POSTURE IN TOP-LEVEL CROATIAN RHYTHMIC GYMNASTS AND NON-TRAINEES

Josipa Radaš and Tatjana Trošt Bobić

University of Zagreb, Faculty of Kinesiology, Zagreb, Croatia

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Abstract:

The main goal of the study was to determine the influence of the long-term rhythmic gymnastics training process on certain motor abilities and on the posture of elite Croatian rhythmic gymnasts. The sample was composed of 35 girls aged 12.89 (±2.32) years from Zagreb, Croatia. Fifteen of them were rhythmic gymnasts who have trained 8.93 hours per week on average, for at least 5 years. The control group consisted of 20 female pupils of the primary school "Borovje" who were not engaged in any regular sporting activity beside physical education classes. The measures consisted of 17 postural variables and 8 tests assessing motor abilities. The *t*-test for independent samples showed marked statistical differences in arithmetic means between the two groups for all the motor variables. *Mann-Whitney U* test showed no differences between the two groups in all the posture variables, but one. The two groups differed significantly only in the variable *kyphosis*, showing that poor kyphotic posture was more frequent in non-trainees (p=.03). The variables *Lorenz's triangle* and *frontal shoulder position* almost reached statistical significance (p=.06 and p=.07, respectively). Although the mentioned results failed to fall within the range of statistical significance, they are of substantial clinical importance, showing the tendency to a greater frequency of poor scoliotic posture in rhythmic gymnasts. The obtained results pointed out the positive side of sport: a good level of motor abilities and a minor incidence of poor kyphotic posture. Clinically, the results also indicate some sport-specific postural problems that may occur due to asymmetric overload. However, since statistical significance was not reached, there is a need to investigate further the influence of persistent asymmetric overloading of the spine on rhythmic gymnasts` posture.

Key words: *rhythmic gymnastics, posture, asymmetric loading, functional asymmetry, long-term practice, kyphotic posture, scoliotic posture, Lorenz's triangle*

Introduction

Every sport has its specific physiological and biomechanical demands. Sporting performance strongly depends on the way the musculoskeletal system of athletes complies with these demands (Kibler & Chandler, 2003). These sport-specific demands change with the level of skill, intensity or frequency with which the sport is done, usually growing with the competition level. The continuous responding to a specific set of inherent demands may, after a period of time, lead to strength imbalance between agonistic and antagonistic muscle groups (Ratamess, et al., 2009; Kums, Leht, Nurmiste, & Pääsuke, 2008; Desnica Bakrač, 2003), as well as to a local deficiency in flexibility (Croisier, Forthomme, Namurois, Nanderthommen, & Crielaard, 2002). Such problems are usually caused by the excessive utilization of some rather than other muscle groups or even parts of the body, and may be responsible for the development of sport-specific postural problems (Kums, Ereline, Gapeyeva, Pääsuke, & Vain, 2007). In addition, this sport-specific utilization of the body may result in a chronic pain syndrome like tennis elbow, jumper's knee and swimmer's shoulder (Bak & Magnusson, 1997), or it can render an athlete more prone to some acute injuries (Croisier, et al., 2002). For example, relatively stronger trunk extensors than trunk flexors may lead to low back pain in alpine skiers (Desnica Bakrač, 2003) and rhythmic gymnasts (Kums, et al., 2008). Relatively decreased knee flexor and increased knee extensor strength in female soccer and basketball players may result in anterior cruciate ligament (ACL) tears (Myer, et al., 2009). Most sports encourage the usage of one side of the body, consequently the unilateral or cross-lateral development. This is difficult to avoid in sports like team handball, basketball, water polo and tennis in which athletes mostly use the dominant hand and the opposite take-off leg. On

the other hand, according to the Code of Points of aesthetic sports, like rhythmic gymnastics, artistic gymnastics and figure skating, equal usage of both sides of the body should be encouraged during the training process as well as during competition. Such an approach is followed by a better performance and a higher mark at the competition. Based on that, one can assume that in rhythmic gymnasts there will be no asymmetric utilization of the body that could cause postural problems.

However, it has been well documented that long-lasting asymmetric overloading of the spine, accompanied with other risk factors such as delayed menarche and generalized joint laxity, may cause scoliosis in young rhythmic gymnasts (Loud & Micheli, 2001; Tanchev, Dzherov, Parushev, Dikov, & Todorov, 2000). Furthermore, functional overloading of the spine in elite rhythmic gymnasts may lead to flat back syndrome (Kums, et al., 2007; Kums, et al., 2008; Tanchev, et al., 2000; Tsai & Wredmark, 1993) as well as to idiopathic low back pain (Kums, et al., 2008; Harrison, et al., 2005; Gardocki, Williams, R., & Williams, L., 2002). Flattened spinal curvature in the thoracic and lumbar part of the spine causes decreased spinal range of motion and loss of sagittal spinal balance, which places the *erector spinae* muscle group in a mechanically disadvantageous position (Gardocki, et al., 2002). This leads to an increase in activity of the trunk extensor muscles, as well as to a greater load of the intervertebral discs in the lower thoracic and lumbar region causing low back pain (Kums, et al., 2008; Harris, Kuramoto, Schulzer, & Retallack, 2009).

According to the current knowledge, the identification of postural problems that are typical for most sports is of great importance in the prevention of structural deformities, pain syndrome or acute injuries in athletes. The aim of this study was to determine the influence of long-term rhythmic gymnastics practice on certain motor abilities and on the posture of top-level Croatian rhythmic gymnasts.

Material and methods

Subjects

The study included 35 girls, aged 12.89 (±2.32) years from Zagreb, Croatia. Fifteen of them were rhythmic gymnasts 13.33 (±3.27) years old, who have trained 8.93 (±2.91) hours per week on average, for at least 5 years (7.9±2.55). The majority of them were medal winners at national competitions, and some of them were members of the Croatian national team. The control group consisted of 20 girls 12.55 (±1.23) years of age, pupils of the primary school "Borovje", Zagreb, and were not engaged in any regular sporting activity beside physical education classes. The basic characteristics of the subjects are presented in Table 2 (see Results section). All the subjects gave their written informed consent, whereas parents gave written consent for the subjects who were minors.

Posture evaluation

Postural evaluation consisted of a head-to-toe examination of the subject's musculoskeletal system. The *forward bend* test (Hackenberg, Hierholzer, Bullmann, Liljenqvist, & Götze, 2006) for the evaluation of the paravertebral muscles aspect was also included. Two expert kinesitherapists evaluated the subjects' posture individually, yet, according to a previously prepared protocol. They both had a sheet in which they registered the presence of a posture problem. If there was a problem, they wrote down the number previously assigned to that specific problem. Taking into consideration the limitations of an expert evaluation, comparing it to the more sophisticated diagnostic methods such as computed tomography or x-ray, the experts decided not to grade the detected postural problem. They rather estimated the marked existence of a certain postural problem (i.e. increased lumbar spine lordosis). They made their judgement only upon the existence or the absence of a postural problem based on their eleven years' clinical experience of working in the field of child kinesitherapy. The absence of a problem was marked with "0". The checked variables were *head position in the frontal plane*, *side head position*, *neck position in the frontal plane*, *side neck position*, *shoulders position in the frontal plane*, *shoulders position in the sagittal plane*, *thorax aspect*, *shoulder blades position*, *scapulae alatae*, *lordosis*, *kyphosis*, *scoliosis*, *Lorenz's triangle*, *spina iliaca anterior superior position*, *knees aspect* and *flat feet*. After the separate posture evaluations, the kinesitherapists compared their check sheets. If there was any non-agreement, they discussed it until agreement upon it has been reached. Oftentimes they agreed, but if they did not share the same opinions even after a discussion, they asked a third expert to evaluate the whole posture of that specific subject and the decision of the majority was taken as valid. *Side head position* (*head forward*) and *side neck position* (*decreased neck lordosis*) were not registered in any of the subjects. These variables were therefore not included in the statistical analysis.

Motor tests

After the postural evaluations, the subject performed 8 motor tests – five tests for the evaluation of the flexibility of different parts of the body, one test to determine abdominal muscles' endurance and two to determine their balance capabilities. Table 1 presents the structure of the test battery applied.

The *shoulder circumduction* test consisted of an extended arms circle backwards with a stick while maintaining the grip as narrow as possible. The result was recorded in centimetres (cm). The task was performed three times. The *forward bend* test requires a forward bend of the trunk from a standing position on a bench with the legs extended. The result was also recorded in centimeters. The task was performed three times. The *right/left leg forward lift* and the *right/left leg backward lift* were two tests that have been previously used to evaluate active flexibility in young athletes (Miletić, Sekulić, & Wolf-Cvitak, 2004; Metikoš, Prot, Hofman, Pintar, & Oreb, 1989). They consisted of an active leg lift from a supine position (*forward leg lift*) or from a prone position (*backward leg lift*). When performed from the supine position, the test may also be called *leg split* (Miletić, Sekulić, & Wolf-Cvitak, 2004; Hume, Hopkins, Robinson, & Hollings, 1993). A surface with marked degrees of movement was placed on the wall next to the subject. The examiner registered the degrees of movement. The tasks were performed three times with each leg. The *sit-up* test consisted of as many sit-ups as possible performed in 30 seconds from the lying position with the knees bent at 45° and arms crossed behind the head. The number of sit-ups performed represented the main outcome. The task was performed only once. The *bilateral* and *unilateral balance stance* tests were conducted on an appropriate balance bench 2 cm wide (Wolf-Cvitak, 1993; Metikoš, et al., 1989; Tkalčić, 1987). The tests consisted of the two-leg (bilateral) and one-leg (unilateral) standing on the bench with the arms beside the trunk and the eyes directed toward a fixed mark in front of the subject. The time spent on a bench (in milliseconds) was recorded as a result. The tasks were performed three times. The mean score of every motor test but one (the *sit-up test*) was extracted for further analysis. Metric characteristics of all tests were well known and previously reported (Meyers, Golding, & Sinning, 1978 in Maud, 1983; Metikoš, et al., 1989; Mraković, Findak, Metikoš, & Neljak, 1996). Additionally, several authors have used a number of these tests to evaluate basic motor abilities in young gymnasts (Miletić, Sekulić, & Wolf-Cvitak, 2004; Wolf-Cvitak, 1993; Hume, et al., 1993) and primary school pupils (Novak, 2010) and reported their good reliability. Reliability for the new *back extension* test was verified by the .99 Cronbach's alpha value. The *back extension* test implied trunk hyperextension measuring in grades. Metric characteristics of the back extension test, including sensitivity, validity, reliability and

Table 1. Motor tests and postural measures

Abbreviation	Measure and test	Ability/Dimension
F-1	Shoulder circumduction	Upper extremity flexibility
F-2	Forward bend on the bench	Lower extremity flexibility
$F\text{-}3_R$, $F\text{-}3_L$	Right/Left leg forward lift	Lower extremity flexibility
$F\text{-}4_R$, $F\text{-}4_L$	Right/Left leg backward lift	Lower extremity flexibility
F-5	Back hyperextension	Trunk flexibility
ME	Sit-ups	Abdominal muscles endurance
B-1	Bilateral balance stance	Bilateral balance
B-2	Unilateral balance stance	Unilateral balance
P-1	Head position in the frontal plane	Head posture
P-2	Neck position in the frontal plane	Neck posture
P-3	Shoulder position in the frontal plane	Posture of the shoulders
P-4	Shoulder position in the sagittal plane	Posture of the shoulders
P-5	Thorax aspect	Thorax posture
P-6	Shoulder blades position	Posture of the shoulder blades
P-7	Scapulae alatae	Posture of the shoulder blades
P-8	Lordosis	Trunk posture
P-9	Kyphosis	Trunk posture
P-10	Scoliosis	Trunk posture
P-11	The triangle formed by the lateral part of the trunk, and the medial part of the forearm and upper arm, established in the upright position (the Lorenz's triangle). In case of scoliotic poor posture, the Lorenz's triangle is greater on the concave side.	Trunk posture
P-12	Spina iliaca anterior superior position	Posture of the hips
P-13	Knees aspect	Posture of the knees
P-14	Flat feet	Posture of the feet

homogeneity have been recently published (Trošt Bobić & Radaš, 2010). Data about the subject's *body height*, *body weight*, *dominant hand* and *date of menarche* were also collected.

Statistical analyses

The data were analysed using the Statistical Package for Social Sciences (ver. 11.0). The *t*-test for independent samples was used to calculate the differences in arithmetic means between the two groups in motor variables. Frequencies of each postural problem in both groups were calculated, and the Mann-Whitney U test was used to determine the differences in the prevalence of postural problems between trainees and non-trainees.

Results

T-test showed no significant differences in growth, anthropometric, maturation and dominant hand variables between the trainees and non--trainees (Table 2).

The *t*-test for independent samples showed marked statistical differences in arithmetic means between the two groups for all the motor variables (Table 3).

Mann-Whitney U test showed no difference between the two groups in all the posture variables, but one (Table 4). There was statistically significant difference only in the variable *kyphosis* (P-9), showing that the poor kyphotic posture was more frequent in non-trainees (p=.01). The variables *Lorenz's triangle* (P-11) and *frontal shoulders position* (P-3) almost reached statistical significance (p=.06 and p=.07, respectively), showing a tendency to a greater frequency of poor scoliotic posture in rhythmic gymnasts. A possible reason for remaining outside the statistical significance level range could be the size of the sample.

Table 2. Growth, anthropometric, maturation and dominant hand data of rhythmic gymnastics trainees and non-trainees

	Non-trainees	Trainees	*t*-test
Age (yrs)	12.55±1.23	13.33±3.27	p=.33
Height (cm)	161.45±8.39	156.37±14.26	p=.20
Body weight (kg)	47.15±11.49	44.27±12.61	p=.49
Body mass index (kg/m^2)	17.83±3.15	17.65±2.09	p=.85
Menarche (%)	60.00	53.33	p=.89
Right-handed (%)	100.00	99.00	p=1.00

Table 3. Results of the t-test for independent samples implemented in the motor tests

Motor tests	Mean - trainees	Mean - non-trainees	t-value	df	p	SD – trainees	SD – non-trainees	F-ratio	p
F-1	38.60	75.90	-6.70	33	.00000	11.47	19.09	2.77	.0572
F-2	18.28	2.65	4.83	33	.00003	8.44	10.18	1.45	.4803
F-3$_R$	141.89	88.75	9.31	33	.00000	13.35	18.82	1.99	.1942
F-3$_L$	139.56	81.00	9.40	33	.00000	13.91	20.85	2.25	.1274
F-4$_R$	71.00	47.58	5.65	33	.00000	11.83	12.36	1.09	.8833
F-4$_L$	72.56	49.58	5.46	33	.00000	11.18	13.09	1.37	.5535
ME	23.60	18.60	3.24	33	.00271	3.11	5.32	2.92	.0461
F-5	85.00	46.33	7.60	33	.00000	17.75	12.37	2.06	.1434
B-1	2.62	1.95	2.67	33	.01163	.97	.51	3.71	.0089
B-2	6.38	2.53	5.60	33	.00000	2.92	.87	11.29	.0000

Table 4. Mann-Whitney U test for posture variables

Posture variables	Rank sum – trainees	Rank sum – non-trainees	U	Z	p-level	Z	p-level	2*1sided
P-1	262.50	367.50	142.50	-.23	.82	-.29	.77	.81
P-2	278.50	351.50	141.50	.27	.79	.33	.74	.78
P-3	318.50	311.50	101.50	1.60	.11	1.84	**.07**	.11
P-4	297.50	332.50	122.50	.90	.37	1.24	.22	.36
P-5	280.00	350.00	140.00	.32	.75	1.10	.27	.75
P-6	306.50	323.50	113.50	1.20	.23	1.36	.17	.23
P-7	269.00	361.00	149.00	-.02	.99	-.02	.98	.99
P-8	284.00	346.00	136.00	.45	.65	.53	.60	.66
P-9	204.50	425.50	84.50	-2.17	.03	-2.68	**.01**	.03
P-10	285.00	345.00	135.00	.48	.63	.51	.61	.63
P-11	323.00	307.00	97.00	1.75	.08	1.87	**.06**	.08
P-12	262.50	367.50	142.50	-.23	.82	-.81	.42	.81
P-13	273.50	356.50	146.50	.10	.92	.11	.91	.91
P-14	319.50	310.50	100.50	1.63	.10	1.67	.10	.10

Discussion and conclusions

No differences between the groups were found for the variables *body height* (p=.20), *body weight* (p=.49), *body mass index* (BMI) (p=.85) and *menarche* (p=.89), meaning that the samples were similar in their growth (Table 2). Such data indicate that the main findings of this paper, for all the motor and certain body posture variables (P-9, P-11, P-3), could be attributed to their distinctive level of physical activity rather than to their growth characteristics. However, there is a need to explain better the absence in body weight and BMI difference between elite trainees and non-trainees since this contradicts the current knowledge in the field. In order to do so, BMI was calculated for each subject separately. The BMI values of the trainees ranged from 14.4 to 20.7.

Since BMI is a measure strongly dependent on the stage of maturation, Cole et al. (2000) developed an internationally acceptable definition of child overweight and obesity, specifying the measurement, the reference population and the age and gender-specific cut-off points, based on a survey conducted on 97,876 males and 94,851 females from birth to 25 years of age from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States. According to those internationally accepted cut-off points, no overweight or obese subject was found in the *trainees* group; however, 40% of them were even judged as *too skinny.* The BMI values for the non-trainees ranged from 11.1 to 25.8, with the first one identified as too skinny and the last one identified as overweight (according to Cole, et al., 2000). Since BMI is a measure of body composition that reflects skeletal and both fat and fat-free components of body weight, it is possible that the two groups studied in this investigation vary with respect to relative amounts of lean body mass and body fat. The distribution of body fat may vary among individuals or populations and it has been recently demonstrated that physical activity may increase lean body mass and decrease body fat with no overall change in BMI or body weight (Harris, et al., 2009). To find any differences in the body composition between the subjects pertaining to these groups as a consequence of different levels of physical activity, measures such as waist circumference, skin-fold thickness and percentage body fat should have been evaluated.

However, the *t*-test for independent groups showed a significant difference between the groups in all the motor variables. Rhythmic gymnasts had markedly better flexibility, balance and muscular endurance (Table 3). One may speculate that the found difference in muscular endurance may represent a functional outcome of a non--measured percentage of lean body mass in favour of the *trainees* group. Yet, this will remain only an assumption in the present research.

The results obtained by the *t*-test for independent groups, which pointed out the differences between the trainees and non-trainees in the measured motor abilities, are in concordance with the results of many other studies that confirmed the positive effect of regular physical activity on the level of motor abilities in children as well as in adults (Malina & Bouchard, 1991; Mraković, et al., 1996). Jurak, Kovač and Strel (2006) have found a significant difference in muscular endurance (measured by applying the *30-second sit-up test*) between secon-

dary school pupils who were and were not enrolled in two additional classes of physical education per week, in favour of the more active ones. Based on their longitudinal four-year study, they concluded that the additional programme of sports classes had a positive impact on the development of the participant`s motor abilities. Recently Ivković (2007) established a much higher level of motor abilities in girls aged 13-14 who did basketball three times per week compared to age-matched controls. Likewise, it is common knowledge that sedentary children have lower levels of motor abilities, reduced physical performance and increased body fat compared to active peer children and that such differences are often accompanied by an increase in overweight associated with co-morbidities such as insulin resistance diabetes or the metabolic syndrome (for a review see Graf, 2010). Therefore, based on the results obtained by the *t*-test for independent groups, it is feasible to assume that long--term practice of rhythmic gymnastics may, like other sports, positively influence motor abilities of those involved.

As for the body posture variables, the two groups differed significantly only in P-9 variable, showing that the poor kyphotic posture was more frequent in non-trainees (p=.01). Only one increment and one decrease of the physiological thoracic kyphosis were found in rhythmic gymnasts. The absence of kyphotic problems is probably due to the aesthetic demands of rhythmic gymnastics which implies an elegant posture. Elegance is determined by many factors, some of which are elongated neck, shoulders held backwards, pelvis back tilt, straight abdomen, extended knees, and slightly open foot position. Since it has been previously demonstrated that gymnasts have stronger trunk extensors than flexors due to specific training loads (Kums, et al., 2008; Harris, et al., 2005; Gardocki, et al., 2002), the factor that probably has played a role in the absence of poor kyphotic posture in rhythmic gymnasts is the specific training load and the everyday demand to withstand those loads in an elegant, upright position.

Contrary to our results obtained on the top--level Croatian gymnasts (physiological thoracic kyphosis), Tanchev et al. (2000), using a similar examination protocol on Bulgarian gymnasts, observed that almost all of 100 subjects, from 10 to 16 years of age, had a flat back posture (the decreased physiological thoracic kyphosis and lumbar lordosis). They explained their results with the elegance and outer appearance required for the girls practising rhythmic gymnastics. A possible reason for a distinction in the posture between the Croatian and Bulgarian rhythmic gymnasts could be found in their different training schools. Although the Croatian sample was significantly smaller than the Bulgarian one, based on the obtained results (only one decreased thoracic kyphosis), it would be hard to expect a significantly higher incidence of flat back posture even by increasing the size of our sample. Besides postural changes in the sagittal plane (flat back), Tanchev et al. (2000) also detected some postural changes in the frontal plane in the Bulgarian rhythmic gymnasts. By using the x-ray imaging, they found scoliotic structural changes of the spine. The authors defined three main factors for the occurrence of poor scoliotic posture in the examined Bulgarian rhythmic gymnasts: generalized joint laxity, delayed maturity and asymmetric spinal load. These three main factors were named "the dangerous triad".

As for the frontal postural changes detected in the current study, only two variables approached statistical significance: the *Lorenz's triangle* (P-11, p=.06) and the *frontal shoulders position* (P-3, p=.07) (Table 4). Although the variables did not reach a statistical significance at the level of p<.05, it should be pointed out that 73.3% of the gymnasts had increased *Lorenz's triangle* values, indicating the side bend of their trunk, and 60% of them had one lowered shoulder. According to recent recommendations of statisticians (Hopkins, 2000), clinically important data should not be excluded from the discussion even though they only approached statistical significance. Since the Lorenz's triangle and the lowered shoulder are postural parameters that measure scoliotic postural changes often used in clinical practice (Filipović & Ciliga, 2010), it is the authors' opinion that detected 73.3% of increased *Lorenz's triangle* and 60% of *lowered shoulders* on the same side are of substantial clinical importance and will therefore be discussed in the following text.

Almost all the lowered shoulders and the Lorenz's triangles were detected on the dominant side of the body as determined according to the dominant hand. The constant usage of the dominant hand (in this case, the right one) for the performance of technical elements with various apparatuses could have caused that. Previous investigators have described a more frequent usage of the dominant body side during everyday life tasks as well as during sporting activities (Farthing, 2009). In addition, it is well established that the dominant limb may exert greater force than the non--dominant one (Munn, Herbert, & Gandevia, 2004). A very typical feature of rhythmic gymnastics is performing with different small hand apparatuses (rope, hoop, ball, ribbon and clubs). Gymnasts usually perform technical elements (swings, circles, rolls, bounces, rotations, figure of eights, throws and catches) with their dominant hand. Jastrjembskaia and Titov (1999) estimated ambidexterity coefficient in rhythmic gymnasts. For the ball, hoop and ribbon it was 41% and less, while for the clubs and rope it was 21% and less. This functional asymmetry

is especially pronounced in competitive sport (Starosta, 2000). The asymmetry of movement has been observed during gymnastics exercises (Maznićenko, 1959, in Starosta, 2000), but most surprisingly even in the breaststroke in swimming (Czabański & Koszczyc, 1982, in Starosta, 2000) which is considered to be the most symmetrical of all strokes. If one takes into account the more frequent usage of the dominant side in rhythmic gymnasts (Jastrjembskaia & Titov, 1999) as well as the knowledge of a greater force that could be exerted by the dominant limb in contrast to the non-dominant one, it seems reasonable that in the rhythmic gymnasts measured in this investigation the shoulder was lowered and the Lorenz's triangle was greater on their dominant body side. However, these results only indicate a tendency to develop postural changes in the frontal plane, rather than structural scoliotic changes. Even though Tanchev et al. (2000) detected structural scoliotic changes in Bulgarian rhythmic gymnasts as a consequence of an asymmetric loading of the spine, pelvis and lower limbs (Tanchev, et al., 2000), it should be pointed out that only one of our trainee subjects had scoliotic deformities (with a Cobb's angle of 16º confirmed by x-ray imaging). Croatian rhythmic gymnasts had a marked flexibility (Table 3) as well as asymmetric spine loading (73.3% of them had a greater Lorenz's triangle on one side and 60% of them had lowered shoulder on the same side on which the Lorenz's triangle was greater) but no signs of delayed puberty were registered (Table 2), meaning that "the dangerous triad", as defined by Tanchev et al. (2000), was not complete. In line with that, structural scoliotic changes were not detected. Since the sample in the current study was relatively small, it is also important to extend this investigation on a bigger group of rhythmic gymnasts, maybe even of a lower level of competition, in order to find out if the asymmetrical poor posture is typical for rhythmic gymnastic trainees. This information could be important for the prevention of poor posture-specific problems in rhythmic gymnasts.

Given that previous investigations showed delayed maturation in female athletes practising aesthetic sports (Castelo-Branco, Reina, Montivero, Colodrón, & Vanrell,, 2006), the authors recorded the date of the menarche in order to see if the Croatian top-level rhythmic gymnasts also had the delayed menarche problem. According to our data, the Croatian gymnasts, who have trained 8.93 (±2.91) hours per week, for at least 5 years (7.9±2.55) and who were medal winners at national competitions, some of them being even members of the Croatian national team, did not have delayed menarche. Since two main causes of delayed menarche reported in literature are great training loads and a low percentage of body fat (Castelo--Branco, et al., 2006), it is important to point out that the Bulgarian girls trained almost 5 hours a day, 6 days a week, whereas the training volume of the Croatian girls was significantly smaller (8.9±2.91 hours per week).

Practical implications

Long-term everyday sports practice leads to significantly better levels of motor abilities in rhythmic gymnasts, causing at the same time a tendency to develop some asymmetries in their posture. It has previously been established that rhythmic gymnasts prefer to use the dominant hand when performing (Jastrjembskaia & Titov, 1999). Likewise, soccer players usually choose to kick a ball with their so-called "preferred leg", the one that they feel more comfortable kicking with (Munn, Herbert, & Gandevia, 2004). A recent study on the influence of leg preference on bilateral muscle activation during cycling (Carpes, et al., 2011) shows a statistically higher variability of muscle activity in the *gastrocnemius medialis* and *vastus lateralis* muscles of the non-preferred leg during cycling. Based on that knowledge, it seems reasonable to expect that rhythmic gymnasts use the dominant body side to leap or to throw a club much more often than the non-dominant one during their training sessions. Despite their knowledge that the usage of both body sides will result in a better mark at the competition, they simply choose to perform an element in a more confident way. Coaches should take into consideration this fact and stress the equal usage of both limbs during training sessions, which should, in time, result with a much more confident performance even with the non-dominant limb. Coaches should include in their programmes the exercises for the right and the left side of the body from the very beginning of the practice with children. This approach should promote the ability of the brain to reorganize neural pathways based on new experiences (brain plasticity) by means of transferring a skill from one part of the body to the other (Starosta, 2000), or by learning new skills with both parts simultaneously. New knowledge from the field of neurology indicates coordination training for the upper limbs may modify the primary motor cortex (M1) maps of one proximal muscle and one distal muscle activated alone and during their co-contraction (Tyč & Boyadjian, 2011). The cortical representation area of the trained muscles may increase after coordination training which suggests the development of overlapping zones specifying functional synergies between distal and proximal muscles (Tyč & Boyadjian, 2011). The development of overlapping zones has also been detected during maximal unilateral training leading to cross-education in strength (strength improvement in the muscles of the contralateral resting arm). These findings support the idea that training of a coordinated movement

involving several muscles and joints requires an activity-dependent coupling of cortical networks that may be improved with training. The Code of Points in rhythmic gymnastics also prefers, even prescribes, the use of both body sides. Therefore, the inclusion of symmetric exercises in the training process of young gymnasts would result in a better performance, as well as in a better posture. This method may prevent poor posture in athletes, eventually prolonging their careers and assure a higher level of competition.

In conclusion, long-term rhythmic gymnastics practice resulted in significantly better flexibility, balance and dynamic muscular strength endurance for the trained girls. Moreover, it seems that the persistent upright position, according to the aesthetic demands of rhythmic gymnastics (elongated neck, shoulder hold backwards, back tilt of the pelvis, extended knees, and slightly open foot position) have prevented poor kyphotic posture that was found in the control peer subjects who did not practise any sport in their leisure time. On the other hand, the persistent asymmetric overloading of the spine (preferred performance with the dominant limb), could have lead to a tendency found to develop poor scoliotic posture (but not to the structural spine changes) in trainees. The obtained results pointed out the positive side of the sport (good level of motor abilities and minor incidence of poor kyphotic posture), but also indicated some probable specific postural problems occurring due to asymmetric overload. Although the sample used in this investigation was not very large, it should be pointed out that scoliotic problems were found in a larger sample of Bulgarian rhythmic gymnasts (Tanchev, et al., 2000). Therefore, the persistent asymmetric overload of the spine should be minimized in the training process with young gymnasts in order to prevent possible later postural problems.

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POSTURA U VRHUNSKIH HRVATSKIH RITMIČARKI

Glavni je cilj ovoga istraživanja bio utvrditi utjecaj dugoročnoga treniranja ritmičke gimnastike na posturu i neke motoričke sposobnosti vrhunskih hrvatskih ritmičarki. Uzorak ispitanica činilo je 35 djevojaka iz Zagreba u dobi od 12,89±2,32 godina. Petnaest su bile ritmičarke koje treniraju u prosjeku 8,93 sati tjedno, u periodu od najmanje 5 godina. Kontrolnu skupinu činilo je 20 učenica Osnovne škole "Borovje" koje osim nastave tjelesne i zdravstvene kulture nisu aktivno sudjelovale ni u jednoj dodatnoj sportskoj aktivnosti. Praćeno je 17 posturalnih i 8 motoričkih varijabla. *T-testom za nezavisne uzorke* utvrđene su značajne razlike između skupina u svim motoričkim sposobnostima. *Mann-Whitneyjevim U* testom utvrđena je značajna razlika između kontrolne i eksperimentalne skupine samo u posturalnoj varijabli *kifoza* (p=0.01) koja je bila učestalija u kontrolnoj skupini. Razlike između kontrolne i eksperimentalne skupine u varijablama *Lorenzov trokut* (p=.06) i *položaj ramena frontalno* (p=0.07) na granici su statističke značajnosti. Iako se rezultati u tim varijablama samo približavaju statističkoj značajnosti, za kliničku su praksu važni jer pokazuju tendenciju pojave skoliotičnoga lošeg držanja u ritmičarki. Dobiveni rezultati ukazuju na pozitivne učinke dugogodišnjega bavljenja sportom (bolja razina motoričkih sposobnosti i manja učestalost kifotičnoga lošega držanja). Klinički gledano, rezultati također upućuju na specifične posturalne probleme do kojih bi u budućnosti moglo doći nastavi li se asimetrično opterećenje. Ipak, s obzirom na to da statistička značajnost nije postignuta, postoji potreba za daljnjim istraživanjem utjecaja ustrajnoga asimetričnoga opterećenja kralježnice na posturu ritmičarki.

Ključne riječi: *ritmička gimnastika, postura, asimetrično opterećenje, funkcionalna asimetrija, dugoročno treniranje, kifotična postura, skoliotična postura, Lorenzov trokut*

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Correspondence to:
Tatjana Trošt Bobić, MagEd, Research Novice
University of Zagreb, Faculty of Kinesiology,
Department of Basic and Applied Kinesiology
Horvaćanski zavoj 15, 10000 Zagreb, Croatia
Phone: +385 91 5454279
E-mail: tatjana.trost@kif.hr

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