do school age children attach to movements per se and to movement skills and physical activity? Specific data are lacking, but inferences from studies of motivation for sport suggest that children perceive movement as fun or enjoyment, and as a major venue for social interactions with peers and friends. The meaning of fun or enjoyment, however, varies with context – play, informal games, physical education, sport, training, etc. Context, in turn, varies with age, and sport emerges as a primary medium for movement and physical activity. It is imperative that teachers and coaches be aware of the influence of their demeanor, behavior and attitude on children's perceptions of movement and physical activity.

The preceding can be extended to physical activity in general. The term physical activity has different meanings to those in the biomedical and behavioral sciences and also to the individuals who are subjects in many of their surveys. What meanings do children and youth attach to physical activity? A small sample of U.S, youth 11-14 years of age was asked to complete a single question: "What does the term 'physical activity' mean to you?" The distribution of descriptors used for physical activity did not vary with school grade or ethnicity. The most commonly reported descriptor for physical activity in both sexes was sport(s). More girls than boys described physical activity as "moving/doing something" and "staying/getting in shape". Though relatively few, more girls than boys also indicated a contrasting descriptor, i.e., not being lazy or inactive (Malina, 2008). The observations should be viewed as preliminary and need to be extended to other samples and ages.

MOTOR COMPETENCE

Development of voluntary control of movement begins in infancy and progresses into childhood as the child attains postural, locomotor and prehensile control. With the refinement of walking,

control of other locomotor and manipulative abilities improves so that a considerable amount of independent action is possible. These basic movement patterns are the foundation upon which other movements and combinations of movements are subsequently developed and refined.

Motor activities are often described in terms of patterns – the basic elements of specific movement behaviors, e.g., walking pattern, running pattern, jumping pattern, and so on. During the preschool years and extending through childhood, children develop competence in a variety of basic or fundamental movement patterns. These are the foundation upon which other skills and sport-specific skills are built. Movement patterns can be arbitrarily labeled as locomotor in which the body is moved through space – walking, running, hopping, skipping, galloping, jumping; non-locomotor in which specific parts of the body are moved – pushing, pulling, curling, twisting; and manipulative in which objects are projected and received – throwing, catching, kicking, striking, dribbling; and combinations thereof. Movement patterns occur in various combinations, including more specific movements as in manual dexterity.

Boys tend to develop the movement patterns of overhand throwing and kicking earlier than girls, whereas girls tend to develop the patterns of hopping and skipping earlier than boys. Other movement patterns (running, jumping, catching and striking) show similarity between boys and girls (Seefeldt & Haubenstricker, 1982). Variation in progress through the sequence of changes for each movement pattern is considerable among individuals and there is overlap between boys and girls.

The concept of patterns is general and focuses on the specific elements that comprise a movement pattern, e.g., arm, trunk and leg actions in an overhand throw, or the preparatory, take-off, flight and landing phases of a standing long jump. Presence of all elements of a mature movement pattern does not necessarily imply skillful performance. All children eventually learn to run, jump, throw, skip, hop, and so on; however, all do not perform these movements with the same degree of skill, which implies precision, accuracy and economy in the performance or execution of specific movement tasks. The term skill often has a different meaning applied to specific demands of a sport, e.g., "…skill refers to a player's ability to select, organize, and execute an action, appropriate to a given situation in an effective, consistent and efficient manner" (Williams, Horn & Hodges, 2003, p. 198). In this context, skill is different from technique, which is more similar to a movement pattern.

The transition from basic movement patterns to more complex skills depends upon individual differences in neuromuscular maturation (which has a significant genotypic component), earlier experiences and opportunities for new movement experiences, and the quality of early instruction and practice. Motor competence is thus the product of the interactions between the growing, maturing and developing child and the environments within which he/she is reared. These in turn influence the interactions between the child and his/her environments at home (family), day care and school (peers, friends), and also influence the emergence of the child's perception of these environments as they relate to his/her motor characteristics.

MOTOR PERFORMANCE

The development of proficiency in basic movement skills is accompanied by improved levels of performance, the products of which can be quantified, i.e., outcomes of the performance of specific tasks done under standardized conditions. These include, for example, the distance or

height jumped (power), the distance a ball is thrown (power and coordination), the time elapsed in completing a 30-meter dash (speed) or a shuttle run (speed and agility), the number of sit-ups performed in 20 seconds (abdominal strength), the force expressed against a fixed resistance (strength), and so on.

Performances on standardized tasks improve with age during childhood. Boys perform, on average, better than girls, but there is considerable overlap between the sexes during early and middle childhood. With the onset of adolescence, performances of boys accelerate, while those of girls improve to a lesser extent to about 13-14 years of age and then level-off or improve only slightly (Malina et al., 2004).

Performance during adolescence is influenced in part by individual differences in the timing of the adolescent growth spurt. Performances of boys in a variety of tasks show well-defined adolescent spurts. Measures of static strength (grip, arm pull), power (vertical jump), and functional strength (flexed arm hang) show peak gains, on average, after the age at peak height velocity (PHV). On the other hand, data suggest that measures of speed and agility (shuttle run), speed of arm movement (plate tapping), and lower back flexibility (sit and reach) show their peak gains before PHV (Beunen et al., 1988). The trends for measures of strength and power are similar in timing to those for body mass and muscle mass, both of which experience their maximum growth after PHV. The earlier adolescent spurts for running speed and lower back flexibility may be related to earlier growth of the lower extremities relative to the trunk. Height is comprised of the legs, trunk, neck and head, and the legs experience maximum growth first. Thus, boys have relatively longer legs for their heights early in the adolescent spurt and this may influence running speed and lower trunk flexibility (Malina et al., 2004).

Data relating performances of girls to the adolescent spurt are not extensive. Like boys, girls show an adolescent spurt in static strength of the arm and power (vertical jump) after PHV. The magnitude of the growth spurt in arm strength is only about one-half of the maximum gain in boys. In contrast, presently available data for flexibility and speed tasks contrast the trends for boys in that both show maximum gains after maximum growth in height of girls (Heras Yague & de la Fuente, 1998; Malina et al., 2004). When performances of girls are related to the time before and after menarche, there are no consistent trends (Espenschade, 1940). Menarche, however, is a late maturational event which occurs after PHV when major gains in growth and performance have already occurred. The attainment of menarche also has special associated meanings which vary among cultures and which may influence perceptions of performance and physical activity.

PHYSICAL ACTIVITY

From the perspective of public health, physical activity is a behavior with important implications for health promotion and disease prevention. The public health objective is to develop a physically active lifestyle among youth which will result in improved health status during childhood and adolescence, and which will persist into and through adulthood. Health- and physical fitness-related benefits of regular physical activity among youth are reasonably well documented (Strong et al., 2005; Physical Activity Guidelines Advisory Committee, 2008). Physical activity also tracks moderately well from adolescence into adulthood and through adulthood, while the persistence of health-related benefits of physical activity from youth into adulthood is less well-established

(Malina, 2001a, 2001b, 2001c). The focus on health promotion and disease prevention seemingly overlooks physical activity as a medium for learning, enjoyment and social interactions in children and youth. The two objectives, however, are not mutually exclusive.

The public health model is largely biomedical. Focus has been historically on physical activity and fitness for cardiovascular health. More recently, focus has shifted to metabolic health which has been driven by the worldwide obesity epidemic and the consequences of excess adiposity and physical inactivity for several metabolic and cardiovascular morbidities. The public health model emphasizes the specific intensity and duration of physical activity to bring about potential health benefits (moderate-to-vigorous physical activity), the energy expenditure (weight regulation, obesity prevention) and mechanical force generation (skeletal health) associated with regular physical activity, and health-related physical fitness benefits of regular activity (cardiovascular endurance, musculoskeletal).

The latter is reflected is the general assumption that habitual level of physical activity is associated with physical fitness among youth (Malina, 1994, 1995, 1997). More recently, there is increasing interest in the relationship between movement proficiency (skill) and physical activity among preschool and school age children and youth. Historically, skill and activity have been the domains of school physical education. There is, moreover, an emerging trend to equate physical education with physical activity. Although physical activity is the primary medium of physical education, its educational objectives cannot and should not be overlooked.

Transportation of children to school (walking in contrast to being driven), public spaces for physical activity and physical education are often the major contexts of physical activity in the public health literature. Other important contexts of physical activity for youth – play, sport, recess, etc., often receive less attention. Little mention is also made of the enjoyment of physical activity. An expert panel convened by the Divisions of Nutrition and Physical Activity and Adolescent and School Health of the Centers for Disease Control and Prevention recommended that "school-age youth should participate every day in 60 minutes or more of moderate to vigorous physical activity that is *enjoyable* and *developmentally appropriate*" (Strong et al., 2005, p. 736).

CHANGES IN ENERGY EXPENDITURE AND PHYSICAL ACTIVITY AMONG YOUTH

Given the trend towards physically inactive lifestyles and increased prevalence of overweight and obesity in many populations, there is considerable interest in monitoring energy expenditure and physical activity among children and adolescents. Energy expenditure is a physiological measure, whereas physical activity is a behavior. Both are affected by physical growth and maturation and behavioral development as well as their interactions. Total energy expenditure (TEE, kcal/day) can be partitioned into its two major fractions: resting (REE) and activity (AEE). TEE increases from early childhood through adolescence. It is influenced by growth in body size and mass, specifically fat-free mass. Per unit body mass, however, TEE (kcal/kg/day) declines systematically with age and is greater in boys than in girls, reflecting the larger muscle mass of males.

AEE is the more variable fraction of TEE but is difficult to measure. The Physical Activity Level (PAL), the ratio of total energy expenditure (TEE) to basal metabolic rate (BMR), is commonly used as an approximation of activity-related energy expenditure over 24 hours (Food and

Agriculture Organization, 2004). PAL based on measures of doubly labeled water increases, on average, from early childhood into adolescence and sex differences are negligible until adolescence (Black, Coward, Cole, & Prentice, 1996; Torun et al., 1996; Brooks, Butte, Rand, Flatt, & Caballero, 2004).

In contrast to measures of energy expenditure, studies of physical activity have historically been based on parental-report and observational data among young children and questionnaires among school-age children and adolescents. On average, level of physical activity tends to gradually increase during childhood, reaches a peak between 12-14 years, and subsequently declines. Boys are, on average, more active than girls, though the sex difference is attenuated when maturity status is controlled in adolescence (Thompson, Baxter-Jones, Mirwald, & Bailey, 2003). However, age trends vary among studies and with measurement instrument and context of activity.

More recent surveys of physical activity are based on accelerometry and often focus on epochs of moderate-to-vigorous physical activity (MVPA), which is the intensity of activity that is most often associated with health benefits (Strong et al., 2005). Observations derived from 4-7 days of accelerometry in a nationally representative sample of U.S. youth indicate a decline in MVPA from 9 through 15 years of age in both sexes, higher levels of MVPA in boys than in girls, and higher levels of MVPA on weekdays compared to weekend days in both sexes (Nader , Bradley, Houts, McRitchie, & O'Brien et al., 2008). Boys exceed the recommended 60 minutes of MVPA at all ages except 15 years when the mean for weekdays is ~60 minutes. Girls exceed the recommendation from 9 to 13 years when levels of MVPA fall below the recommendation.

Systematic reviews (Sallis, Prochaska, & Taylor, 2000; Van der Horst, Paw, Twisk, & van Mechelen, 2007) indicate a variety of factors which influence physical activity among children and adolescents. The reviews, however, define childhood too broadly, 3-12 years. At the younger ages, children are still developing basic movement skills, while at the upper ages many girls and some boys are already pubertal. Except for the BMI, other potential biological correlates of activity are not considered. As noted, inter-individual variation in biological maturity status is an important correlate of activity among adolescents (Sherar, Cumming, Eisenmann, Baxter-Jones, & Malina, 2010). Twin and family studies show familial aggregation of physical activity-related traits suggesting an important influence of genetic factors (Bouchard, Malina, & Perusse, 1997; Teran-Garcia, Rankinen, & Bouchard, 2008). Interestingly, motor proficiency and level of physical fitness have not been systematically evaluated among correlates of physical activity.

Among young children 3-8 years, sex (boys are more active than girls), parental physical activity (children with active parents are more likely to be active), parents who are active with their children, and time spent outdoors are important predictors of activity. Unfortunately, data on the potential role of siblings, playmates and/or peers; day care or preschool attendance; and caregivers and/or teachers as an influence on physical activity in young children are lacking.

In addition to sex (males more active than females), preference for activity, intention to be active, previous physical activity, and access to community facilities and sports are important correlates of activity from later childhood through adolescence. Parental, sibling and peer support is a positive correlate among adolescents 13-18 years, whereas increased age, barriers to activity, and sedentary behavior after school and weekends are negative correlates of activity.

MOVEMENT PROFICIENCY AND PHYSICAL ACTIVITY

Interest in relationships between motor proficiency and physical activity has increased recently (Stodden et al., 2008). Several studies spanning early childhood to adolescence are subsequently summarized. Among three year old children, for example, the percentage of time devoted to sedentary, light, MVPA and vigorous physical activity (VPA) measured with accelerometry was not significantly related to locomotor and object control skills. Highest correlations ranged from 0.16 to 0.22 between object control skill and a total skill score and MVPA and VPA. On the other hand, among four year old children, correlations with MVPA and VPA, respectively, were higher and significant for locomotor skill (0.31, 0.37), object control skill (0.26, 0.32) and the total skill score (0.33 to 0.41) (Williams et al., 2008). In another study based on accelerometry among 3.6 to 5.0 year old children, correlations between a movement skill score were 0.10 for total activity, 0.02 for light physical activity and 0.18 for MVPA (Fisher et al., 2005). However, at the extremes of the movement skill scores (quartiles), children more proficient in movement skills (highest quartile) spent proportionally more time in MVPA compared to children with movement skills in the other quartiles.

Although not focused on motor proficiency and physical activity per se, a longitudinal study of children from 6 to 9 years of age highlighted the importance of early motor coordination and subsequent physical activity (Lopes, Rodrigues, Maia, & Malina, 2011). Children in the highest tertile of motor coordination at 6 years of age had a higher level of physical activity which changed negligibly from 6 to 9 years, whereas children in the middle and lowest tertiles of coordination at 6 years had a lower level of activity which declined linearly with age from 6 to 9 years of age. Thus, it appeared that better motor coordination at 6 years attenuated the decline in activity, whereas less developed motor coordination at 6 years amplified the decline in physical activity from 6 to 9 years. Better motor coordination at 6 years was also associated with attenuated accumulation of subcutaneous fatness between 6 and 10 years of age (Lopes, Maia, Rodrigues, & Malina, 2012).

Among children 8-10 years of age, a motor proficiency scores was negatively correlated with percentage of accelerometry time spent in sedentary pursuits (-0.31) and positively correlated with time spent in MPVA (0.30); corresponding correlations were positive but lower for light activity (0.22) and VPA (0.18). In contrast to the overall movement proficiency score, correlations for specific items and physical activity were higher and reached moderate levels. Correlations for running speed and agility were 0.36 for MVPA, 0.25 for VPA and 0.39 for accelerometer counts per minute, while the corresponding correlations for the standing long jump were, respectively, 0.40, 0.30 and 0.39. In addition, visual motor skill in a tracing task was positively correlated the percentage of time spent in MVPA, 0.25 (Wrotniak, Epstein, Dorn, Jones, & Kindilis, 2006). As in the study of younger children (Fisher et al., 2005), the association between physical activity (% time in MVPA, counts per minute) and movement proficiency was more apparent at the highest quartile of the movement skill scores. Results of regression analyses, controlling for sex, socioeconomic status, number of TVs in the home, number of children, child and parent BMIs, and child self-perception of physical activity, children more proficient in movement skills (highest quartile) spent proportionally more tithe movement proficiency score accounted for only 9% of the variance in accelerometer measured physical activity (Wrotniak et al., 2006). Although this is a small percentage of variance accounted for by physical activity, the results highlight the relationship between movement proficiency and physical activity, and also the many factors potentially associated with the observed relationship.

Similar results have been observed in adolescents. Physical activity (hours per week) was moderately correlated with motor coordination (0.48) and basic motor skills (0.51) in a small sample of 12 year old boys (Schmücker, Rigauer, Hinrichs, & Trawinski, 1993). Among boys and girls in grade 8 (mean age 13.3 years) and 10 (mean age 15.3 years), a movement proficiency score based on six movement patterns (run, vertical jump, catch, overhand throw, forehand strike, kick) was related to time spent in organized physical activity (Okely, Booth, & Patterson, 2001). There was a linear trend from lowest to highest quintile of movement proficiency with increasing time in organized physical activity; the trend was more clearly defined in girls than in boys. In contrast, there was little relationship between time in non-organized physical activity and movement proficiency. Although the composite score for several fundamental movement skills was related to organized physical activity, the variance explained by motor proficiency was only 3%; the corresponding estimate for time in non-organized activity was <1% (Okely et al., 2001).

The preceding studies span early childhood through adolescence and indicate a positive relationship between movement proficiency and physical activity – more skilled children and youth tend to be more active. Nevertheless, the variance in physical activity accounted for by motor skill is relatively small. By inference, there is a need to include other factors which may influence motor proficiency and physical activity in the analyses, e.g., quality of pre-school programs and physical education, peer interactions, biological maturation, more specific indicators of body composition instead of the BMI, among others.

PHYSICAL ACTIVITY AND PHYSICAL FITNESS

The observed correlations between motor proficiency and physical activity overlap those between physical activity and physical fitness, and perhaps are slightly higher. Among children 6-9 years, for example, correlations between cardiorespiratory fitness (distance run) and several indicators of physical activity (parental and teacher questionnaires) ranged from -0.22 to +0.24 (Pate, Dowda, & Ross, 1990), while among children about 9-10 years of age, correlations between indicators of health-related physical fitness (one mile run, pull-ups, sit-ups, sit and reach, skinfold thickness) and physical activity (accelerometry, parental report, child self-report) ranged from -0.16 to +0.24 (Sallis et al., 1993). After controlling for age and sex, physical activity accounted for only 3% to 11% of the variance in health-related physical fitness.

Similar relationships have been noted with accelerometry. Among children 6-7 years of age, the correlations between time spent sedentary and in light, moderate, moderate-to-vigorous and vigorous physical activity and aerobic fitness (peak VO_2) ranged from 0.00 (sedentary) to 0.28 (moderate activity) in boys and -0.06 (sedentary) to 0.14 (moderate activity) in girls (Dencker, Bugge, Hermansen & Andersen, 2010). Overall, total accelerometer-based physical activity accounted for 3% of the variance in aerobic fitness in boys and none of the variance in girls. However, the percentage of time in moderate physical activity accounted for 8% and 2% of the variance in aerobic fitness in boys and girls, respectively.

Traditional indicators of physical activity and aerobic fitness (Schmücker et al., 1993; Aaron et al., 1993) and other components of health-related fitness (Katzmarzyk, Malina, Song, & Bouchard, 1998) are also related among adolescents. More recent observations noted significant but lower relationships between MVPA (accelerometry) and aerobic fitness in adolescent boys and girls 13-16 years, but correlations varied with urban and rural residence (Machado et al., 2012).

Relationship between physical activity and indicators of health-related physical fitness, though statistically significant, are not strong among children and adolescents. This reflects in part the different measures of physical activity and health-related physical fitness. Nevertheless, most of the variance in fitness is not accounted for by physical activity, which implies that factors other than activity influence the fitness of youth. As in the discussion of the relationship between motor proficiency and activity, there is a need to include other factors in analyses of physical activity and physical fitness. Given available data, it would also make sense to include indicators of motor proficiency, physical activity and physical fitness in future studies.

IMPLICATIONS FOR YOUTH SPORT

Sport is a fact of life for youth throughout the world and is also a major context for physical activity. By inference, sport is valued by society. However, more emphasis is placed upon and attention devoted to the identification and development of the talented minority in contrast to the overwhelming majority of youth who participate in sport (Malina, 2009).

Proficiency in general movement and sport-specific skills is basic to participation in sport. The teaching of skills, rules and strategies is often indicated as an objective of youth sport and talent development programs. This is consistent with stated reasons of youth for participation in sport. Data for youth 10-18 years of age in the United States (Ewing & Seefeldt, 1989), Mexico (Siegel, Peña Reyes, Cárdenas Barahona, & Malina, 2009), Botswana (Malete, 2004) and Portugal (Coelho e Silva, & Malina, 2009) indicate improvement of skills and learning new skills among primary reasons for participation in sport. Although corresponding data on motivations younger children are not available, many parents enroll children in organized youth sports programs at 5 or 6 years of age and perhaps earlier in some sports. At these ages, movement patterns are in the process of developing. It is imperative that teachers and coaches of young children entering a sport have an understanding of the physical growth and maturation and behavioral development of children in general and the development of specific movement patterns and sequences. More importantly, teachers and coaches of young children entering a sport should have knowledge of how to provide an environment in which developing movement patterns can be nurtured and improved.

Evidence indicates that planned instructional programs can enhance the development of basic movement patterns in children 4 and 5 years of age and more complex skills in older children. Guided instruction by specialists, trained parents or qualified coaches, appropriate motor task sequences, adequate time for practice, and constructive feedback and guidance are essential components of successful instructional programs at young ages (Haubenstricker & Seefeldt, 1986). More recent studies have applied dynamical systems concepts which highlight variation in constraints on specific movements. For example, a basic motor skill intervention program with 4 year old children resulted in improvements in specific components of the overhand throwing pattern – trunk rotation, elbow-humeral flexion, stride, and so on (Goodway, Quinones-Padovani, Segarra-Roman, Robinson, & Hugo, 2005). Boys attained a more advanced throwing profile than girls, suggesting perhaps sex differences in response to the motor intervention program. Features of the overhand throwing pattern, e.g., linear and angular velocities of the trunk, trunk tilt and stride characteristics, and ball velocity also varied by developmental level and were identified as "important kinematic constraints" (Stodden, Langendorfer, Fleisig, & Andrews, 2006a, Stodden, Langendorfer, Fleisig, & Andrews, 2006b). Results of the more recent studies complement earlier

studies in showing that systematic instruction and practice can favorably influence components of the overhand throwing pattern in young children. Advances in technology permit better definition of "constraints" which are modified by the instruction and practice.

Overall, evidence indicates a beneficial role for instruction and practice on skill acquisition in early childhood and the transition into middle childhood. More data are necessary and other variables need consideration, especially those related to environmental constraints. The role of parental, sibling or peer modeling in the development of motor proficiency merits consideration given the amount of time that these individuals spend with each other in a variety of settings and activities. This can also be extended to individual differences among teachers and coaches to whom children are exposed at relatively young ages.

Although parents enroll youth in sport programs at young ages and youth indicate skill improvement as a reason for participation in sport, youth also discontinue sport for reasons related to skill. For example, United States (Ewing & Seefeldt, 1989) and Mexican (Siegel et al., 2009) youth ranked coaches' ability to teach among the ten major reasons for discontinuing participation in sport – "coach was a poor teacher". Other issues related to coaches include lack of playing time and lack of progress in skills, both of which are probably related to sport-specific movement proficiency.

The issue of discontinuation of participation in sport, colloquially labeled as "dropping-out", is of interest seeing the value youth place on sport per se and sport as a major context of physical activity. Motives for discontinuation of participation in sport can be classified broadly into two categories. The first is related the individual and includes personal and inter-personal factors: lack of enjoyment ("sport was no longer fun"), parental and peer pressures, unrealistic expectations, changing interests, and changing demands of home, school, social activities and perhaps other sports. The latter are part of normal behavioral development. The second category is sport-related: injury; the sport environment – lack of playing time, lack of success, lack of progress in skills, intensive competition; and coach behaviors - poor instruction and coaching, player treatment ("coach played favorites"), among others. Of course, as port becomes more elite, it becomes more selective, which begs the question, "Does 'cutting' or selective exclusion represent premature dropping-out? What is the impact of being cut from a team, which essentially translates into "you are not good enough, on the youngster and perhaps his family? To my knowledge, this has not been systematically studied.

The study of expert performance, a popular topic in sport psychology, is relevant to youth sport. Expert performance is viewed as dependent upon "… acquired characteristics resulting from extended deliberate practice (Ericsson, Krampe, & Tesch-Römer, 1993, p 363). The concept of expertise places primary emphasis on quality of instruction and practice, and the ability of the individual to organize the specific knowledge. The process involves explicit teaching of specific skills, supervised practice and corrections as needed. Frequent repetition under the watchful eye of an expert coach is a feature of deliberate practice. The accumulation of experience is ultimately represented in the motor and cognitive neural substrates. Biological variables and bio-behavioral interactions were not explicitly considered in early discussions, although the potential role of biological factors, specifically genetic, is recognized (Ericsson, 2003).

Observational and anecdotal data suggest that at least 10 years of experience and 10,000 hours of deliberate practice are necessary for international success in music, chess and other disciplines,

and also sport (Starkes, & Ericsson, 2003). The evidence for sport is not consistent, however, with the proposed time scales (Abernethy, Farrow, & Berry, 2003; Fraser-Thomas, & Côté, 2006).

The "10 year" or "10,000 hour" rule has made its way into the popular press and coaching literature, and has probably contributed to early specialization in sport. Parents and coaches may view an early start in a single sport as essential, often to the exclusion of other childhood activities and sports. Information on the effectiveness of early sport specialization and long term success of young athletes is quite limited and not consistent with the "10 year" or "10,000 hour" rule. Studies tend to focus exclusively on the successful, but early success is no guarantee of later success in elite sport. Moreover, limiting experiences to a single sport year round may not be the best path to elite status (Malina, 2010).

In contrast to the deliberate practice implicit in the preceding, the issue of informal play, games and sports merits consideration. Informal play, games and sports do not involved adult supervision and specific instruction. Rather, informal games and sport involve trial and error, experimentation and repetition; exposure to different situations, skills and rules; and variable settings associated with conditions (street, playground, beach, etc.), numbers of youth available and seasons of the year. Movement skills, including sport-related skills, developed under such conditions are apparently learned without awareness or explicit knowledge of the skills. This represents informal or implicit learning (Malina, 2010).

One can also inquire whether there is a critical level of movement proficiency that facilitates participation in physical activity and sport among children and adolescents. A concept of a "proficiency barrier" has been proposed by Seefeldt (1980) who postulated a critical level of competence in motor skills above which a youngster is likely to be active and to use the skills in games and sports, and below which a youngster is not likely to be active and not involved in games and sports. Such a barrier may exist for those children who have not had opportunities for free play, informal games and sports, and/or appropriate instruction and practice.

If a "proficiency barrier" exists, three questions (and probably others) come to mind. First, when does the barrier first become apparent? A likely period is middle childhood when fundamental movement skills should be developed and when involvement in organized sports ordinarily begins for most children. Adolescence may be another period. Differential timing of sexual maturation and the growth spurt, and associated biobehavioral interactions may influence interests in sport and activity and/or perhaps movement proficiency. Second, can the barrier be remedied with appropriate intervention? As noted, specific motor skill instructional interventions are associated with improvements in basic movement skills of children. And third, what are the correlates of the proficiency barrier? This is a complex issue which probably relates to intra-individual, familial and environmental factors.

In closing, teachers and coaches are central to the development of movement proficiency, physical activity and fitness of children and youth. Understanding the physical growth and biological maturation and behavioral development of youth is essential to effectively meet the developmental needs of youngsters in general and youth athletes in particular.

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