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Research Article

The relationship between postural components and muscle strength balance among 9 to 14-year old children

Abstract

Study was to examine the differences between the strength of linked agonist and antagonist muscles according to their location and postural role. Study included 102 schoolchildren: age 11,28±1,55 (x ±SD); BMI 18,87±3,71. Body posture was assessed visually in the sagittal plane (neck, chest, shoulders, upper back, trunk, abdomen, lower back position) and in the frontal plane (head, shoulders, spine, hips, feet, arches position) using the New York State Posture Rating Chart. Each component was rated on a scale 5 (normal), 3 (slightly deviated), 1 (markedly deviated). Maximal isometric muscle strength was measured with manual dynamometer on the muscles: neck flexors and extensors, upper and lower part of pectoralis major, middle and lower part of trapezius, trunk flexors and extensors, hip flexors and extensors, hip adductors and abductors. Children were divided into two groups: normal posture and deviated posture. We found that the detrimental effect on the posture of the divergence in strength between opposing muscles was dependent on their location. There were cases of pronounced strength imbalance among children with normal posture, for example in relationship of hip extensors to hip flexors, while deviated posture group showed negligent imbalance. On the other hand, children with postural deviation appear to have imbalances in other locations. For example, in the relationship of the pectoralis group to the trapezius. Likely explanation is that there are normal differences between anterior and posterior muscle groups, but posture related problems seem to be dependent on the strength imbalance of antagonistic muscle groups at a specific location.

Introduction

Poor posture is a common problem among schoolchildren. The most frequently occurred defects in frontal plane are scoliosis [1] and protruding scapulae [2,3], in sagittal plane there is increase in lumbar lordosis [1,2] and thoracic kyphosis [2,4].

Already in 2004, Kopecky brought out: "The main reason for the defective posture is muscular dysbalance, the so-called upper-cross syndrome and lower cross syndrome manifested in keeping the head stuck forward, a round back, outstanding shoulder blades, high pelvis inclination accompanied with lumbar lordosis, and in many cases with loose abdominal muscles." It is known that upper crossed syndrome is related to the weakness in the neck flexors in front of the neck and also weakness in the middle and lower trapezius together with the rhomboid muscles on the back side of the chest, but on the other hand with shortened and tight upper trapezius together with levator scapulae on the back side of the neck and pectoralis minor and major in front of the chest [5]. Likewise, weak and tight muscles are crossed on lumbar region, identified as lower crossed syndrome. There are thoracolumbar extensors and iliopsoas together with rectus femoris in the shortened and tight muscle group, and abdominals together with gluteus medius and maximus on the weak group [5]. Poor posture is also related to a lower value in isokinetic strength of the trunk muscle [6] and also to a lower endurance capacity of trunk muscles, especially for hyper-lordotic spine [4]. But we cannot find studies describing the ratios of muscle strength and grouping that assess the size of differences between the agonists and antagonists according to the impact on deviations in the posture. However, the agonist/antagonist ratio of muscular strength may play an important role in clinical functional analysis and rehabilitation [7].

With the aim of exploring the issue, purpose of the study was to examine differences between strength of linked agonist and antagonist muscles according to their location and role in the posture.

Methods

This study was carried out in spring 2014, in an Estonian private school, at a school doctor's office. Study informed and

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inquired approval from all parents of participating pupils from 3rd to 7th grade. As a result, study involved only volunteers whose parents had signed the consent sheet and who did not have any musculoskeletal injury. The assessment of posture was a part of annual school health check. The posture and muscle force of all subjects were evaluated by experienced physiotherapist.

Subjects

The cross-sectional study included 102 schoolchildren (44 boys and 58 girls), ages 9-14 years (x±SD:11,28±1,55). Each subject filed a results registration sheet with questions about age and health. Study session started with introduction of measurements and methods, followed by registration of body weight and height, and subsequently the assessment of posture with measurements of strength. Table 1 depicts anthropometric characteristics of the study subjects.

Experimental design

Body posture was assessed visually by the New York State Posture Rating Chart [8], using the plumb line and grid. Table 2 shows assessed components by 5 points criteria.

Maximal isometric muscle force was measured with manual dynamometer (BASELAINE, Hydraulic LCD Push-Pull Dynamometer). The maximum isometric force tests were performed on the therapy board where the subject´s body was stabilized to ensure that the muscle or muscle group being tested is isolated. The subject initiated and exerted a force against the dynamometer (that was firmly hold by the tester) until it began to move. Tested muscles or muscles groups and positions of testing are given in Table 3. Each muscle group was tested three times, and the best result was recorded.

Data analysis

All data were collected and analyzed using SPSS Statistic (IBM Corporation, USA). Independent samples T-test was used to assess the group differences (normal posture versus postural deviation). $p<0.05$ indicated statistical significance. The results were expressed as means and standard deviations (±SD).

Results

Most frequent postural deviations on sagittal plane (Table 4) were as follows: neck forward, chin out (52% of all children) and shoulders forward (51.9% of all children), and on frontal plane: one shoulder higher (70.5% of all children), one hip higher (52% of all children), feet pronation (58.8% of all children) and arches lower, feet flat (70.5% of all children).

Children were divided into two groups according to assessment of the posture: normal posture (NP) and deviated posture (DP). Comparing the force ratios of postural groups (Table 5), there were statistically significant differences ($p<0.001$) between NP and DP in ratios of neck flexors and extensors in relationship to the head position.

Table 1: Age, Sex and Physical Characteristics of the Subjects (mean±SD).

Age (yr)	N	Gender (n)		Height (m)	Body weight (kg)	BMI (kg/m²)
		M	F			
9	12	4	8	1.44±0.07	41.71±13.39	19.78±5.19
10	28	14	14	1.45±0.06	38.35±11.21	17.89±3.74
11	18	6	12	1.53±0.08	44.31±8.57	18.96±3.32
12	17	8	9	1.55±0.06	44.83±9.12	18.66±3.10
13	17	8	9	1.67±0.08	55.68±12.49	19.85±3.75
14	10	4	6	1.68±0.09	53.81±9.46	19.08±3.24
Total	102	44	58	1.54±0.11	45.28±12.32	18.87±3.71

Note. M: male; F: female; BMI: body mass index.

Table 2: Body Posture Assessment by the New York State Posture Rating Chart (New York State Education Department, 1999).

Component of posture	5 points	3 points	1 point
In the sagittal plane			
Neck position	Neck erect, chin in, head in balance directly above shoulders	Neck slightly forward, chin slightly out	Neck markedly forward, chin markedly out
Chest position	Chest elevated, breastbone furthest forward part of body	Chest slightly depressed	Chest markedly depressed (flat)
Shoulders position	Shoulders centered	Shoulders slightly forward	Shoulders markedly forward (shoulder blades protruding in rear)
Upper back position	Upper back normally rounded	Upper back slightly more rounded	Upper back markedly rounded
Trunk position	Trunk erect	Trunk inclined to rear slightly	Trunk inclined to rear markedly
Abdomen position	Abdomen flat	Abdomen protruding	Abdomen protruding and sagging
Lower back position	Lower back normally curved	Lower back slightly hollow	Lower back markedly hollow
In the frontal plane			
Head position	Head erect, gravity line passes directly through center	Head twisted or turned to one side slightly	Head twisted or turned to one side markedly
Shoulders position	Shoulders level (horizontally)	One shoulder slightly higher than other	One shoulder markedly higher than other
Spine position	Spine straight	Spine slightly curved laterally	Spine markedly curved laterally
Hips position	Hips level (horizontally)	One hip slightly higher	One hip markedly higher
Feet position	Feet pointed straight ahead	Feet pointed out	Feet pointed out markedly, ankles sag in (pronation)
Arches position	Arches high	Arches lower, feet slightly flat	Arches low, feet markedly flat

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Table 3: Tested Muscles or Muscles Groups and Positions of Testing.

Tested muscles or muscles groups	Patient start position	Placement of dynamometer
Neck flexors	Supine; Head mid-line; Chin slightly tucked; Knees bent and feet flat	On forehead
Neck extensors	Prone; Head mid-line; Arms at sides; Chin slightly tucked	On back of head (occipital)
Pectoralis major - upper part	Supine; Test arm flexed 90°(stands vertically)	On distal end and on medial side of the humerus
Pectoralis major - lower part	Supine; Test arm flexed 90°(stands vertically)	On distal end and on medial-dorsal side of the humerus
Trapezius - middle part	Prone with shoulder at edge of table; Test arm horizontally abducted 90°; Thumb is above	Slightly above elbow on dorsal side of test arm
Trapezius - lower part	Prone with shoulder at edge of table; Test arm horizontally abducted 145°; thumb is above	Slightly above elbow on dorsal side of test arm
Trunk flexors	Supine; Knees bent; Feet flat; Arms resting at side; Head mid-line	On the sternum at the centre of the chest
Trunk extensors	Prone; Arms resting at side; Head mid-line	At the inferior angle of the scapulae on the centre of the back between the shoulder blades
Hip flexors	Supine with knees bent and feet flat; Hip of test leg flexed to about 90°	Slightly above knee of test leg
Hip extensors	Prone with arms at side; Test leg is bent at knee with hip extended and knee off table	Slightly above knee on back of test leg
Hip adductors	Lye on side with test (bottom) leg touching table, in line with trunk; Top leg in step position to allow movement	Slightly above knee on inside of test leg
Hip abductors	Lye on side with test leg on top, in line with trunk; Bottom leg bent to stabilize body	Slightly above knee on outside of test leg

Table 4: Distribution of Cases by Postural Assessment Points for All Subjects (n=102).

Component of posture	5 points	3 points	1 point
In the sagittal plane:			
Neck position	49 (48.0%)	46 (45.1%)	7 (6.9%)
Chest position	86 (84.3%)	16 (15.7%)	-
Shoulders position	49 (48.0%)	49 (48.0%)	4 (3.9%)
Upper back position	86 (84.3%)	14 (13.7%)	2 (2.0%)
Trunk position	64 (62.7%)	36 (35.3%)	2 (2.0%)
Abdomen positionv	66 (64.7%)	32 (31.4%)	4 (3.9%)
Lower back position	55 (53.9%)	38 (37.3%)	9 (8.8%)
In the frontal plane:			
Head position	79 (77.5%)	23 (22.5%)	-
Shoulders position	30 (29.4%)	69 (67.6%)	3 (2.9%)
Spine position	62 (60.8%)	40 (39.2%)	-
Hips position	49 (48.0%)	52 (51.0%)	1 (1.0%)
Feet position	42 (41.2%)	57 (55.9%)	3 (2.9%)
Arches position	30 (29.4%)	59 (57.8%)	13 (12.7%)

There were statistically significant differences between NP and DP groups in force ratio of pectoralis major upper part and trapezius middle part on the right side in relationship to the shoulder position as in sagittal as in frontal plane; however, no significant differences were found in same ratios on left side. There were no statistically significant differences in pectoralis major lower part and trapezius lower part ratio related to the shoulder position in sagittal plane. But there was statistically significant difference between NP and DP group in the same ratio in frontal plane, but only on left side.

Typically, subjects did not show significant differences between NP and DP groups in the strength ratios of trunk flexors and extensors, in hip flexors and extensors, in hip adductors and abductors in relationship to the spine, trunk and pelvic positions accordingly. Just only one statistically significant difference was found in the ratio of hip adductors to abductors on left side at hip position if one hip was higher.

Comparison of position of feet (pronation) found statistically significant differences ($p<0.001$) between NP and DP in the ratios of strength of hip extensors to flexors on both sides, but no significant differences in strength were registered between the groups regarding ratio of hip adductors to abductors.

Discussion

In everyday life, most noticeable defects of posture are forward head position and rounded shoulders together with protruding scapulae. Current study confirms the above observations. Neck forward was found among 52% of all children and shoulders forward was exhibited among 51.9% of all children. According to Rosa et al., [1], their study found the forward head position with 66.7% of the schoolboys and 58.3% of the schoolgirls. On the other hand Asl and Savucu [9], found that only 20.6% of male students at the age between 11-16 had forward head. Kratenová et al., [2], found that 50% of all children have protruding scapulae, and Penha, João, Casaratto, Amino and Penteado [10], brought out that shoulder protraction is very widespread among 10 years old students, 82%.

Forward head position and rounded shoulders together with protruding scapulae are related to upper crossed syndrome. Based on Janda's view [5], in the cases of upper crossed syndrome the cause seems to be related to weak neck

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Tabel 5: Force Ratios (mean±SD) for Different Components of Posture.

Component of posture	Force ratio	Normal posture	Deviated posture
Head position in the sagittal plane	Neck flexors/neck extensors	0.69±0.48	0.69±0.28
Head position in the frontal plane	Neck flexors/neck extensors	0.74±0.41	0.51±0.14***
Shoulders position in the sagittal plane	Trapezius - middle part/ Pectoralis major - upper part on the right	0.71±0.19	0.61±0.22*
	Trapezius - middle part/ Pectoralis major - upper part on the left	0.6±0,18	0.57±025
	Trapezius - lower part/ Pectoralis major - lower part on the right	0.42±0.14	0.37±0.16
	Trapezius - lower part/ Pectoralis major - lower part on the left	0.33±0.11	0.33±0.15
Shoulders position in the frontal plane	Trapezius - middle part/ Pectoralis major - upper part on the right	0.60±0.22	0.69±0.21*
	Trapezius - middle part/ Pectoralis major - upper part on the left	0.53±0.25	0.61±0.2
	Trapezius - lower part/ Pectoralis major - lower part on the right	0.35±0.15	0.41±0.16
	Trapezius - lower part/ Pectoralis major - lower part on the left	0.31±0.15	0.37±0.13*
Spine position in the frontal plane	Trunk flexors/ Trunk extensors	0.9±0.3	0.84±0.29
Trunk position in the sagittal plane	Trunk flexors/ Trunk extensors	0.84±0.26	0.94±0.35
Abdomen position in the sagittal plane	Trunk flexors/ Trunk extensors	0.84±0.26	0.95±0.35
Lower back position in the sagittal plane	Trunk flexors/ Trunk extensors	0.87±0.26	0.89±0.34
Lower back position in the sagittal plane	Hip extensors/ Hip flexors on the right	0.91±0.3	0.82±0.37
	Hip extensors/ Hip flexors on the left	0.95±0.34	0.86±0.34
	Hip adductors/ Hip abductors on the right	0.67±0.22	0.66±0.21
	Hip adductors/ Hip abductors on the left	0.65±0.22	0.64±0.18
Hips position in the frontal plane	Hip extensors/ Hip flexors on the right	0.82±0.31	0.91±0.36
	Hip extensors/ Hip flexors on the left	0.85±0.36	0.96±0.32
	Hip adductors/ Hip abductors on the right	0.64±0.19	0.68±0.23
	Hip adductors/ Hip abductors on the left	0.6±0.18	0.69±0.22*
Feet position in the frontal plane	Hip extensors/ Hip flexors on the right	0.71±0.3	0.97±0.32***
	Hip extensors/ Hip flexors on the left	0.78±0.33	1.0±0.32***
	Hip adductors/ Hip abductors on the right	0.66±0.24	0.67±0.19
	Hip adductors/ Hip abductors on the left	0.64±0.2	0.64±0.21

Note. ***p<0.001, *p<0.05 compared with normal posture.

flexors in front side of the neck and tightened and shortened neck extensors in back side of the neck. Our study indicated that neck extensors are approximately 30% stronger than neck flexors and there is no difference among schoolchildren between normal posture group and deviated posture group in the sagittal plane. But there is significant difference (p<0,001) between posture groups in frontal plane at head position. Force ratio of neck flexors and extensors is 0.51 on deviated posture group what means that neck extensors are two time stronger than neck flexors. We can hypothesize that if the force ratio between neck agonist and antagonist is ca 2/3 then it does not cause problems in the posture and does not bring along forward head position, but if the force ratio is ½ then it can cause deviations in the posture. Quite often the physiotherapists associate the forward head position with headaches but Weber Hellstenius [11], found that among 10-13-year old students the headache is not related with forward head posture.

In cases of upper-crossed syndrome the common observations are weak middle and lower trapezius together with rhomboid muscles on the back side of the chest and tight pectoralis minor and major in front of the chest [5]. We compared muscle strength between pectoralis major upper part and trapezius middle part and also between pectoralis major lower part and trapezius lower part. And we found that the differences of strength are bigger for the lower part. The force ratio of trapezius against pectoralis was 0.31 to 0.42. It means that pectoralis major lower part is approximately three time stronger than trapezius lower part, but it may not yet cause deviations in the posture. We got only one significant difference between normal and deviated posture groups in the strength ratio of trapezius lower part to pectoralis major lower part, and that in frontal plane at shoulder position on the left side. We found interesting that on both sides of the body the deviated posture group had higher ratio in strength rising the possible explanation that persons with deviated posture have enhanced balance between muscle strength between trapezius and pectoralis major. The same tendency can be seen in ratios of strength between trapezius middle parts to pectoralis major upper part in frontal plane on both sides of body, but differences in upper part muscle strength are not so much pronounced like these were in lower part of the chest. The ratio of trapezius middle part to pectoralis major upper part varies from 0.53 to 0.71 taken all measures together, in both sagittal and frontal plane. One discrepancy on the ratios of chest muscles between lower and upper part is this that on upper part there were two significant differences between ratios of normal and deviated posture group, both on right side. But in sagittal plane force ratios of deviated posture group, at shoulder position were smaller. This seems to indicate to a higher imbalance between trapezius and pectoralis muscles.

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We also examined posture to antagonistic muscle group balance from the perspective of lower crossed syndrome. It is known that lower crossed syndrome is related with weak abdominal and tight as well to shorten back muscles on upper part and also with weak gluteal and tight and shortened hip flexors muscles on lower part [5].

We assessed the ratio of strength of trunk flexors to trunk extensors. We compared the groups of normal posture and deviated posture at four different positions: the spine position in frontal plane; the trunk position, the abdomen position and the lower back position in sagittal plane. We observed that the trunk extensors were stronger (approximately 5-16%) than the trunk flexors, however there was no significant differences between posture groups. Fortunately, trunk posture deviations were registered less frequently, among fewer than half of test subjects. We registered the laterally curved spine on 39,2%, the trunk inclination on 37,3%, the protruding abdomen on 35,3% and the hollow lower back on 46,1% of the cases. These findings agree with other investigators, for example: the increased lumbar lordosis occurs on 32% of schoolchildren by Kratenova et al., [2], on 51,3% of male students by Asl and Savucu [9] and on 31%, on average, by Dejanovic et al., [4]. We could not confirm the results of Kim et al. (2006)[12] who found among adults that bigger imbalance between trunk extensors and flexors is significantly related to bigger lordotic curve which in turn can predict potential low back pain in the future. On the other hand, Lee et al., [13], brought out that if the extensor strength is more balanced to the flexors and even weaker than the flexors then it might be a risk factor for the low back pain later in life.

Similarly, to the ratio of strength of trunk flexors/ extensors, we did not register significant differences between normal posture and deviated posture groups comparing the ratios of hip extensors to flexors. We studied these ratios at two position: lower back position in sagittal plane and hips position in frontal plane. Looking these results at the position of lower back one could see that on normal posture group the ratio of hip extensors to flexors was more balanced, difference between the muscle strength was around 5-9%. Observing the same ratio on deviated posture group revealed bigger difference between extensors and flexors (14-18%). This may indicate that children who have hollow lower back seem to demonstrate higher imbalance of strength between hip flexors and extensors, thereby the flexors are stronger then the extensors. But on the other hand, at hips position in frontal plane we saw that children in deviated posture group demonstrated strength-wise more balanced muscles, showing difference between hip flexors and extensors around 5-9% while among the normal posture group the same indicator was 15-18%. The problematic hips level – one hip was higher than the other – was observed on 52% of all assessed subjects. But Rosa et al., [1], did not find any change by pelvic alignment in frontal plane for schoolchildren.

Hips level link to lower back position, both are related also with hip abductors and adductors [5,14]. We evaluated the ratio of strength of hip adductors to abductors and registered bigger difference between agonist and antagonist muscles - hip abductors were 31-40% stronger compared to adductors. At the lower back position this ratio was fairly equal, but at hips level position there was a larger disparity between normal and deviated posture group. The deviated posture group had more balanced muscles compared to the normal posture group. We also registered a statistically significant difference between the hip adductors/abductors strength ratios of normal and deviated posture group on the left leg.

Assessment of muscular strength with manual dynamometer revealed that hip flexors are stronger than hip extensors and hip abductors are stronger than hip adductors. Previously have been used isokinetic dynamometer to evaluate muscle strength and strength ratios of agonist and antagonist muscles. Therefore, the relationship between agonist and antagonist muscles may show distinctive outcomes to previous studies with different methodological approach. For example, Kushner, Reid, Saboe and Penrose [15], tested ballet dancers and found out that the hip extensors are approximately 28% stronger than hip flexors and hip adductors were 24% stronger than hip abductors. On the other example, Tis, Perrin, Snead and Weltman [16], tested female runners and got quite equal results between hip flexors and extensors. By concentric test – the hip extensors were 2% stronger and by eccentric test the hip flexors were 3% stronger [16].

In addition to the position of hips we assessed the same ratios (hip extensors/flexors, adductors/abductors) at feet position, too. Feet pronation is fairly widespread deviation of posture, in our study we registered the pointed out feet on 58,8% of cases. Ilić and Đurić [17]. registered among 40% of girls and 53,3% of boys change in Achilles tendon position – Disortion in *Pes planus*.

It is known that straight ankles and correct feet arches are dependent on the status of anterior and posterior tibialis muscles on the calf [18]. Present approach to relate the problems within ankle joint to hip muscles was based on the concept of whole-body fascial and myofascial linkage, also known as “anatomical trains”. The calf and hip muscles are linked to each other in the Superficial Back Line and the Superficial Front Line [19]. With our study we found that depending on the position of the feet there were significant differences ($p<0.001$) between the hip extensors/flexors ratios of strength in normal and deviated posture group at both sides of the body. It was more remarkable that on deviated posture group (at feet position) hip extensors and flexors muscle strengths were equal (the ratios were 0.97 on right side and 1.0 on left side). At the same time, the ratios on normal posture group were 0.71 and 0.78, accordingly. Unfortunately, we were unable to find similar study outcomes [20].

In addition, we compared the strength ratios of hip adductors/abductors at feet position, but did not register significant differences between the posture groups. We did observe that hip abductors were 33-36% stronger compared to hip adductors despite differences in feet positions.

Conclusion

Two groups of 9-14 years old children with normal and deviated posture demonstrated significant differences in the

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strength ratios between antagonistic muscles of the postural muscle groups. The impact of the above ratio on the posture was dependent of location of the muscle group. There were cases of pronounced strength imbalance among children with normal posture, for example in comparison of hip flexors to hip extensors, while deviated posture group showed negligent imbalance. On the other hand, postural deviation appears to be related to imbalances in other locations, for example in comparison of the pectoralis group to the trapezius etc. Likely explanation is that there are normal differences between anterior and posterior muscle groups, but problems arise based on the location.

This topic definitely needs further follow-up studies to find out how big the agonist and antagonist muscle strength disparity could be in different body regions without causing the postural deviations.

Permission of ethics committee

This study has been coordinated by the Ethics Committee of Tallinn University.

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