BIOMECHANICS OF SPORT PATTERNS AND MOTOR DEVELOPMENT

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INTRODUCTION

As fundamental movement patterns are refined through practice and instruction, the quality and quantity of performance improve, and the patterns are integrated into more complex motor activities, such as those in games and sports. Developmental biomechanics is the study of movement patterns and how they change due to interaction between human beings and their environment. The majority of research concerning motor development has been focused upon children. These studies have been descriptive in nature, with limited process-oriented experimentation.

The stage theory is the primary analytical model for the study of developmental movement patterns. (Stage theory models were advanced by Wild, 1938; Seefeld et al., 1982 Substages were introduced by Roberton et al., 1976; Adrian, Toole, Randall proposed that movement patterns be considered as a continuum rather than as discrete stages. In Adrian & Cooper, 1989.) There are representative movement patterns of children and assessment of developmental stages. The Biomechanical approach is to identify the range of motion, planes of motion and axis of motion. If the goal is maximum speed or distance, then the level of maturation of the movement pattern is evaluated by the amount and complexity of space, temporal aspects, sequencing of the body parts and the speed of the parts utilised. The maturation, the highest stage of development involves the fastest and most effective timing of the body parts.

Motor development is one part of the study of human development. The growth and development is manifested in both physical structure and motor performance. These factors interact and are determined genetically as well as socially, culturally and economically.

The aim of this lecture was to discuss the biomechanical requirements during the motor pattern development process and to display the motor performance scores, referential values of motor development in different stages of different groups categorised by gender and age expressed in percentiles, based on cross-sectional investigation of Hungarian youth (Eiben, Barabas, Pantó, 1991; Bretz and Kaske, 1994).

The motor performance development appears in the most important factors of strength (explosive strength or power), muscular endurance, running speed, balance, flexibility and aerobic performance.

METHODS

A variety of, motor tests can be used to document levels of motor development. Strength is included with motor performance because it is an essential component of motor performance and because motor performance tasks are often used as indicators of muscular strength involvement.

Tests of strength and motor performance obviously overlap. Performance tests incorporating fundamental motor skills require some combination of strength and motor control in jumping, throwing and running tasks. The motor performance tests used to assess motor development were: hand grip strength, standing broad jump, medicine ball push, 30 sec sit-ups, 60 m dash and 12 min. endurance run

Measurable neuromuscular modifications characterise the growing process of children and adolescents. Characteristics and performances of postural control are affected by the alterations of sensory and muscular subsystems. The stability of equilibrium in an upright posture, postural sway modifications accompany the normal aging process. In the posturographic investigation the displacements of centre of pressure as well as the vertical projection of centre of mass, the time functions on anteroposterior and mediolateral directions and Fourier spectra have been recorded in traditional and/or sharpened Romberg positions, with open and closed eyes. Special track tasks with voluntary moving of centre of pressure have been solved by the subjects with audio-visual feedback. There are data of different age-groups to lay the foundation of mass investigations in the schools as well as special equilibrium measurements in sports requiring high accuracy equilibrium. (Subjects of nursery school, primary school, secondary school and university student took part in the investigation.)

The measuring equipment included an "Adam type" force platform, Psycho 8 differential measurement device, ADDON microcomputer and personal computer. The measuring programs were: stabilometry in a traditional Romberg position, movement co-ordination test in connection with the voluntary displacement of centre of mass controlled by an audio-visual biofeedback system and dispersion display of sampled data describing the moving of the centre of mass, completed with displacement -time diagram and Fourier spectra.

DISCUSSION OF GROWTH AND DEVELOPMENT

Strength and motor performance generally improve with age during childhood and adolescence, but the pattern of improvement is not uniform for all tasks. There are fundamental differences between performances of boys and those of girls in each age group and each test. In fact, girls seem to start out in life with certain advantages over boys. Until the age of five months, girls lead in the ability to perform the movements that are pre-requisite for creeping, sitting and walking, and even after that age they generally remain ahead in acquiring skills that demand fine movements and motor co-ordination. They usually learn to control their bladders somewhat earlier. In theory, this feminine advantage should result from a more rapid development of the brain, paralleling the faster sceletal development of girls. It is at the beginning of adolescence the developmental differences between girls and boys become most evident. Girls generally reach puberty ahead of boys: they embark on the adolescent growth spurt at an average age of 10.5 as against 12.5 for boys. Though the growth spurt begins earlier in girls, it is during this period that boys outstrip them in development. The boy's spurt is markedly greater. In both sexes, strength increases although the increase is proportionally much greater in boys than in girls. The boys' performances are higher and better than those of girls The differences among the girls' age groups decreased as their age advanced and finally stabilised at a relatively low value and a relatively early age, at the age of 12-13. This phenomenon appears in every performance test.

The age - and sex-associated trends in strength and motor performance derived from cross-sectional (Eiben, Barabas & Pantó, 1991) and longitudinal or mixed-longitudinal studies (Beunen & Malina, 1988) are consistent.

The curves of systematic growth reported by Scammon (Scarnmon, 1930) provide a good starting point for discussion. Upon analysis of size of various parts and organs of the body., Scammon proposed that the growth of different tissues and system could be summarised in four patterns (or curves) of growth. Although such general curves have limitations, they provide a convenient means of summarising the differential nature of postnatal growth. The data shown in the figure are relative size attained by each structure is expressed as a percentage of the total gain between birth and 20 years

- The **general** or body curve describes the body as a whole and of most of its parts - the growth pattern of stature, weight and most external dimension of the body. It is also characteristic of the growth pattern of most systems of the body, including muscle mass, the skeleton (with the exception of certain parts of the skull and face), the respiratory system, the heart and blood vessels, the digestive system and the urinary portion of the urogenital system. The growth pattern is S-shaped (sigmoid) and has four phases, rapid growth in infancy and early childhood, steady but rather constant growth during middle childhood, rapid growth during the adolescent spurt and slow increase and eventual cessation of growth after adolescence. The latter part of the curve continues into the 20s for most dimensions.
- The **neural** curve characterises the growth of the brain, nervous system, and associated structure, such as the eyes, face, and parts of the skull. These tissues experience rapid growth early in postnatal life, so that about 95% of the total increment in size of the central nervous system between birth and 20 years is already attained by about 7 years of age. Neural tissues show steady gain after 7 years of age , with a slight growth spurt during adolescence.
- The **genital** curve characterises the growth pattern of the primary and secondary sex characteristics. Genital tissues show slight growth in infancy, followed by a latent period during most of the childhood. Genital tissues then experience extremely rapid growth and maturation during the adolescent spurt.
- The lymphoid curve describes the growth of the lymph glands, thymus gland, tonsils, appendix, and lymphoid patches of tissue in the intestine. These tissues are involved in general, with the child's developing immunological capacities, including resistance to infections (infectious diseases). Lymphatic tissues show rapid growth during infancy and childhood, reaching a maximum at about 11 to 13 years of age. At these ages children have, on a relative basis, about twice as much lymphoid tissues as they have as adults. The decline of the lymphoid curve during the second decade of life is related to the involution (shrinking) of the thymus and tonsils at this time.

Scammon's curves thus indicate the differential nature of postnatal growth. Growth occurs in different areas and tissues of the body at different times and at different rates. Although somewhat simplified and diagrammatic, the curves give a sense of order to the structural and functional changes that occur with growth and maturation. There are several exceptions to the four curves .

-The integrated nature of growth and maturation and development is achieved by the interaction of genes, hormones, nutrients and the environment in which the individual lives. This complex interaction regulates the child's growth, neuromuscular maturation, sexual maturation and general physical metamorphosis during the first 2 decades of life. However the regulation of growth and maturation is complex and not fully understood.

- Regular physical activity is often viewed as necessary for optimal growth but its effects are quite difficult to specify. More important. perhaps it is only one of many factors known to influence growth and maturation including general socio-economic conditions, hygiene and physical environment (Lowrey, 1973; Scammon, 1930).

Strength and sport motor **performance** development during growth

The pre-school years are characterised by gradual neurornuscular maturation and the development of a variety of fundamental movement patterns. The fundamental motor skills are reasonably developed in most children by age *6* or 7, although the mature patterns for some basic skills develop somewhat later. As the fundamental movement patterns are refined through practice and instruction the quality and quantity of performance improve and the patterns are integrated into more complex motor activities, such as those in games and sports.

A variety of tasks can be used to document levels of strength and motor performance outside of the laboratory . It is important to use tasks that provide an indication of the child's strength and motor performance characteristics. Strength is included with motor performance because it is essential component of motor performance (i.e. a certain level of muscular strength is necessary) and because motor performance tasks are often used as indicators of aspects of muscular strength.

Strength is an expression of muscular force or the individual's capacity to develop tension against an external resistance. There are several types of strength.

- Static strength or isometric strength is the force exerted against an external resistance without any change in muscle length. It is general measured for specific muscle groups, such as grip strength, pulling or pushing strength of the shoulder, or flexion and extension of the elbow or knee.
- Explosive strength or power is the ability of muscles to release maximal force in the shortest possible time. Outside of the laboratory jumping tasks are commonly used as indicators of explosive strength.
- Dynamic strength is the force generated by repetitive contractions of muscles. Pull-ups and push-ups are commonly used to measure this component of strength.

Muscular endurance is the ability to repeat or maintain muscular contractions over time. A commonly used measure of muscular endurance is the flexed -arm hang.

Tests of strength and motor performance obviously overlap. Performance tests incorporating fundamental motor skills require some combination of strength and motor control.

Jumping tasks require motor co-ordination and muscular power to project the body horizontally forward in the standing long jump or vertically in the standing high jump.

Throwing tasks require co-ordination and power in projecting an object, most often in form of the softball throw for distance.

Running tests are more variable. The dashes are tests of running speed that require power and co-ordination to move the body as rapidly as possible from the starting to the finishing line. Shuttle runs are used as indicators of agility, the ability to rapidly change direction of movement.

Tests of balance and flexibility are also incorporated in test batteries for motor performance. Clearly balance is essential to the performance of motor activities. It is measured either as static (maintenance of balance without having to move as in balancing on a beam or stick) or dynamic (maintenance of balance while moving as in the beam walk).

Flexibility is range of motion of different segments at various joints of the body. It is commonly viewed as the maximum range of joint motion. Flexibility is very joint-specific, so that no single measure of flexibility is indicative of general body flexibility. Lower back and hip flexibility as measured by the sit and reach test, have received most attention recently.

Other fundamental motor skills can also be tested. But data for these basic skillls are not extensive across the growing years. Quite often they are limited to the pre-school and elementary school ages, given the importance of motor skill development in children's behavioural repertoires.

a.) Motor performance in early childhood

Information on attained levels of strength and motor performance is not as extensive for early childhood or approximately, the pre-school years, as that for middle childhood and adolescence. There is also much intra- and interindividual variability in performance among young children, which is expressed from day to day and even trial to trial on a given day. Changes in mean levels of performance with age should be viewed with this in mind.

Changes in several measures of strength and motor performance from age 3 through age 6 are published (Krogman, 1972). The data are from a study that concerned various measures of manual strength in young children relative to their capacities to open different types of containers (e.g. those for medications). The problem facing designers is the need to develop a container that can be opened by elderly people with diminished manual strength and perhaps arthritis, but that cannot be easily opened by young children. It is clear that muscular strength increases gradually during early childhood. Sex differences in average strength are small, and there is considerably overlap.

Performance in a variety of fundamental motor tasks also improves during early childhood. Improvement with age is linear for all tasks except the balance test. On the average, sex differences are generally small but consistently favour boys for running, jumping and especially throwing. Girls perform slightly better in the balance test between ages 3 and 5 and then exceptionally better than boys at age 6, while catching shows negligible differences. The suggested trends (Morris, 1982) are generally consistent with what is known about sex differences in the motor performance of young children. On the average, boys excel in tasks that require power and speed, such as jumping, throwing and running, whereas girls excel in tasks require balance such as hopping. The differences between boys and girls are relatively small, however, and there is much overlap. They probably reflect, in part to the types of activities available and societal expectations for boys and girls at these young ages (Malina, Bouchard. 1989).

b.) Motor performance in middle childhood and adolescence

Strength and motor performance generally improve with age, but the pattern of improvement is not uniform for all tasks.

- Static strength

Changes in measures of static strength occur between 6 and 18 years of age. The data are derived from a mixed-longitudinal sample aged 6 through 11 (Malina & Roche, 1983) and from a longitudinal sample aged 11 through 18 (Jones, 1949). Strength increases linearly with age until 13 to 14 years of age in boys, when there is an acceleration in strength development, an adolescent strength spurt. In girls, strength improves linearly with age through about 16 or 17 years with no clear evidence for an adolescent spurt as in boys. From the data of Morris and Malina and Jones combined there is a continuous increase in strength from age 3 on.

The sex difference in strength is consistent, though small, through childhood. The marked acceleration of strength development during the male adolescent spurt magnifies the sex difference. With increasing age during adolescence, the percentage of girls whose performance on strength tests equals or exceeds that of boys declines considerably. After age 16, few girls perform as high as the average strength of boys and conversely few boys perform as low as the average strength of girls. Age trends and sex differences in other measurement of static strength are generally similar to those for grip strength. Although growth studies generally stop at age 18, strength continues to increase into the third decade of life, especially in males.

- Muscular endurance

Changes in muscular endurance of the upper body as measures by the flexed arm hang are shown - the data are derived from Leuven Growth Study.

Muscular endurance improves linearly, with age from 5 to 13 or 14 years of age in boys, followed by a spurt similar to that for static strength. Muscular endurance also increases with age in girls, but there is no clear evidence of a spurt as in boys. In Belgian girls, performance on the flexed-arm hang improves gradually but slightly from 13 to 18 years of age.

Sex differences in muscular endurance are especially apparent at all ages from 13 to 18 in the Leuven Growth study. Variations in lifestyle (habitual physical activity, quality and quantity of school physical education) may also be contributory factors.

- Jumping

Age and sex associated variation in jumping performance are shown respectively (Seefeld, 1982). On the average performance in the standing long jump increases linearly with age in both sexes until 12 years in girls and 13 years in boys. After age 12 in girls, attained levels of performance in the standing long jump hit a plateau and then decline somewhat, whereas, those of boys increase more sharply, which is indicative of an adolescent spurt. Sex differences are relatively small but consistent during childhood and become magnified during adolescent (Barabás-Eiben, 1991). Apparent differences between samples are because of possible cultural variations in habitual physical activity and physical education programs.

- Throwing

Mean performances of boys and girls between ***6*** and 17 years in the softball throw for distance - the performance of boys increases markedly and linearly with age, with no apparent indication of an adolescent spurt, whereas that of girls improves only slightly between ages **6** and 14 and then is stable. The sex difference in throwing performance during childhood is greater than for other basic **skills** and is magnified to a much greater extent during adolescent (Barabas-Eiben, 1993).

- Running

Changes in running speed during childhood and adolescence is occurs (Seefeldt et al., 1982). The data are expressed in meters run per second in dashes with standing start. Running speed improves linearly from 5 through 17 years of age in boys with no indication of a clear adolescent spurt in the composite data. The running speed of girls improves to age 11 or 12 in the composite data and shows only slight change through age 17. Shuttle running performance an indicator of agility also improves with age. Sex differences in average running speed are not very large from 5 to 8 years of age. They become reasonably well established by about age 9 and persist through adolescence. Given the plateau in the average performances of girls, the sex difference becomes magnified during adolescence.

- Flexibility

Changes in the sit and reach test, a measure of flexibility of the lower back, hip and upper thigh (Beunen et al., 1988). Mean scores are stable from **5** through 8 years in boys. They subsequently decline with age, reaching a nadir at 12 and 13 years, and then increase through age 18. In girls mean scores are rather stable from 5 to 11 years, increase to age 14 and then appear to reach a plateau. Girls are more flexible than boys at all ages, and it appears that the sex difference is greatest during the adolescent spurt and sexual maturation. The unique pattern of age and sex associated variation in this measure of flexibility is related in part to the growth of the lower extremities and the trunk during adolescence, the ratio of sitting height to stature is increase during growth. The increase in flexibility of girls after about 11 years coincides with fhe adolescent spurt in sitting height (trunk length) In addition the adolescent spurts of the long bones of the upper extremity, which should influence the individual's reach, occur close to that for sitting height. Similarly the low point in boys' sit and reach performance is generally coincident with the adolescent spurt in leg length and the subsequent increase appears to coincide with the adolescent spurt in sitting height and upper extremity length. Anatomical and functional changes in the joints during adolescence also probably influence flexibility in this time.

- Balance

Balance is essential to the performance of many tasks. The balance-beam walk is one of the more commonly used test of balance. It requires the child to walk the length of the beam without stepping out. Balance performance improves with age. Girls on the average perform better in balance task during childhood. Data for adolescence are limited.

Significant correlation has been found between the results of Romberg test (with closed eyes) and the co-ordination test described above as well as between the co-ordination test performance and the reaction time. Real time visual feedback enhances motivation and helps the subject link perception to movement. Fourier spectra reflect the nature of the sway and give objective information about amplitudes of harmonic components of body sway as well as the dominant frequencies (Bretz-Kaske, 1994).

Overview of performance

The time from 5 to 8 years of age appears to be a transitional period in the development of strength and motor performance. The basic movement patterns are reaching maturity at this time, but with a wide range of variation among children. In addition the application of these movement patterns to specific test situation must be practised or learned. So it is not surprising to find variation in the performance of specific strength and motor items at these ages. Some skills show considerable increase in performance between 5 and 8 years of age (running speed) and others show a steady, gradual increase in attained performance from 5 years of age through middle childhood (jumping throwing and strength) Muscular endurance appears to show an increased pace of development in boys but not in girls. This may reflects a learning effect as the youngsters get adjusted to the test situation. Controlling for learning effect is a significant logistical problem in longitudinal studies of motor performance; how much of the observed improvement reflects learning to perform the tasks? In general, age and sex-associated trends in strength and motor performance derived from longitudinal and cross-sectional studies are consistent.

On the average the motor performance of girls from a variety of samples reaches a plateau and even declines during adolescence, whereas strength increases slowly with age through adolescence. However some data (Leuven Growth Study of Flemish Girls) indicate slight but continued improvement in several motor performance items through adolescence. In contrast the strength and motor performance of boys generally increase through adolescence, resulting in significant sex differences (Espanshade, 1940, Jones, 1949).

On the average, in early adolescence the strength and motor performance of girls is within one standard deviation of the average performance of boys on all tasks with the exception of the softball throw for distance. However after age 14 the average strength and motor performance of girls is consistently outside of the limits of the standard deviation below the averages for boys.

Relationships of strength and motor performance to size, physique and body composition

Body size, physique and body composition are important factors that affect strength and motor performance. The relationships, however , vary among performance measures and with age.

- During childhood

Correlation's of stature and weight with performance on a variety of motor tasks during childhood are generally low. Distinction must be made between tasks in which the body is projected (as in jumps and dashes) and tasks in which an object is projected (as in throws). Body weight tends to be negatively correlated with jumping and running performance (heavier children do not perform as well as the lighter children in these tasks) and positively correlated with throwing performance (heavier children tend to perform better).

Correlation's of stature and weight with strength during childhood are better than those for motor performance and tend to fall in the moderate range. Thus the bigger child tends to be the stronger child.

The relationships between size and physique on the one hand, and strength and motor performance, on the other hand, are consistent with those for estimates of body composition. During childhood, absolutely and relative fatness are negatively related to motor items in which the body must be projected. Throwing is an exception. Absolute fat-free mass is more related to throwing performance than relative fat-free mass, indicating the role of absolute body size in distance throwing. Results of studies relating skinfold thickness' to motor performance give similar results (low to moderate negative correlation's), which indicate the negative effect of fatness on performances requiring movement of the entire body.

Because the strength is related to body size and especially fat-free mass, sex differences in strength during childhood might be related to the size and fat-free mass advantage of boys. When boys and girls are matched for measurements of arm and leg muscle size, boys tend to demonstrate greater strength per unit of muscle area than girls. When stature differences between boys and girls are controlled, boys are significantly stronger than girls in upper extremity and trunk strength, but not in lower extremity strength. However, boys are stronger per unit body weight then girls, probably reflecting the greater contribution of muscle mass to body weight in boys than in girls.

- During adolescence

Individual variation in the timing, duration and intensity of the adolescent growth spurt adds another dimension to the interrelationships among size, physique, body composition and physical performance. Correlations of stature and weight with motor performance during adolescence are generally low and in the same direction as those in childhood. Age, stature and weight account for only a small percentage of the variance in motor performance during adolescence, thus implying a significant role for biological maturity status (the timing of the adolescent growth spurt and sexual maturation). Social and motivational factors are additional considerations, especially in adolescent girls.

Correlations of stature and weight with strength are higher than those for motor performance. The highest correlations in boys tend to occur between 13 and 15 years of age , which is generally the period of the male adolescent spurt. Similar age-associated variation in correlations is not evident in girls during adolescence. This probably reflects both biological and social factors. Changes in body composition associated with adolescence, particularly gains in absolute and relative fatness may contribute to the lower correlation's in girls. Similarly, changes in interests and attitudes toward physical activity are associated with adolescence, and this may influence girl's motivation to perform at this time.

The available information on relationships between physique and performance during adolescence is limited to boys. Longitudinal data from the Medford Growth Study of boys in Oregon indicate a consistently low to moderate, negative relationship between endomorphy and performance between age 12 and 17. On the other hand correlation between mesomorphy and motor performance tend to be consistently low, whereas those between ectomorphy are variable between ages 12 and 17. The negative relationship between endomorphy and motor performance implies a negative effect of fatness. The effect is especially evident from the mixed-longitudinal Leuven Growth Study. (Performances of fattest and leanest 5% of boys).

Although the fattest boys are taller and heavier than the leanest boys, they exceed the leanest boys in arm pull strength. The two groups do not differ in flexibility but the leanest boys perform better than the fattest boys in the other motor items at all ages. The poorer motor performance of the fattest boys in items that require the movement or projection of the body mass is most likely due to the inert, non-contributory load imposed by the fat tissue. On the other hand the performance success of the leanest boys is related in part to their minimal fatness levels. In addition the leanest boys have greater strength and power per unit body size. Although they are smaller than the fat boys, the leanest have proportionally more lean tissue so that they are "as strong as they appear" in spite of their small body size. In contrast the fattest boys are not as strong as their overall body size might suggest.

As in the case of childhood sex differences in strength and performance during adolescence reflect, in part, sex differences in size and body composition. The greater relative fatness of girls and the greater absolute and relative leaness of boys exert opposite effects on performance. Excessive fatness tends to have a negative effect on most motor performance tasks and greater fat-free mass tends to have a positive effect. As in childhood adolescent boys tend to have greater strength per unit body size, especially in the upper extremities and the trunk, than adolescent girls, whereas there are negligible sex differences in lower extremity strength when body size is controlled. Boys gain more in upper arm musculature than girls during adolescence and have a considerably larger adolescent spurt in arm musculature compared to that of the lower leg.(Tanner et al, 1981).

Stability of strength and motor performance

Stability here refers to the relative position of a child within his or her age and sex group over a period of time. Stability or consistency is estimated by correlating attained levels of strength and motor performance for a given child at one age with levels of strength and performance of the same child at another age. Longitudinal data are thus necessary to estimate stability.

Stability of strength measurement varies with the age interval between measurements. The smaller the time span between measurements, the higher the correlation and thus the greater the stability. For example correlation between measurements of several muscle groups taken at age 11 and at the age 12 are moderate to high, ranging from about 0.65 to 0.90 in boys and girls. Thus year-to-year stability is quite good. However as the time span between observations increases, correlations decline. When correlations are done between measurements taken at 5 to 6-year intervals during childhood and adolescence, most interage correlation range from low to moderate, about 0 to 0.65 and correlations between 7 to 12 years tend to be lower than those between 12 to 17 years. There is thus less stability or consistency in the strength of a child over longer times. Stability of strength of the lower extremities tends to be slightly better than for those of the upper extremities. This is perhaps related to the continual weight-bearing and locomotion use of the lower extremities, whereas there is considerable individual variation in the use of upper extremity musculature. Composite measures which treat a variety of specific strength measurements as a unit tend to be somewhat more stable than specific strength measurements.

Motor performance during childhood and adolescence is more variable than strength. Interage correlations tend to be lower and there is considerable variation among motor tasks . Stability from one age to the next is quite good. However as the time interval increases to 5 or 6 years, correlations decline substantially. Performance in power tasks such as the softball throw for distance, the standing broad jump and the dash, tends to show reasonably good stability over periods of 2 to 3 years, whereas other tasks such as hopping the flexed-arm hang and the sit and reach test (flexibility) are less stable. As the time interval between measures of performance approaches 5 and 6 years, motor performance in nearly all motor tasks becomes less stable. In general stability of motor performance is better later in childhood (8-10-11) than earlier in childhood (5-8). Data for adolescence are less extensive and more variable.

Although there is variation among motor tasks, changes in the relative positions of individuals within an age group occur more commonly for boys than for girls during adolescence. This probably reflects individual variation in the timing of the male adolescent growth spurt and sexual maturation - for instance the surge in male sex hormones that accompanies sexual maturation has a specific influence upon muscular strength. On the other hand, changes in relative group positions among girls are probably related both to variafion in the timing of the growth spurt and sexual maturation and to changing social demands, expectations and interest of adolescents that influence their motivations to give maximal efforts in performance tests.

CONCLUSIONS

Gradual neuromuscular maturation and development of a variety of fundamental movement patterns occur during childhood. The fundamental motor skills are reasonably developed in most children by age six or seven, although the mature patterns for some basic skills develop somewhat later. Strength and motor performance generally improve with age during childhood and adolescence, but the pattern of improvement is not uniform for all tasks. Growth and development, changes of anthropometrical variables of the structure influence the functions as well as the location of centre of gravity, mass of muscle and length of extremities during movement.

Many variables interact. For example, as the main propelling force in the stepping-running-jumping pattern is derived from extension at the knee; to this is added the force of gravity, which rotates the entire body around the metatarsophalangeal joints. At the same time the extension at the ankle and hip keep the centre of gravity in an advantageous position to move it in the desired direction.

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