BIOMECHANICS AND MOTOR DEVELOPMENT

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Introduction

The observation and examination of sports movements of children generate a number of new questions the answers to which are found beyond the general examination of human or sports movement. The child's growth and development is manifested in physical structure and performance. These factors interact and are determined genetically as well as socially, culturally and economically. The period of growth and development of children is the time during which physical and physiological changes take place (Anderson et. al. 1984., Bar-Or, 1983, Malina, 1980, Borms, 1984).

In this period, the child's body increases in size and organs develop and mature until they function on the level required to meet the demands of daily life and physical activities. The time of the early childhood to maturity brings about a great increase in physical performance capacity. This increase is due to the biological changes occurring as a process of maturation regardless of physical training.

Numerous studies have shown differences in somatic and motor characteristics of boys and girls up until puberty. However, the differences are rather small and the growth and development patterns run closely parallel. (Bailay, 1982, Beunen et. al. 1981, Astrand, 1985, Malina, 1974, Tanner, 1962) Starting at puberty sexual differences are clearly appearing. The focus of this presentation will be on the changing of gross motor abilities and performances in children.

The data collected are from Hungary, a fairly developed

Central-European country of ten and half million inhabitants. However in other countries a largely similar picture probably would be seen.

Materials and Methods

The fact-finding activities of our first, comprehensive, nationwide, cross-sectional examinations, initiated to record the biological development and the level of physical performance ability of Hungarian youth have only recently been finished. The surveyed sample, close to 28 thousand school-aged children, represents 1.5 percent of Hungarian youth aged in the 1980s between 6 to 18 years. The number of boys and girls in each age category are shown in Table 1.

The functional tests characterizing the active part of human biology, namely the motoric aspect, reflect motor performance ability, that is, conditioning abilities such as strength, speed and endurance, that manifest themselves in basic forms of movement (running, jumping, throwing).

The applied motor tests were the following: hand grip test for measuring general strength; standing broad jump and standing high jump test for measuring the explosive (dynamic) strength; medicine ball push and throw test for measuring the explosive shoulder strength , 60m dash for measuring running speed, and the sit-up and Burpee tests for measuring the muscular strength-endurance of the trunk. The 12-minute endurance run (Cooper test) was selected to measure the endurance of the whole body.

Data were processed by applying SPSS-X statistical program package on an IBM 30-10 type computer.

Table 1

Sygnificance levels of Pearson correlations

between performances (1-7) and height and weight

B O Y S

Age (years)	Height							Weight						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
6	xxx	xxx	-	-	-	¯xx	-	xxx	xxx	-	-	-	¯xxx	-
7	xxx	xxx	-	¯x	-	¯xxx	¯x	xxx	xxx	xxx	-	-	¯xxx	-
8	xxx	xxx	¯x	¯x	-	-	¯xx	xxx	xxx	xx	-	x	¯xxx	-
9	xxx	xxx	¯xx	¯xx	-	-	¯xxx	xxx	xxx	xx	-	x	¯xx	-
10	xxx	xxx	¯xxx	¯xxx	¯x	xxx	¯xxx	xxx	xxx	xxx	-	-	¯xx	¯x
11	xxx	xxx	¯xxx	¯xxx	¯xxx	xxx	¯xxx	xxx	xxx	-	¯xxx	¯xx	-	¯xxx
12	xxx	xxx	¯xxx	¯xxx	¯xxx	xxx	¯xxx	xxx	xxx	xxx	¯xxx	-	¯xxx	-
13	xxx	xxx	-	¯xxx	¯xx	-	¯xxx	xxx	xxx	xxx	¯xx	-	¯xxx	-
14	xxx	xxx	xxx	¯xxx	¯x	¯x	¯xxx	xxx	xxx	xxx	-	-	¯xxx	-
15	xxx	xxx	xxx	¯xxx	¯x	¯xxx	¯xxx	xxx	xxx	xxx	-	-	¯xxx	x
16	xxx	xxx	-	¯x	-	-	¯xxx	xxx	xxx	xxx	-	-	¯xxx	-
17	xxx	xxx	-	¯xxx	-	-	¯xxx	xxx	xxx	xxx	-	-	¯xxx	-
18	xxx	xxx	¯xx	¯xxx	¯xx	xxx	¯xxx	xxx	xxx	xxx	¯xx	-	-	-

Simbols

1	hand grip strength	5	Sit-up test	xxx:	p	0.001
2	medicine ball puss	6	60 m dash	xx:	p	0.01
3	standing long jump	7	12 minute endurance vun	x:	p	0.05
4	Burpee-test					

Results and Discussion

1. Changes of strength, speed and endurance (12-minute endurance test) related to age. The correlates for strength, speed and endurance and heights and weights for boys and girls of various ages are discussed below.

There was a possibility beyond the basic statistical elaboration of the available data, for a deeper analysis of performance results measured in conditioning ability tests. Although a cross-sectional examination has, by definition, certain limits, one can still draw certain conclusions concerning the development of motor abilities such as strength, speed and endurance. There are positive and negative correlations between height, weight and physical performance scores. Data for boys are shown in Table 2 and for girls in Table 3.

Table 2

Pearson correlations in case of boys between standing broad jump and

Age (years)	- height		- weight	
	corr. coeft.	p.	corr. coeft.	p.
6	. o418	. 287	. o797	. 141
7	. o15o	. 316	..16o9	. ooo
8	-. o514	. o43	. o863	. oo2
9	-. o746	. oo5	. o6o9	. o17
1o	-. o974	. oo1	. o947	. oo1
11	-. 1446	. ooo	. o349	. 12o
12	-. 1152	. ooo	. 1144	. ooo
13	. oo76	. 4oo	. 2264	. ooo
14	. 1o14	. ooo	. 3165	. ooo
15	. o822	. oo1	. 2278	. ooo
16	-. o289	. 134	. 178o	. ooo
17	. o124	. 332	. 1848	. ooo
18	-. o95o	. oo6	. 1386	. ooo

Table 3

Sygnificance levels of Pearson correlations

between performances (1-7) and height and weight

GIRLS

Age (years)	Height 1	Height 2	Height 3	Height 4	Height 5	Height 6	Height 7	Weight 1	Weight 2	Weight 3	Weight 4	Weight 5	Weight 6	Weight 7
6	xxx	xxx	-	-	-	-	-	xxx	xxx	-	-	-	-xxx	-
7	xxx	xxx	-xx	-x	-	-xx	-x	xxx	xxx	xx	-	x	-xxx	-
8	xxx	xxx	-	-xx	-	-xx	-xxx	xxx	xxx	xxx	-	x	-xxx	-
9	xxx	xxx	-x	-xx	-	xx	-x	xxx	xxx	xxx	-	xx	-xxx	-
1o	xxx	xxx	-xxx	-xxx	-x	xxx	-xxx	xxx	xxx	xxx	xx	-	-x	-xx
11	xxx	xxx	-xx	-xxx	-	xx	-xxx	xxx	xxx	-	-	-	-	-xxx
12	xxx	xxx	-	-xxx	-x	xx	-xxx	xxx	xxx	xxx	-x	-x	-xxx	-
13	xxx	xxx	-xxx	-xxx	-xxx	xx	-xxx	xxx	xxx	x	-xx	-	-xxx	-
14	xxx	xxx	-xxx	-xxx	-x	xxx	-xxx	xxx	xxx	xxx	-	-	-xxx	-
15	xxx	xxx	-xxx	-xxx	-	xxx	-xxx	xxx	xxx	x	-xx	-	-	-
16	xxx	xxx	-xx	-x	-	x	-x	xxx	xxx	xxx	-	-	-xx	-
17	xxx	xxx	-	-xxx	-	xx	-	xxx	xxx	xxx	-	-	-xxx	xx
18	xxx	xxx	-xxx	-	-	xx	-x	xxx	xxx	xx	-	-	-x	-

Simbols

1 hand grip strength
2 medicine ball puss
3 standing long jump
4 Burpee-test

5 Sit-up test
6 6o m dash
7 12 minute endurance vun

xxx: p o.ool
xx: p o.ol
x: p o.o5

Comparing the rate of motor development with increase of body height and body weight one can state that the highest peak of the development of strength occurs after the peak of the velocity of body height increase. The greatest changes in both muscular strength and endurance and general endurance occur before adolescence. The greatest development in running speed can be observed in the early school-age. Table 4 shows the peak ages of physical and motor development.

Table 4

Table 4 Pearson correlations in case of girls between standing long jump

Age (years)	height		weight	
	corr. coeff.	p	corr. coeff.	p
6	. 0699	. 000	. 4131	. 000
7	-. 0895	. 004	. 0808	. 007
8	-. 0093	. 379	. 1324	. 000
9	-. 0598	. 024	. 1298	. 000
1o	-. 13o5	. 000	. 0898	. 002
11	-. 0916	. 002	. 0659	. 018
12	-. 0462	. 072	1 18o6	. 000
13	-. 1436	. 000	. 067o	. 016
14	-. 1o84	. 000	. 0993	. 001
15	-. 1511	. 000	. 0662	. 011
16	-. 0847	. 003	. 1386	. 000
17	-. 05oo	. 067	. 1889	. 000
18	-. 2o42	. 000	. 1o51	. 008

Adolescence causes disharmony in motoric development as well. The discrepancies between boys and girls in maturity-performance relationships led Malina (1980) to the hypothesis that at sexual maturation girls are socialized away from sports and physical activity which ultimately results in poorer performance. The sexual dimorphism in strength can mainly be explained by the larger muscle mass of boys (Astrand, 1985). In the case of girls, performances reach a plateau or decrease after age 14.

Our sample represents the average of boys and girls. Performances of girls stabilize in early ages (after 13) and at a relatively low level. It is well known that sports and physical activity change this tendency as the performance stabilization occurs on a higher level and later.

2. Test - economy investigations. During the administration of the final test battery, a special examination was carried out: the performance values of motor tests measuring the explosive strength of arms and legs. These partial examinations had admittedly test-economy aims, and on the basis of these results the most suitable tests could be selected.

It was established by cross-correlational process that the standing broad jump and standing high jump do measure the same abilities. There were significant correlations between the standing broad jumpa dn the standing high jump. The correlation coefficients were 0.6 and 0.7. Therefore, the standing broad jump test requiring less preparation and equipment was preferred. Further, it was found that for girls the standing broad jump test was more appropriate, (Barabas, 1984).

Several forms of the medicine ball push and throw are in use for measuring the explosive strength of the arms and shoulders. The performance results in three different medicine ball tests (ball throwing forward, backward and ball pushing forward) showed significant correlations. In every age group significant correlations were found between different throws. In the case of boys, the correlation coefficient was 0.7 - 0.9 and in the case of girls, 0.5 - 0.6.

3. Standing broad jump results related to the velocity of changes in height and weight.

The special attention devoted to the standing broad jump and medicine ball tests is further justified by the fact that the motor test score characterizing physical performance ability results from the strength of the arms and the legs. The optimal case would be that the body weight increase according to age would mean a proportionally bigger volume of muscles, too, which would result in better performances. However this assumption is only partially justifiable. In the case of girls, the increase of body weight is to a great extent caused, in connection with sexual characteristics, by the growth of fat tissues and thus puts a limit of increasing physical performance. On the other hand, greater body weight bears greater inertia and therefore greater strength would be necessary to mobilize this body weight from its state of rest.

The changing values of standing broad jump related to body weight characterize performance more exactly in the cases of both boys and girls. The standing broad jump values related to body weight decrease with growing age.Figures 4 and 5 show height, weight and jumping scores.

There are negative correlations between the performance and weight, and positive correlations between the performances and height. The more weight increases the more performance decreases. A greater height increase is associated with increased performance. (Tables 2 and 3)

4. Medicine ball pushing as related to height and weight changes by age. Results of the medicine ball push for boys and girls were examined in light of body height, weight and age. Table 5 presents the mean ball velocities for boys and girls by age.

Table 5

Pearson correlations in case of girls

between medicine ball push and

Age (years)	height		weight	
	corr. coeff.	p	corr. coeff.	p
6	.3427	.000	.4131	.000
7	.36o8	.000	.3935	.000
8	.4567	.000	.4o58	.000
9	.4349	.000	.4387	.000
1o	.4272	.000	.4747	.000
11	.2582	.000	.2575	.000
12	.5138	.000	.5228	.000
13	.464o	.000	.3851	.000
14	.3838	.000	.2267	.000
15	.335o	.000	.1735	.000
16	.3697	.000	.2855	.000
17	.3541	.000	.3917	.000
18	.38o9	.000	.31o3	.000

There are also very significant correlations in the case of boys and girls between medicine ball pushing and their heights and weights, in all age-groups. Table 6 presents the equations of polynomial regression.

Table 6

Pearson correlations in case of boys between medicine ball push and

Age (years)	height		weight	
	corr. coeff.	p	corr. coeff.	p
6	.3249	.000	.45o5	.000
7	.3378	.000	.4295	.000
8	.4164	.000	.47o9	.000
9	.4451	.000	.4oo8	.000
1o	.4248	.000	.46o6	.000
11	.44o7	.000	.3443	.000
12	.5494	.000	.5559	.000
13	.5525	.000	.5812	.000
14	.5489	.000	.57o1	.000
15	.4831	.000	.4276	.000
16	.4451	.000	.4139	.000
17	.4424	.000	.3459	.000
18	.35o1	.000	.3o63	.000

The primary human biological research had a biomechanical approach as well. The examination of biomechanical reasons influencing performance also falls within the sphere of interest.

Studies have shown that throwing involves a sequential action of body segments, progressing from the larger leg and trunk actions to the faster moving ones (Kreighbaum and Bartels 1981, Sakurai and Mijashita 1983). It is generally accepted that the deceleration of proximal segments is associated with the accelerations of the distal segments (Azciorsky et. al. 1981, Terauds 1978, Joris et. al. 1985). In the case of one medicine ball push test, the throwing distance is the result of the sequential action of the arms and shoulders.

The pushing height of the ball plays an important role in the successful medicine ball push (pushing height nearly equals that of body height). The formula describing the distance of the slanting throw from height "h" is well-known. Tables 7 and 8 show the medicine ball push scores for different heights for boys and girls respectively.

Table 7

Girls' medicine ball scores in different

height - group

Age (years)	Height mean $- \frac{1}{2}$ SD		$- \frac{1}{2}$ SD Height $+ \frac{1}{2}$ SD		mean $+ \frac{1}{2}$ SD Height	
	M	SD	M	SD	M	SD
11	254	18	266	28	271	28
12	361	23	342	76	372	16
13	327	31	374	74	37o	42
14	329	54	368	39	388	44
15	332	44	347	4o	384	87
16	325	39	3o5	18	35o	39
17	322	9	331	25	325	39
18	323	16	341	44	327	24

Table 8

Boys' medicine ball push scores in different

height - group

Age (years)	Height mean - $\frac{1}{2}$ SD		- $\frac{1}{2}$ SD Height + $\frac{1}{2}$ SD		mean + $\frac{1}{2}$ SD Height	
	M	SD	M	SD	M	SD
11	267	28	291	24	314	35
12	290	43	347	60	404	47
13	339	38	388	44	447	67
14	376	60	467	73	485	47
15	378	70	457	78	515	66
16	360	45	363	23	475	30
17	490	28	500	-	440	85
18	440	44	445	17	512	67

There are very significant correlations between the medicine ball push and their body height and body weight for both boys and girls (See Tables 2 and 3).

A nomogram was constructed on the basis of the performance values depending on the body height of the different age groups. In the examined sample the results are very distinctive. Results are shown for boys and girls are shown in Figures 6 and 7 respectively.

Calculated velocities of the medicine ball push at the release in a model situation. In the case of the examined sample, that is a subgroup (N-150 boys and N-150 girls between 11-18 years of age) the performances of medicine ball push are distinctive.

The distribution of velocity scores are similar to the distribution of push distance, reflecting sexual dimorphism. It means the lower and more stable value in the case of girls.

The regressions were examined the medicine ball push results and the different body height in the age groups (Table 6 and Figure 7). The three height groups are: (a) height is below x - 1/2 SD, (b) height is x $\pm$ 12 SD, and (c) height is over x + 1/2 SD; where x is the mean body height of the examined girls or boys.

In our examination we tried to approximate the ball velocity at release in a model situation in which the release angle was 45 degrees. However the most trained school children are usually unable to carry out a medicine ball push under the ideal inclination. In the case of pushing the ball from the chest, the anatomical position of the arms from the point of view of exerting power does not favor the push under 45 degrees. The caluculated velocities of ball-release by the age are presented in Table 9 and for boys and girls in Figures 8 and 9 respectively.

Table 9

Mean ball velocity at release (ms^{-1})

(calculated from mean of ball push distance and height)

Age years	B o y s	G i r l s
6	1,98	1,51
7	2,28	1,77
8	2,85	2,32
9	3,26	2,7o
lo	3,67	3,12
11	4,o6	3,66
12	4,46	4,lo
13	4,92	4,51
14	5,36	4,59
15	5,39	4,36
16	5,72	4,43
17	5,91	4,44
18	6,lo	4,54

Table 10

Mean ball velocity at release in

different height- group

Age years	Boys			Girls		
11	3,56	3,78	3,98	3,34	3,39	3,37
12	3,81	4,39	4,81	4,54	4,23	4,48
13	4,32	4,75	5,22	4,15	5,56	4,47
14	4,68	5,44	5,51	4,1o	4,48	4,63
15	4,63	5,3o	5,72	4,12	4,23	4,56
16	4,4o	4,33	5,38	4,oo	3,69	4,18
17	5,61	5,66	5,o1	4,o1	4,o7	3,92
18	5,14	5,12	5,68	3,99	4,14	3,9o

Conclusions

In the future we plan to substantiate our tentative conclusions by making detailed investigations in order to be able to analyze individual cases. The anatomical and biomechanical analysis of these movements raises new and so far unanswered questions. From our work it seems to be clear that the most abrupt development in endurance takes place before adolescence while strength develops after this age motor performance has strong dependencies on the body height and weight and must be observed with all its consequences in order to determine training methodology.

Further indepth and more comprehensive examinations and analyses are necessary to follow the motor development of children, the relationships between movements and the other factors influencing motor development.

This lecture touched on some partial aspects of most important factors related to motor development.

References

Anderson, K. L., Rutenfranz, J., Seliger, V., Ilmarinen, I., Berndt, I., Kylian, H., Ruppel, M. (1984). The growth of lung volumes affected by physical performance capacity in boys and girls during childhood and adolescence. *European Journal of Applied Physiology.* 52. 380-384.

Astrand, P.-O. (1985). Sexual dimorphism in exercise and sport. In J. Ghesquiere, R.D. Martin F. Newcombe (Eds), *Human sexual dimorphism, symposia of the society for the study of human biology*, 24 (pp. 247-256). London: Taylor-Francis.

Bailey, S.M. (1982). *Absolute and relative sex differences in body composition.* In R.L. Hall (Ed.), Sexual dimorphism in homo sapiens (pp. 263-316). New York: Praeger.

Barabas, A. (1984). Comparativ examinations of dynamic leg-force performances. (A dinamikus labero teljesitemenyek osszehasonlito vizsgalata) *A Testnevelesi Foiskola Kozlemenyei.* 3 p. 47-53.

Barabas, A. (1986). Selected factors of physical performance in the Hungarian youth. *Anthrop. Kozl.* 30 233-242.

Bar-Or, O. (1983). *Pediatric sports medicine for the practitionar.* New York: Springer-Verlag.

Borms, J. (1986). The child and exercise: an overview. *Journal of Sports Medicine.* 4:3-20.

Beunen, G., Simons, J., Renson, R., Van Gerven, D. and Ostyn, M. (1980). Growth curves for anthropometric and motor components. In: Ostyn, M., Simons, J. Beunen, G., Renson, R. and Van Gerven, D., *Somatic and motor development of Belgian secondary school boys.* Norms and standards. Leuven: Leuven University Press, 49-71.

Eiben, O-Panto, E. (1984). Data for the oigarche-age and menarche-age of Hungarian boys and girls - *Anthrop. Kozl.* 28 191-194.

Eiben, O.G., Panto, E. (1986). The Hungarian National Growth Standards. *Anthrop. Kozl.* 30.

Joris, H.I.I et al. (1985). Force, velocity and energy flow during the overarm throw in female handball players. *J. Biom.* Vol 18.

No. 6. pp. 409-414.
Kreighbaum, E. and Barthels, K.M. (1985). *Biomechanics, a qualitative approach for studying human movement.* Burgess, Minneapolis.
Malina, R.M. (1984). Secular changes in strength and physical performance. *Studies in Human Ecology,* 6, 73-91.
Malina, R.M. (1980). Growth, strength and physical performance. In, Stull, G.A. and Cureton, T.K. (Eds), *Encyclopedia of Physical Education, Fitness and Sports Training, Environment, Nutrition and Fitness.* Salt Lake City: Brighton, 443-470.
Sakurai, S. and Miyashita, M. (1983). Developmental aspects of overarm throwing related to age and sex. *Hum. Movement Sci.* 2, 67-76.
Tanner, J.M. (1962). Growth at adolescence. Oxford: Blackwell.
Terauds, J. (1978). Computerized biomechanical analysis of selected javelin throwers at the 1976 Montreal Olympics. *Track and Field Q. Rev.* 78, 29-31.
Zatsiorsky, V.M., Lanka, G.E. and Shalmanov, A.A. (1981). Biomechanical analysis of shot putting technique. *Exercise and Sport Science Reviews,* Vol. 9 (Edited by Miller, D.I.), pp. 353-389. Franklin Institute Press, Philadelphia.