Journal of Human Kinetics volume 11, 2004, 15-34

The Influence of Ballet Training on Somatic and Coordination Differentiation in 11-15-Year Old Girls

by

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The main aim of this work is the evaluation of increased amount of specific movement activity on variability of somatic features and the level of coordination of ballet school students in comparison to control group of the same age. The hypothesis that female students from ballet school would show higher level of coordination in comparison to control ones, what is the effect of introductory selection and directed stimulation was formulated. It was also assumed, that the level of differentiation is different in specific abilities and grows at different degree in dependence to trainability (reactivity). The research was conducted on 184 girls aged from 11 to 15 years from Public Ballet School in Bytom, as well as the Elementary School nr 5 in Katowice. The research protocol included body height and mass measurements and coordination field, laboratory and computer tests (Viener Test System – VST). At the first stage test battery included 38 tests diagnosing 8 specific coordination abilities. In light of factor analysis calculated on normalized values it was reduced to 16 most informative tests. They characterize 5 specific coordination abilities. There were not extracted factors which were assumed to diagnose: space orientation, movement frequency and motor adjustment.

Introduction

The motor potential understood as possibilities hidden in structure and functions of human organism, expressed in flow and effects of movement, develops naturally in spontaneous movement activity. Its specific elements are the focus of directed stimulation (development) in process of physical education, sport training and recreation.

Currently in the area of human motor potential two areas are differentiated: first, structural and functional properties and processes securing the energy production, and second, embracing processes conditioning the efficiency of motor coordination (steering and regulation of movement). In light of contemporary concepts the measure of this area are coordination abilities, with its information processes background i.e. central nervous system functions (Gundlach 1968, Hirtz 1985, Raczek 1986, Ljach 1987, Szopa 1992, Raczek and Mynarski 1992, Mynarski 1995, Osinski 2003, Starosta 2003, et al).

Coordination abilities as "relatively solid and general forms of psychophysical processes of movement regulation, conditions utility functions, sport and recreational movement activities of human (Raczek 1991, 2001, Raczek and Mynarski 1992, Juras and Waskiewicz 2002, Juras 2003, Mynarski 2003, Starosta 2003, and others). The necessity of research in area of recognition of their role and meaning in life of different social groups, vocational, sport or artistic is undoubtful and actual.

Important research problem is the evaluation of influence of directed stimulation (training) on motor coordination development. In this work the attempt to describe this problem on ballet students aged 11-15 was undertaken. They practiced for 16 hours per week, mainly with specific exercises directed at improvement of dance skills and general physical conditioning (acrobatics).

The main aim of this work is the evaluation of increased amount of specific movement activity on variability of somatic features and the level of coordination of ballet school students in comparison to control group of the same age. The hypothesis that female students from ballet school would show higher level of coordination in comparison to control ones, what is the effect of introductory selection and directed stimulation was formulated. It was also assumed, that the level of differentiation is different in specific abilities and grows at different degree in dependence to trainability (reactivity).

Material and methods

The research was conducted on 184 girls aged from 11 to 15 years (tab. 1) from Public Ballet School in Bytom, as well as the Elementary School nr 5 in Katowice.

Table 1. The amount of girls in specific age categories

Age (years)	Ballet School (n)	Control group (n)	Total (n)
11	19	21	40
12	15	25	40
13	18	23	41
14	15	18	33
15	10	20	30
Total	77	107	184

The research protocol included body height and mass measurements and coordination field, laboratory and computer tests (Viener Test System – VST). At the first stage test battery included 38 tests diagnosing 8 specific coordination abilities (Raczek et al. 2002, Mynarski 2003). In light of factor analysis calculated on normalized values it was reduced to 16 most informative tests. They characterize 5 specific coordination abilities. There were not extracted factors which were assumed to diagnose: space orientation, movement frequency and motor adjustment.

Finally test battery included:

1. Movement combining (SP)
   a) SP1 – the difference between forward and backward jumps with and without countermovement (hands on hips),
   b) SP2 – as above (arm on the neck),
   c) SP3 – average time of task performance in VST test,
   d) SP4 – the coefficient of error time and total trial time in above task.
2. Kinesthetic differentiation (RR)
   a) RR1 – hand dynamometry,
   b) RR2 – as above with error information,
   c) RR3 – amount of errors in drawing figures,
   d) RR4 - amount of errors in drawing figures looking to the mirror.
3. Sense of static (RS) and dynamic (RD) balance
   a) RD1 – time of 4 turns on gymnastic bench,
   b) RD2 – the amount of turns in 20 on gymnastic bench,

c) RS1 – the module of absolute deviation of stabilometer platform.

4. Sense of rhythm (RT)
   a) RT1 – the amount of cycles in test “rhythmic hand tapping”
   b) RT2 - the amount of cycles in test “rhythmic hand and leg tapping”
5. Speed of motor reaction (SR)
   a) SR1 – the median of simple reaction time to visual stimuli (VST)
   b) SR2 – as above, median of speed of reaction,
   c) SR3 – as above – median of simple movement time.

Detailed testing protocols are described in works of Raczek et al. (1998, 2002) and Mynarski and Zywicka (2004).

Statistical analysis included:

- mean values (X), standard deviations (SD) and coefficients of variance (V),
- coefficients of skewness (Sk) and kurtosis (K),
- analysis of variance with two-factor classification, were grouping factors were age and specific group (ballet vs. control),
- as method verifying the analysis of variance the analysis of coordination fitness profiles and somatic feature was used (U Mann-Whitney test).

Results

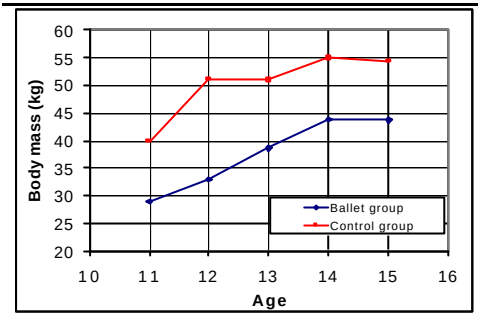
During statistical analysis it was stated that all variables are characterized with normal dispersion (skewness and kurtosis) and may be used in further research. The detailed data may be found in work by Kaminski (2003).

Collected empirical data allowed attempting to determine the range and direction of differences of specific coordination aspects and somatic features in ballet students and control group representatives. The data presented in table 2 shows, that girls from control group had body mass significantly larger than ballet ones (first factor) in all age categories (factor two). The difference seems to be the result introductory selection (fig. 1).

Table 1. The analysis of variance of body mass and height

Grouping variable	MS Efect	MS Error	F	p
Body mass				
1 - group	6898,49	23,554	292,877	**0,001**
2 - age	1351,44	23,554	57,375	**0,001**
Body height				
1 - group	75,147	85,589	0,878	0,350

2 - age	2616,02	85,589	30,564	**0,001**



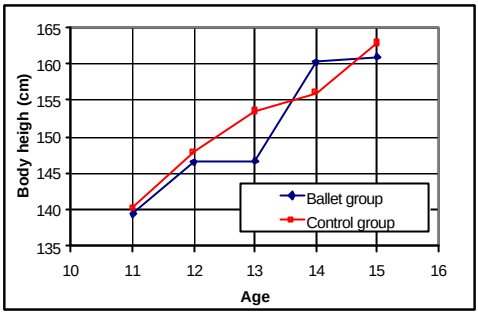


Fig. 1 and 2 The variability of body mass and height with age

In case of body height there was no significant difference between the groups, while the differentiating was is age of girls (tab. 2). The curves describing the increments of body height suggest that acceleration period appeared between 13 and 14 years of life (increase by 13 cm). In effect 14-year old girls are slightly taller than girls from control group (fig, 2).

The analysis of variance of movement combining tests (SP1 and SP2) evaluating the whole body movements showed that level of this ability is similar in compared groups (tab. 3). The differences were registered as significant dynamics of changes of this variable with age. Inter-group differences in speed of analyzed form of movement combining are presented on fig. 3 and 4.

The analysis of mean values of tests SP1 and SP2 it may be stated that in ballet students significant increase appears only in age of 11-13 years, followed be regression, while in control results lower in 12th year, and increase in following 3 years.

Table 3. The analysis of variance in movement combining (SP1, SP2)

Grouping variable	MS Efect	MS Error	F	p
		SP1		
1 - group	35,002	25,608	1,366	0,243
2 - age	123,47	25,608	4,821	**0,001**
		SP2		
1 - group	2,953	29,311	0,100	0,751

2 - age	95,208	29,311	3,248	**0,013**

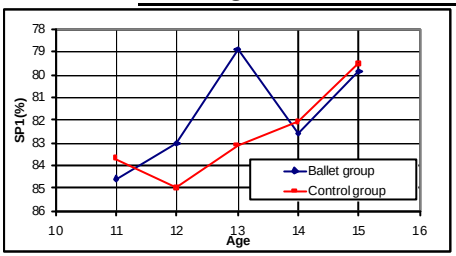


Fig. 3 The variability of movement combining (SP1) with age

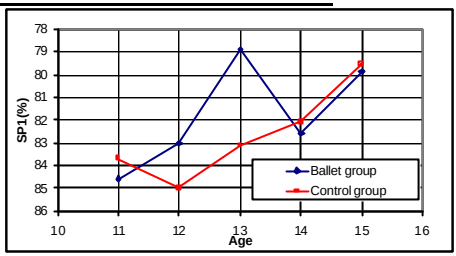


Fig. 4 The variability of movement combining (SP2) with age

Among computer test diagnosing the level of movement combining two variables were taken into account from test "Two-hand" from VST (SP3 and SP4). Similarly, as in earlier two cases, only dynamics of development differentiate the level of this variable (tab. 4). The developmental tendencies in SP3 and SP4 are significantly more progressive than in case of SP1 and SP2. Surprisingly slightly higher dynamics was presented by control group (fig. 5 and 6). It may be caused by fact, that this test evaluates so called "fine motor" (hand coordination), which in ballet training is not the aim practicing.

Table 4. The analysis of variance in movement combining (SP3, SP4)

Grouping variable	MS Efect	MS Error	F	p
		SP3		
1 - group	1828970	823359	2,221	0,138
2 - age	10154521	823359	12,333	**0,001**
		SP4		
1 - group	168307	187606	0,897	0,344
2 - age	1409869	187606	7,515	**0,001**

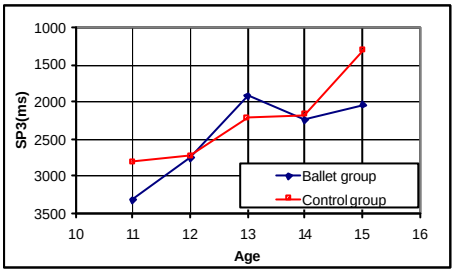


Fig. 5 The variability of movement combining (SP3) with age

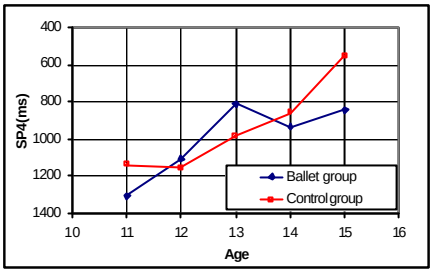


Fig. 6 The variability of movement combining (SP4) with age

Resuming the results of movement combing test it is possible to state, that effect of field motor tests (SP1, SP2), as well as computer (SP3, SP4) evaluating "fine motor" showed, that ability to combine movement with whole body and hands developed similarly in both tested groups (lack of significant differences in specific years).

The ability to differentiate the forearm strength was evaluated with the use of hand dynamometer, testing the ability to reproduce 50% of maximal strength (RR1) followed by reproduction with feedback information about error (RR2). The data presented in table 5 showed, that analyzed ability developed significantly different in both groups. The grouping facto "GROUP", as well as "AGE" of tested subjects shows statistical significance, however the differences are rather irregular and general tendency hard to determine. From the developmental dynamics may be seen, that best result were achieved by the ballet student at the age of 12 and 15 years. Only at 14th year sligthly better results were reached by control group girls (fog. 7 and 8).

Table 5. The analysis of variance of movement differentiation (RR1, RR2)

Grouping variable	MS Efect	MS Error	F	p
		RR 1		
1 - group	8778,38	405,577	21,644	**0,001**
2 - age	2025,07	405,577	4,993	**0,001**
		RR 2		
1 - group	7327,85	289,031	25,353	**0,001**
2 - age	1069,78	289,031	3,701	**0,006**

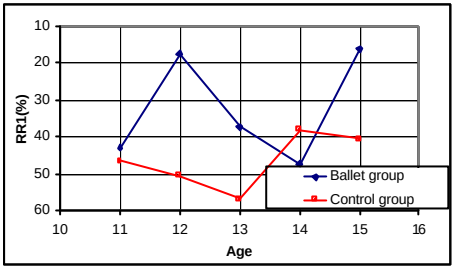


Fig. 7 The variability of movement differentiation (RR1) with age

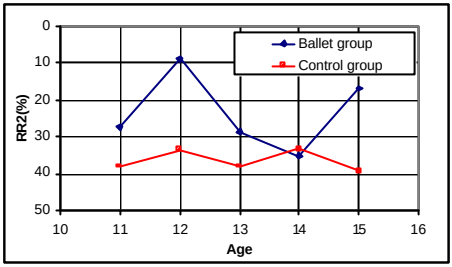


Fig. 8 The variability of movement differentiation (RR2) with age

The ability to differentiate movements in space-dynamic aspect was diagnosed with "Figures in mirror", in effect of which two variables were calculated: time of figures drawing (RR3) and amount of errors (RR4). The results of analysis of variance were shown in table 6, while the variability of dynamics was presented graphically on fig. 9 and 10. The results suggest, that in RR3 test, where time was general factor, there were no significant differences between both groups. Such the differences appeared in RR4 test (the precision of test performance) where ballet students were significantly better. The direction of these changes is similar in both groups and has evident increasing tendency (fig. 9 and 10.

Resuming the results it may be stated that tested aspects of movement differentiation, based mainly on prioprioceptive sense, showed significantly greater developmental tendency than incase of movement combining. The level of these abilities is also generally higher in ballet school students.

Table 6. The analysis of variance of movement differentiation (RR3, RR4)

Grouping variable	MS Efect	MS Error	F	p
		RR 3		
1 - group	12786,1	3786,73	3,376	0,067
2 - age	20965,8	3786,73	5,536	**0,001**
		RR 4		
1 - group	30556,1	3262,59	9,365	**0,002**
2 - age	16324,2	3262,59	5,003	**0,001**

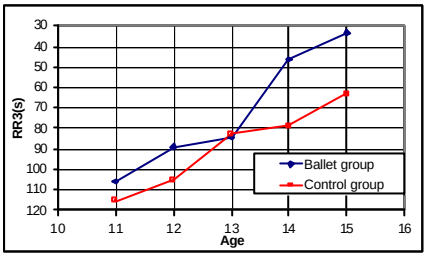


Fig. 9 The variability of movement differentiation (RR3) with age

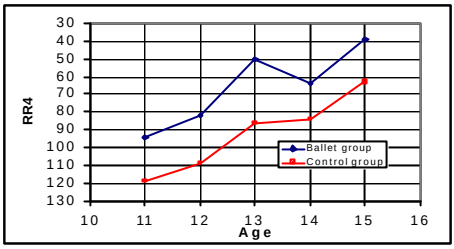


Fig. 10 The variability of movement differentiation (RR4) with age

The analysis of variance of sense of dynamic and static balance showed significant differences between average values in compared groups in all variables. The changes in the level of diagnosed variable with also showed significant changes in both tested groups (tab. 7)

Observation of variability of level of sense of dynamic balance (fig. 12 and 13) allow to state, that girls from ballet school reach significantly better results in this age period. In case of dynamic balance the best result appeared in the age of 14. Girls from ballet school showed better possibilities in sense of balance in comparison to control group. There was no significant increase in differences with age. These differences are the result of introductory selection to school.

Table 7. The analysis of variance of sense of dynamic balance (RD1, RD2)

Grouping variable	MS Efect	MS Error	F	p
RD 1				
1 - group	119,582	7,232	16,535	**0,001**
2 - age	33,122	7,232	4,580	**0,001**
RD 2				
1 - group	51,227	1,245	41,134	**0,001**
2 - age	10,285	1,245	8,258	**0,001**
RS 1				
1 - group	35,609	1,238	28,754	**0,001**
2 - age	11,816	1,238	9,541	**0,001**

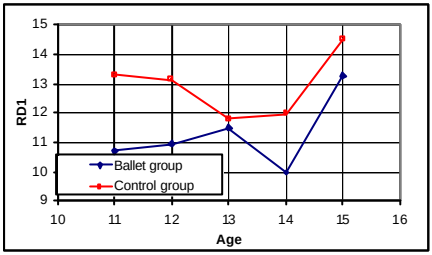


Fig. 11 The variability of sense of dynamic balance (RD1) with age

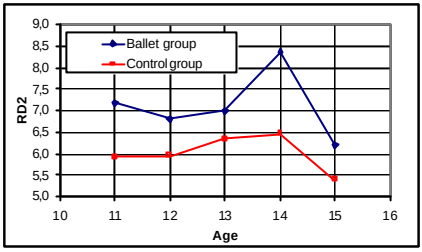


Fig. 12 The variability of sense of dynamic balance (RD2) with age

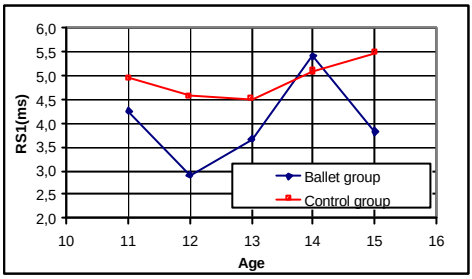


Fig. 13 The variability of sense of static balance (RS1) with age

The sense of rhythm was evaluated with two field-motor tests ("rhythmic hand tapping" – RT1 and the amount of cycles in test "rhythmic hand and leg tapping" – RT2). The analysis of variance showed statistically significant differences between tested groups of girls. Clear differentiation (p=0,001) appeared in both grouping factors; group and age of girls (tab. 8). It may be seen very clearly on fig. 14 and 15, where predominance of ballet school girls over girls from the control group in whole age period is significant.

Table 8. The analysis of variance of sense of rhythm (RT1, RT2)

Grouping variable	MS Efect	MS Error	F	p
		RT1		
1 - group	203,814	5,53042	36,8533	**0,001**
2 - age	31,0936	5,53042	5,62228	**0,001**
		RT2		
1 - group	267,299	2,2346	119,618	**0,001**
2 - age	33,204	2,2346	14,859	**0,001**

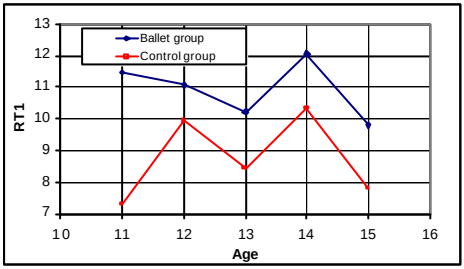


Fig. 14 The variability of sense of rhythm (RT1) with age

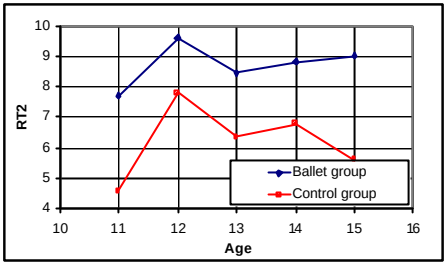


Fig. 15 The variability of sense of rhythm (RT2) with age

The speed of motor reaction was evaluated with the use of field tests and "RG" device from Vienna Test System, which allows to record different aspects of motor reaction. The analysis of variance of simple reaction time to visual stimuli (SR1) showed significant differences only between groups. Statistically insignificant were differences of variability with age (tab. 6), however the difference between age of 14 and 15 years seems to be quite dear. The curves on fig. 16 shoed the developmental variability of described ability suggests, that girls from ballet school are characterized with slightly better reaction time (excluding 13th year of age). These differences are statistically insignificant.

Table 9. The analysis of variance of time, speed of reaction (SR1, SR2) and time of simple movement (SR3).

Grouping variable	MS Efect	MS Error	F	p
		SR1		
1 - group	13018,4	2059,52	6,321	**0,012**
2 - age	1590,36	2059,52	0,772	0,544
		SR2		
1 - group	46368,3	4003,11	11,583	**0,001**
2 - age	4630,79	4003,11	1,156	0,331
		SR3		
1 - group	10775,6	1335,05	8,071	**0,005**
2 - age	1693,84	1335,05	1,268	0,284

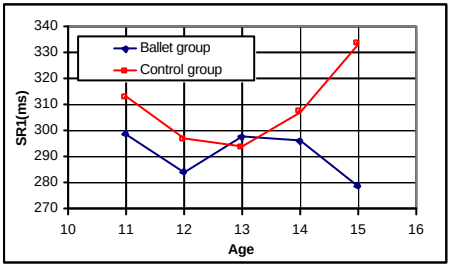


Fig. 16 The variability of simple reaction time (SR1) with age

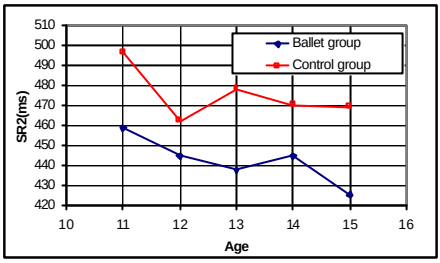


Fig. 17 The variability of speed of reaction (SR2) with age

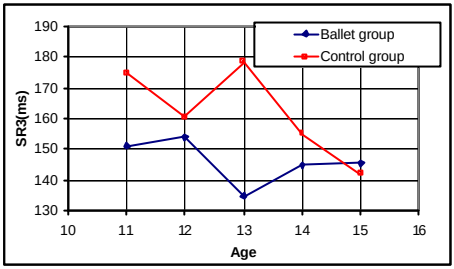


Fig. 18 The variability of speed of reaction (SR2) with age

Second variable describing the potential in area of motor reaction is speed of motor reaction (SR2). It is the sum of reaction time and simple movement time. The analysis of variance showed significant differences in area of tested groups. The age of girls appeared to be the factor which did not differentiated both populations (tab. 9). Presented on fig. 17 shape of curves showed, that girls from ballet school are better in case of SR2 variable from their control group. The difference did not increased with age what shows, that was the effect of introductory selection to school. The last variable related to motor reaction is time of simple movement (SR3). Similarly as in earlier variables age was not significant factor (only in 13 –year old girls) while group factor appeared once again to be statistically significant.

In order to perform more synthetic analysis of acquired empirical data the profiles of coordination fitness were calculated for both tested groups. These profiles were calculated on the basis of standardized values for each variable. It allowed comparing girls from different schools without age categories. The results U Mann-Whitney test are presented in table 10.

Table 10. The results of U Mann-Whitney test for specific variables in both tested groups

Variables	Sum of ranks in ballet group	Sum of ranks in control group	U	Z	p
SP1	6623,0	10397	3620,0	-1,402	0,161
SP2	6765,0	10255	3762,0	-1,003	0,315
SP3	7335,5	8417,5	3061,5	2,229	0,025
SP4	7117,0	8636	3280,0	1,579	0,114
RR1	5922,0	11098	2919,0	-3,368	**0,001**
RR2	5536,0	11484	2533,0	-4,452	**0,001**
RR3	6546,0	10474	3543,0	-1,618	0,105
RR4	5973,0	11047	2970,0	-3,225	**0,001**
RR5	6380,0	10640	3377,0	-2,083	0,037
RD1	5786,5	11233,5	2783,5	-3,749	**0,001**
RD2	9120,0	7900	2122,0	5,605	**0,001**
RS1	5218,0	11802	2215,0	-5,344	**0,001**
RT1	9242,5	7777,5	1999,5	5,948	**0,001**
RT2	10193,0	6827	1049,0	8,615	**0,001**
SR1	6083,0	9848	3308,0	-1,594	0,111
SR2	5489,0	10442	2714,0	-3,347	**0,001**
SR3	5671,0	10260	2896,0	-2,810	**0,005**
Body mass	3288,5	13731,5	285,5	-10,758	**0,001**
Body height	7044,0	9976	4041,0	-0,220	0,8257

Only six variables, which were taken into the calculation of coordination and somatic profiles, did not differentiate statistically significant girls from both groups. This group includes: all three variables from movement combining (SP1, SP2, SP3), one of aspects of movement differentiation (RR3) and speed of motor reaction (SR1), as well as the body height. Other 13 variables showed statistical significance in differences between girls from ballet school and control group. Presented profiles (fig. 19) is clearly visible which variables differentiated significantly (* - p=0,05). Symbol "*" appeared always on side of better result after logical (not mathematical) analysis. The results of this analysis confirmed and clearly verified the results of analysis of variance, where the same variables showed statistical significance. However, the differences in specific age groups, were not clearly different (analysis of variance), then with the use of standardized values in evident way appeared to be significant (the profile analysis).

The greatest differences between the girls from the ballet school and control group appeared in case of body mass, because the distance between two groups is in that case highest. The negative sign determines that girls from ballet school are significantly lighter from control girls in whole age period (11-15). It was also confirmed with the use of analysis of variance. Significant differences were also observed in case of sense of rhythm (RT1 and RT2), as well as sense of balance (RD1, RD2 and RS1). In case of these variables different signs (+) or (-) were dependent upon the interpretation of test results, in which lower (in mathematical sense) result was interpreted as expression of higher level of ability and vice-versa. Among other variables it possible to observe significant variability of results of test diagnosing movement differentiation in dynamic aspect (RR1 and RR2), as well as space-dynamic aspect (RR4 and RR%). Slightly smaller diversification was observed in case motor reaction (SR2 and SR3 and movement combining (SP3). In all case the results of analysis of variance confirmed the results acquired in standardized profiles.

Discussion

The problem of influence of increased movement activity on human organism is the scope of interest of sport scientists. The research projects on influence of movement stimuli on the level and dynamics of somatic and functional development focus on three main areas:

1. The evaluation of influence of different amounts of physical activity on human body.
2. The description of the degree of trainability of different somatic traits and motor abilities to external influences.
3. The evaluation of sensitivity (reactivity) of the human organism to movement stimuli in dependence of age and gender.

The subject of this paper embraces, in general, area of the first mentioned problems, and indirectly also third one. There were many research projects describing status of sport classes practicing from 8 to 12 hours of physical education per week. The results are diversified, mainly because of methodological mistakes, to which Szopa (1998) includes:

1. The accidental selection to sport classes, without proper selection criterion including basic somatic predispositions and motor abilities.
2. The lack of separation of two main factors influencing the level of development i.e. the introductory selection and movement activity (improper choice of control groups).

3. Cross-sectional character of studies which does not enable methodologically proper evaluation of development dynamics (non-homogeneous genetic character of subsequent classes).

The research problem of this paper was determination of different coordination fitness of ballet school students and control group, followed by evaluation of directed stimulation (large volume ballet practice i.e. 16 hours per week)on motor coordination abilities. From mentioned above reasons, typical for sport classes, this work also does not fulfill classical requirements for experimental design. In effect of selection process the ballet and control groups differed significantly already at the beginning of learning in ballet school. Author had no influence on selection to ballet school, however it is multistage and very selective. Each year, almost 150 candidates attempt to start ballet training, while only 30 is given this chance.

During data analysis it was shown that girls from ballet school differed significantly from control group in case of somatic traits. They were smaller but leaner. The variable which differed significantly was body mass, what is the effect of selection, because during next three years this difference disappears.

Girls from ballet school are generally better in area of coordination potential, than representatives from control group. It is possible then to verify positively the research hypothesis. During analysis it was evidenced that range of diversification is dependent on specific abilities. The most differentiating abilities were sense of rhythm and balance, as well as movement differentiation. In a lower degree it was speed of motor reaction and movement combining.

Interpreting the results more detailed it may be assumed, that significant regression of movement combining at the age of 14 years in girls from ballet school may be caused by pubertal spurt. This phenomenon occurred consequently in tested variables. Deceleration or regression of the level of all coordination aspects in pubertal spurt was confirmed by many authors (see review in Raczek et al. 1998, 2002). The significant developmental tendency in differentiation of spatial movement parameters confirms earlier observations, that first apogee of this ability appears at the age of 13-15 years (Hirtz 1985, Raczek and Mynarski 1992, Mynarski 1995, Raczek et al. 2002).

In case of sense of dynamic balance the best results were achieved by girls in age of 14 years, what from one side surprising, because it is already time of pubertal spurt and center of gravity raises. From other point of view it is probably the result of specific ballet training on the sense of balance and the high trainability of this ability. It may not by excluded also accidental fluctuations resulting from the small amount of subjects. It was confirmed by other authors (Raczek 1989, Wyznikiewicz-Kopp 1992, Juras 2003, and others). The reversed

occurrence was observed in case of static balance what very difficult to logical interpretation.

It seems interesting, that there was no significant developmental tendency in sense of rhythm with increased age. It underlines, that during selection to ballet school the level of sense of rhythm was already very high. However it seems to be obvious, then the proposal and recommendation of tests evaluating sense of rhythm as proper selection tool was suggested by authors.

From presented analysis appeared that in group of 19 analyzed variables, the grouping variable (ballet vs. control) was significant in 11 variables. The smallest differentiation was observed in case of body height and all variables explaining movement combining. Because the differences in explaining variables in many cases appeared to be statistically insignificant, in order to verify the results of ANOVA the analysis of coordination and somatic profiles was performed (U Mann-Whitney test). It which fully confirmed earlier results. The evaluation of developmental variability and fitness profiles, calculated for the whole populations seems to deny, that ballet training stimulates the development of coordination to a high degree.

Because of cross-sectional character of this study such a conclusion should be discussed as an assumption, not determined fact. Longitudinal research in this area are very rare and their result not univocal (Komorowski 1983, Ziemilska 1985). The cautiousness in conclusions formulation in this area suggests results of Szopa and Srutowski (1990). Authors in longitudinal study (1985-1988) evaluated the influence of increased amount of additional movement activity (track and field and handball classes). They stated that there was no influence of additional stimuli even on body composition. It was confirmed also by Malina et al. (1997) and Malina and Bielicki (1992, 1996). Similar facts mentioned above authors registered in case of motor fitness.

In general, it was stated that influence of additional activity (10-12 hours per week), typical for sport classes in Poland, has little influence on motor fitness and causes only maintenance of selection profits. Presented data seems to point, that similar occurrence exists in case of additional activity on coordination in girls from ballet school.

Conclusions

Presented above data allow formulating following conclusions:

1. Body leanness is the most characteristic somatic trait for candidates to ballet school.

2. The level of coordination is significantly higher in girls from ballet school than from control one.
3. These differences are caused mainly by the introductory selection, and in smaller degree by the ballet training.
4. In coordination structure in ballet student leading importance is played by sense of rhythm, kinesthetic differentiation and sense of balance.
5. Age of tested subject influences chosen aspects of coordination only in a small degree.

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