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Survey of neck posture, mobility and muscle strength among schoolchildren

Introduction

Chronic neck pain caused by degenerative spinal disorders is an increasing global problem and the association with reduced neck muscle strength (NMS) and forward head/neck posture are generally accepted as being important factors [1–11]. They have become more frequent among younger ages, especially due to computer use and as a consequence of minor whiplash trauma [12–15]. Neck muscle strengthening in the rehabilitation of chronic neck pain has already been investigated in adults [16–22]. There is a paucity of data on neck posture, mobility and NMS in school aged children and the correction of neck posture by restoring neck muscle strength in children has not been published. Objectives of this survey were to develop methods for head, neck and shoulder posture, neck mobility, neck muscle strength measurement among schoolchildren and furthermore to establish correlations between data in different age groups. The aim of measuring neck muscle strength in nodding is to evaluate the strength of deep neck flexors which are predominantly responsible for neck posture. Exercises for strengthening neck muscles, performed at schools was also investigated for their effect.

Subjects and methods

Subjects

In this study 428 boys and girls aged 9, 12 and 16 years old in the same proportion were surveyed. Informed consent was obtained from all children and their parents and approval was also obtained from the local ethics committee.

Methods

1. Anthropometric data included measuring weight and height that were calculated to form the BMI values. The neck length was measured by a tape measure as the distance between spinal processes of C 2–7 first strained (A) and then laid on to the neck curvature (B). The A/B values were calculated as the neck lordosis index.
2. To measure neck posture digital photos were taken while the subjects were sitting in a neutral head position [22].

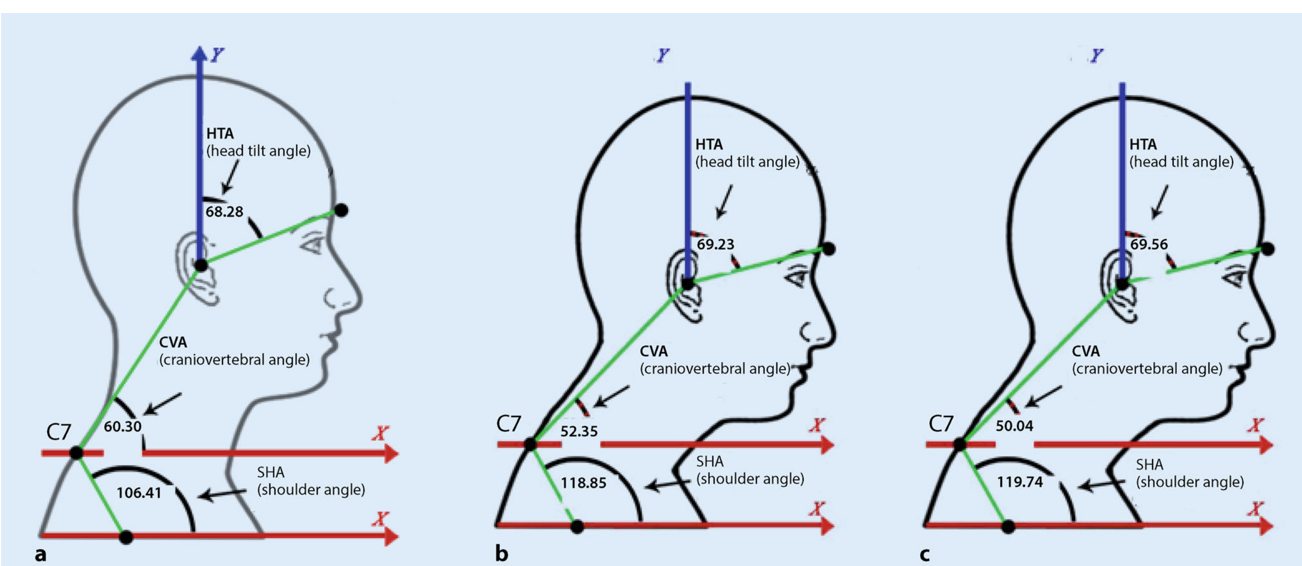

Fig. 1 ▲ Diagrammatic representation of **a** neck posture at the age of 9 years, **b** at the age of 12 years and **c** at the age of 16 years

Table 1 Anthropometric data

Age (years)	Gender	Weight (kg)		Height (cm)		Body mass index	
	$n = 428$	Average	SD	Average	SD	Average	SD
9	Boys $n = 69$	32.2	5.8	141	6.9	15.9	1.9
	Girls $n = 78$	27.8	5.7	137	7.9	14.6	1.8
12	Boys $n = 66$	50.8	13.8	159	8.7	19.8	4
	Girls $n = 72$	43.7	7.1	157	7.4	17.7	2.5
16	Boys $n = 71$	68.6	15.3	178	9.4	21.5	4.1
	Girls $n = 72$	61.2	13.4	169	5.9	21.2	4.4

Table 2 Neck lordosis data (in 12-year-olds, $n = 138$)

Neck length (C2–7)	Gender	Min	Max	Average	SD
Neck length strained (cm)	Girls	6	11.5	**8.6**	1.3
	Boys	6	11	**8.5**	1.3
Neck length laid on (cm)	Girls	5.5	11	**8.1**	1.3
	Boys	5	28.5	**8**	1.4
Neck lordosis index	Girls	0.7	1.28	**0.95**	0.05
	Boys	0.8	1	**0.94**	0.04

Table 3 Correlations of neck lordosis index (12-year-olds $n = 138$)

			Neck lordosis index
Spearman's rho	Weight	Correlation coefficient	0.234(*)
	Body height	Correlation coefficient	0.378(**)
	Neck length	Correlation coefficient	0.933(**)
	SHA	Correlation coefficient	0.425(*)
	CVA	Correlation coefficient	0.415(*)
	Muscle strength values summed	Correlation coefficient	0.284(*)

SHA shoulder angle, *CVA* craniovertebral angle
**Significant $P = 0.01$ (2-sided)
*Significant $P = 0.05$ (2-sided)

Table 4 Correlations of BMI values (12-year-olds $n = 138$)

			BMI
Spearman's rho	CVA	Correlation coefficient	0.362(**)
	HTA	Correlation coefficient	0.278(*)
	SHA	Correlation coefficient	0.415(*)
	Mobility	Correlation coefficient	0.384(*)
	Muscle strength values summed	Correlation coefficient	0.478(**)

BMI body mass index, *CVA* craniovertebral angle, *HTA* head tilt angle, *SHA* shoulder angle
**Significant $P = 0.01$ (2-sided)
*Significant $P = 0.05$ (2-sided)

The digital photos were evaluated using a computer software program for three angles [2, 4] as follows (see **Fig. 1**):

a. Craniovertebral angle (CVA) between the line connecting the tragus and C 7 spinal process and the x-axis,
b. Head tilt angle (HTA) between the line connecting the tragus and the base of the nose and the y-axis,
c. Shoulder angle (SHA) between the line connecting the acromion and C 7 spinal process and the x-axis.

3. The isometric muscle strength in nodding, flexion, extension, left and right lateral flexion was measured using a strain gauge dynamometer. The device was fixed on one side to the wall and on the other side to the subject's head by a helmet. The subjects were stabilized using a belt on their thighs and held at their shoulders by a physiotherapist who controlled the procedure in order to make sure only the neck muscles were used. The subjects pulled the dynamometer with their head and always turned in the appropriate direction. The maximal isometric force "breaking force" was measured in flexion, extension, lateral flexion to the right and to the left and also in nodding (that meant chin tuck with neck extended). Each motion was performed for 10 s, with resting intervals of 20 s and was repeated three times. The measurements were expressed in Newton, the device's measuring range was 1–250 N, with a minimum of 1 N. An average of the efforts in each direction was calculated and was summed up to a value of total neck muscle strength.
4. Mobility was measured in degrees by a goniometer constructed as a combination of an inclinometer and a compass [23]. This instrument is able to perform measurements in flexion, extension, lateral flexion and rotation to both sides and in nodding. Nodding is defined as the flexion motion in the atlanto-occipital joint. Each test was repeated three times and the average value was calculated.

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Survey of neck posture, mobility and muscle strength among schoolchildren

Abstract

Background. Degenerative diseases of the cervical spine have become a public health problem. In the etiology faulty neck posture and weakened neck muscles have been published. The objective of this study was to survey the neck posture, mobility and muscle strength among schoolchildren.

Subjects and methods. The subjects were 428 schoolchildren aged 9, 12 and 16 years with equal proportions of girls and boys. Anthropometric data: body mass index (BMI) values were calculated and neck length was measured. Neck posture was characterized by three angles: craniovertebral (CVA), head tilt (HTA) and shoulder (SHA) angles. The range of movement was measured by a goniometer. Isometric neck muscle strength was measured by a dynamometer in five directions: flexion, extension, side bending on both sides and nodding. A group of the 12-year-olds, who were labeled as "weaks" on the basis of cluster analysis, took part in a 2-month exercise training at the school.

Results. The BMI correlated to the neck muscle strength and was inversely proportional to mobility and the CVA values. Mobility was significantly reduced in the 16-year-old children compared to the 9 and 12-year-old children. The CVA values were found to be reduced between ages 9 and 16 years with the average of 8°, the SHA values higher with 13°, the HTA values with 1.3° higher. Muscle strength values in the different age groups were increased with age where the average value in the 9-year-old age group was 96.65 N, in the 12-year-old age group 133.4 N and in the 16-year-old age group 141.25 N. No significant differences were found between the 12 and 16-year-old age groups. The neck muscle strengthening exercises at school resulted in 2 or 3 times higher muscle strength values and significantly higher CVA values but lower SHA and HTA values that showed the correction of neck posture.

Conclusion. Neck posture deteriorated with age, i.e. the neck became more forwardly projected and the shoulders more protracted between the ages of 9 and 16 years. The neck mobility of the 16-year-olds was significantly reduced compared to 9 and 12 years old and the neck muscle strength, especially in nodding of the 16-year-olds was relatively reduced compared to younger ages. Strengthening exercises performed at schools resulted in a 2 to 3-fold increase in muscle strength and significant correction in neck posture.

Keywords

Neck posture · Neck muscle strength · Schoolchildren · Posture correction

Untersuchung der Haltung, Beweglichkeit und Muskelkraft des Halses bei Schulkindern

Zusammenfassung

Hintergrund. Degenerative Erkrankungen der Halswirbelsäule stellen mittlerweile ein Problem der öffentlichen Gesundheit dar. Bezüglich ihrer Ätiologie wird in der Literatur auf eine falsche Kopfhaltung und geschwächte Halsmuskulatur hingewiesen. Ziel der vorliegenden Arbeit war es, die Haltung, Beweglichkeit und Muskelkraft des Halses bei Schulkindern zu untersuchen.

Probanden und Methoden. An der Studie nahmen 428 Schulkinder im Alter von 9, 12 und 16 Jahren teil, Mädchen und Jungen zu gleichen Anteilen. Anthropometrische Daten: Gewicht und Größe wurden gemessen und daraus der Body-Mass-Index(BMI)-Wert berechnet, darüber hinaus wurde die Halslänge gemessen. Die Kopfhaltung wurde durch 3 Winkel gekennzeichnet: Der kraniovertebrale [„craniovertebral angle" (CVA)], Kopfüberstreckungs- [„head tilt angle" (HTA)] und Schulterwinkel [„shoulder angle" (SHA)] wurden ermittelt. Die Bestimmung des Bewegungsumfangs erfolgte mit einem Goniometer (Winkelmesser). Die isometrische Kraft der Halsmuskulatur wurde mit einem Dynamometer in 5 Richtungen ermittelt: Flexion, Extension, Kopfneigung zu beiden Seiten und Kopfnicken. Eine Gruppe der 12-Jährigen, die auf der Grundlage der Clusteranalyse als „schwach" bezeichnet wurde, nahm an einem 2-monatigen Bewegungstraining in ihren jeweiligen Schulen teil.

Ergebnisse. Der BMI korrelierte mit der Halsmuskelkraft und war umgekehrt proportional zur Beweglichkeit und den CVA-Werten. Die Beweglichkeit war bei den 16-Jährigen im Vergleich zu den 9- und 12-Jährigen signifikant eingeschränkt. Die CVA-Werte stellten sich beim Vergleich der 16-Jährigen als im Durchschnitt um 8° gegenüber den 9-Jährigen geringer heraus, die SHA-Werte als um 13° höher, die HTA-Werte waren bei den 16-Jährigen um 1,3° höher. Die Werte für die Muskelkraft in den verschiedenen Altersgruppen nahm mit dem Alter zu, der Durchschnittswert in der Gruppe der 9-Jährigen betrug 96,65 N, in der Gruppe der 12-Jährigen 133,4 N und in der Gruppe der 16-Jährigen 141,25 N. Zwischen der Gruppe der 12- und der Gruppe der 16-Jährigen war kein signifikanter Unterschied festzustellen. Die Übungen zur Stärkung der Halsmuskulatur in den Schulen bewirkten 2- bis 3-fach höhere Werte für die Muskelkraft und signifikant höhere CVA-Werte, bei niedrigeren SHA und HTA-Werten, was auf die Korrektur der Kopfhaltung hinwies.

Schlussfolgerung. Die Kopfhaltung verschlechtert sich mit dem Alter, d. h., der Hals wird zwischen dem Alter von 9 und dem Alter von 16 Jahren mehr vornübergebeugt und die Schulter mehr vorgezogen. Die Beweglichkeit des Halses ist bei 16-Jährigen signifikant gegenüber der bei 9- bzw. 12-Jährigen vermindert. Die Muskelkraft, insbesondere beim Kopfnicken der 16-Jährigen, ist im Vergleich zu den Jüngeren relativ vermindert. Übungen zur Stärkung, die in den jeweiligen Schulen durchgeführt wurden, führten zu einem 2- bis 3-fachen Anstieg der Muskelkraft und einer signifikanten Korrektur der Kopfhaltung.

Schlüsselwörter

Kopfhaltung · Halsmuskelkraft · Schulkinder · Haltungskorrektur

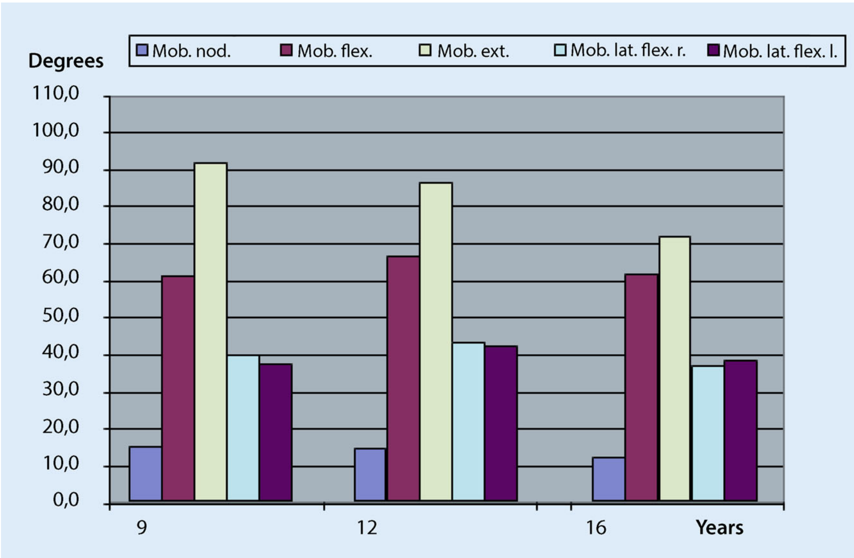

Fig. 2 ▲ Neck mobility data (9, 12 and 16-year-olds)

Table 5 Correlations of neck mobility (12-year-olds $n = 138$)

			Mobility
Spearman's rho	BMI	Correlation coefficient	0.362(**)
	CVA	Correlation coefficient	0.384(*)
	SHA	Correlation coefficient	0.321(*)
	HTA	Correlation coefficient	0.431(**)
	Muscle strength values summed	Correlation coefficient	0.391(*)

BMI body mass index, *CVA* craniovertebral angle, *SHA* shoulder angle, *HTA* head tilt angle
**Significant $P = 0.01$ (2-sided)
*Significant $P = 0.05$ (2-sided)

Table 6 Neck posture data

Neck posture data (degrees)

Age groups: 9-year-olds $n = 147$, 12-year-olds $n = 138$, 16-year-olds $n = 143$

	Age group (years)	Average value (degrees)	SD
CVA	9	60.30	1.88
	12	50.04	4.22
	16	52.35	1.35
SHA	9	106.41	2.74
	12	118.85	4.52
	16	119.74	2.74
HTA	9	68.26	1.27
	12	69.23	4.10
	16	69.56	1.88

CVA craniovertebral angle, *SHA* shoulder angle, *HTA* head tilt angle

5. The resulting descriptive data were analyzed for correlations.
6. The data of strength values were evaluated by cluster analysis for strength categories according to the age groups and the 12-year-old subjects, who were found to be "weaks" took part in a 25 min isometric neck muscle strengthening program. The exercises were performed at schools, 2 times per week for 2 months and after that their neck muscle strength and neck posture were measured.
7. Reliability study: The reproducibility of strength and mobility measurements was between 8–15 %, based on calculating the coefficients of variation. The significance was calculated by the t-test and Mann-Witney test whereas the correlations were tested by Spearman's rho test.

Results

1. Anthropometric data

- The subject's weight, height and the calculated BMI values according to the age and sex showed a proportional increase with age (**Table 1**).
- The neck length and the new neck lordosis index (**Table 2**).
- The neck lordosis index correlated to body height and neck length (**Table 3**).
- The BMI was proportional to the muscle strength, whereas it was inversely proportional to mobility and to the CVA values (**Table 4**).

2. Neck mobility

- Between 9 and 12-year-olds there were no significant differences; however with the 16-year-olds a significantly reduced mobility was found compared to both the 9 and the 12-year-olds. The mobility in nodding was proportional to the mobility measured in the other directions (**Fig. 2**).
- The mobility significantly correlated to the CVA values, while to a lesser extent to the muscle strength and was inversely proportional with the BMI, SHA and HTA values (**Table 5**).

Table 7 Correlations of CVA values (12 yr olds $n = 138$)

			CVA
Spearman's rho	BMI	Correlation coefficient	0.362(**)
	HTA	Correlation coefficient	0.278(*)
	SHA	Correlation coefficient	0.415(*)
	Mobility	Correlation coefficient	0.384(*)
	Muscle strength values summed	Correlation coefficient	0.478(**)

BMI body mass index, *CVA* craniovertebral angle, *SHA* shoulder angle, *HTA* head tilt angle
**Significant $P = 0.01$ (2-sided)
*Significant $P = 0.05$ (2-sided)

Table 8 Correlations of SHA values (12-year-olds $n = 138$)

			SHA
Spearman's rho	Neck length	Correlation coefficient	0.539(**)
	HTA	Correlation coefficient	0.178(*)
	CVA	Correlation coefficient	0.415(*)
	Muscle strength values summed	Correlation coefficient	0.477(**)

HTA head tilt angle, *CVA* craniovertebral angle, *SHA* shoulder angle
**Significant $P = 0.01$ (2-sided)
*Significant $P = 0.05$ (2-sided)

Table 9 Correlations of HTA values (12-year-olds $n = 138$)

			HTA
Spearman's rho	CVA	Correlation coefficient	0.278(*)
	SHA	Correlation coefficient	0.178(*)
	Mobility	Correlation coefficient	0.431(**)
	Muscle strength values summed	Correlation coefficient	0.290(*)

HTA head tilt angle, *CVA* craniovertebral angle, *SHA* shoulder angle
**Significant $P = 0.01$ (2-sided)
*Significant $P = 0.05$ (2-sided)

3. Neck posture

3.1. Angles characterizing neck posture

(Values from **Table 6**)

- The CVA values were found to be reduced on average of 8° between ages 9–16 years that represented more forwarded neck posture.
- The SHA values were found on average 13° higher with age, that represented more protracted shoulder.
- The HTA values were found on average 1.6° higher with age, that represented more extended head posture.

3.2. Correlations within angles characterizing posture

- The CVA was proportional to muscle strength, while to a lesser degree to mobility and inversely proportional to BMI and SHA (**Table 7**).
- The SHA was inversely proportional to CVA, neck length, muscle strength and proportional to HTA (**Table 8**).
- The HTA was proportional to SHA and inversely proportional to CVA (**Table 9**).

4. Neck muscle strength

4.1. Comparison of neck muscle strength values

- The muscle strength values were increased in different age groups with age. The total neck muscle strength average value with the 9-year-old age group was 96.65 N, with the 12-year-old age group 133.4 N and with the 16-year-old group 141.25 N. (**Table 10**)
- A slight difference (approximately 10 N) was found between the 9 and 12-year-old age groups while practically no differences were found between the 12 and 16-year-olds. Impact of gender on neck muscle strength (**Table 11**)
- The average total muscle strength values were calculated by cluster analysis and categories have been distinguished, as "weak", "medium" and "strong". This showed that there was a higher percentage of "weaks" with the 16 and 12-year-olds than with the 9-year-olds, while the "strong" distribution was equal between the age groups (**Table 12**).

The values for 9-year-old girls were slightly (only 1–2 N plus) higher than those of the boys but those of the 16-year-old boys were much stronger (average of 30 N plus) than the girls.

4.3. Correlations concerning neck muscle strength values

- The neck muscle strength was found to be in direct proportion to CVA and inversely to SHA and HTA (**Table 7, 8, 9**).
- The neck muscle strength highly correlated to BMI whereas its correlation was on a lower significance level to neck length (**Table 4**).

5. Effects of neck muscle strengthening exercises

The "weak" category of children based on cluster analysis took part in the strengthening exercise program at their schools and the control measurements showed significant improvement in all directions (**Table 13**). After the completion of the strengthening exercise program, significantly higher CVA and HTA values, while lesser SHA values represent the correction of neck posture (**Table 14**).

Table 10 Neck muscle strength data					
Neck muscle strength values (Newton)					
9-year-olds *n* = 147, 12-year-olds *n* = 138, 16-year-olds *n* = 143					
	Age (years)	**Min**	**Max**	**Average**	**SD**
Nodding	9	5.00	16.00	10.07	2.29
	12	6.00	22.00	10.12	4.00
	16	5.00	22.00	10.36	5.51
Flexion	9	12.00	58.00	22.41	9.2
	12	13.00	61.00	27.74	14.00
	16	18.00	78.00	32.14	15.38
Extension	9	9.33	40.00	25.62	7.00
	12	11.00	105.00	34.22	23.00
	16	14.67	89.67	42.01	20.53
Side flexion right	9	6.00	61.00	19.39	10.46
	12	9.00	67.00	25.45	13.00
	16	11.33	71.00	28.25	13.1
Side flexion left	9	5.33	48.00	19.16	8.64
	12	9.00	57.00	22.65	12.00
	16	11.00	75.00	28.49	13.14
Muscle strength values summed	9	41.67	216.00	96.65	33.16
	12	48.00	312.00	133.4	66.00
	16	55.67	268.67	141.25	58.70

Table 11 Neck muscle strength values as to gender in different age groups				
Neck muscle strength values as to gender (Newton)				
Gender	Age (years)	Min	Max	Average
Boys	9	41.6	145.5	96.6
	12	49.5	219.5	150.8
	16	1.6	286.7	174.4
Girls	9	51.7	216.8	97.7
	12	51.5	221.9	128.3
	16	55.6	307	153.9

Table 12 Proportion of summed neck muscle strength values in different age groups (by cluster analysis)						
Proportion of summed neck muscle strength values (*n* = 428)						
Age group	**"Weak"**		**"Medium"**		**"Strong"**	
	n	%	*n*	%	*n*	%
9-year-olds *n* = 147	78	53.06	56	38.1	13	8.84
12-year-olds *n* = 138	89	64.49	44	31.88	5	3.63
16-year-olds *n* = 143	97	67.83	29	20.28	17	11.89

Conclusion

Anthropometric data

Cervical lordosis was correlated to body height and neck length. Subjects with higher BMI values were stronger but they were less mobile and they had more forward neck posture (in the 12 year age group).

Neck posture

The results proved that neck posture deteriorated with age, i.e. the neck became more forward and the shoulders more protracted between ages 9 and 16 years (see **Fig. 1a–c**).

The "good" (i. e. the "neutral") neck posture was in correlation with mobility, neck muscle strength and "good" shoulder posture (i. e. lesser SHA angle).

The "bad" (protracted) shoulder posture was in correlation with neck muscle weakness.

Head posture

The higher HTA value represents what can be seen in everyday life that the forward neck posture used to be associated to extended head. That faulty posture could be the explanation as a pathomechanism of upper cervical syndrome.

Neck mobility

Between the 9 and 12-year-old age groups there were no significant differences in mobility but the mobility of the 16-year-olds is significantly reduced compared to the 9 and 12-year-olds.

Neck muscle strength

The neck muscle strength of the 16-year-olds was relatively reduced compared to 9-year-olds. The muscle strength was found to be weak especially in nodding.

Strengthening exercises performed at schools

Strengthening exercises performed at schools over 8 weeks, 2 times a week resulted in a 2-3-fold increase in muscle

Table 13 Neck muscle strength values of 12-year-old "weaks" before and after exercises

Neck muscle strength values of 12-year-old "weaks" before and after exercises (Newton) *n* = 89 (48 boys, 41 girls)											
Nodding		**Flexion**		**Extension**		**Side flexion right**		**Side flexion left**		**Summed strength values**	
Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
8.5	22.7	20.2	34.6	19.8	44.6	18.1	31.5	16.2	34.1	83.8	147.5
Significant 0.001		Significant 0.006		Significant 0.000		Significant 0.000		Significant 0.000		Significant 0.000	

Table 14 Neck posture values of 12-year-old "weaks" before and after exercises

Neck posture values before and after exercises (degree)						
	CVA	**SD**	**HTA**	**SD**	**SHA**	**SD**
Before	52.3	4.2	69.23	4.1	118.85	4.5
After	60.3	1.8	68.26	1.27	106.4	2.7
Significance	$P = 000003$		$P = 000001$		$P = 000005$	

HTA head tilt angle, *CVA* craniovertebral angle, *SHA* shoulder angle

strength, especially in nodding. Thus muscle strength can be restored in a relatively short period of time thus making correction of neck posture possible.

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Compliance with ethical guidelines

Conflicts of interest. G. Ormos states that there are no conflicts of interest.

All studies on humans described in this manuscript were carried out with the approval of the responsible ethics committee and in accordance with national law and the Helsinki Declaration of 1975 (in its current revised form). Informed consent was obtained from all participants or in the case of underage participants from a parent or legal guardian.

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