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RESEARCH / ARAŞTIRMA

Does Head Posture Alter Gait Parameters and Symmetry in Young Adults with Forward Head Posture? A Cross-Sectional Study

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ABSTRACT

Objective: Forward head posture (FHP) is a common postural problem. However, its influence on gait kinematics remains unclear. The purpose of this study was to investigate the effect of head posture on gait spatiotemporal parameters and asymmetry in young adults.
Material and Method: A cross-sectional study was conducted on young adults categorized into two groups: FHP and normal posture, based on the cut-off value of the craniovertebral angle (CVA). The CVA, cranial rotation angle, and cranial horizontal angle were calculated using lateral photographs and analyzed using MB-Ruler software. Demographic information, including gender, age, height, and weight, was recorded, and gait spatio-temporal parameters—initial contact, support, swing, step phases, dynamic pressure, and gait symmetry scores—were measured using the FreeMED force platform (Sensor Medica, Italy). Gait symmetry was calculated using the symmetry index.
Results: A total of 66 participants (41 females and 25 males) were included in the study, with an average age of 23 (22–23 IQR). There was a moderate positive correlation between left step cycle length and cranial rotation angle (r=0.316, p=0.024). However, no significant differences were determined in other gait kinematic parameters between groups (p>0.05). Additionally, no significant correlation was found between CVA and gait spatiotemporal parameters or gait symmetry (p>0.05).
Conclusion: The findings suggest that FHP does not significantly alter kinematic spatiotemporal gait parameters and gait symmetry in young adults. Research is required to investigate three-dimensional posture and gait analysis methods that can provide more accurate measurements.
Keywords: Craniovertebral angle, forward head posture, gait, symmetry.

Baş Önde Postürü Olan Genç Yetişkinlerde Baş Postürü Yürüyüş Parametrelerini ve Simetrisini Değiştirir Mi? Kesitsel Bir Çalışma

ÖZET

Amaç: Baş önde postür (BÖP) bozukluğu yaygın bir postüral problemdir. Bununla birlikte, yürüyüş kinematiği üzerindeki etkisi belirsizliğini korumaktadır. Bu çalışmanın amacı, genç yetişkinlerde baş postürünün yürüyüşün spatio-temporal parametreleri ve asimetrisine etkisini araştırmaktır.
Gereç ve Yöntem: Genç erişkinlerde gerçekleştirilen bu kesitsel çalışmada katılımcılar kraniovertebral açı (KVA) değerine göre BÖP ve normal postür olmak üzere iki gruba ayrıldı. Katılımcıların KVA, kranial rotasyon açısı ve kraniohorizontal açıları lateralden çekilen fotoğraflar ile değerlendirildi ve MB-Ruler yazılımı ile analiz edildi. Katılımcıların demografik bilgileri (cinsiyet, yaş, boy, kilo) kaydedildi ve yürüyüş spatio-temporal parametreleri—ilk temas, destek, sallanma fazları, adım döngüsü, dinamik basınç ve yürüyüş simetri skorları—FreeMED force platformu (Sensor Medica, İtalya) kullanılarak ölçüldü. Yürüyüş simetrisi simetri indeksi kullanılarak hesaplandı.
Bulgular: Çalışmaya ortalama yaşları 23 yıl (22-23 ÇAA) olan 66 katılımcı (41 kadın ve 25 erkek) dahil edildi. Sol adım döngüsü uzunluğu ile kranial rotasyon açısı arasında orta düzeyde pozitif bir ilişki bulundu (r=0,316, p=0,024). Ancak, gruplar arasında diğer yürüyüş kinematik parametrelerinde anlamlı fark bulunmadı (p>0,05). Ayrıca, CVA ile yürüyüş spatio-temporal parametreleri veya yürüyüş simetrisi arasında anlamlı bir korelasyon bulunmadı (p>0,05).
Sonuç: Baş önde postürün genç yetişkinlerde kinematik spatio-temporal yürüyüş parametrelerini ve yürüyüş simetrisini önemli ölçüde değiştirmediğini göstermektedir. Daha hassas ölçümler sağlayabilecek üç boyutlu postür ve yürüme analizi yöntemleri ile planlanan çalışmalara ihtiyaç vardır.
Anahtar Kelimeler: Kraniovertebral açı, baş önde postür, yürüyüş, simetri.

1. Introduction

Forward head posture (FHP) is defined as a common postural problem characterized by altered head position in the sagittal plane with an incidence of approximately 66% to 80%. This condition may induce alterations in the biomechanical stress on the cervical spine, which may result in headaches, temporomandibular joint (TMJ) dysfunction, and neck pain (1). The anterior and posterior cervical spine components are able to withstand the weight of the head more effectively when there is optimal cervical lordosis. When FHP causes the cervical spine to flatten, the anterior vertebral elements are subjected to increased compressive and tensile stress (2).

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There is some early evidence to support that proper posture and cervical spine alignment are critical for postural control process (3–5). Orienting the head against gravity is the primary role of the cervical spine (6). Stabilizing the head promotes the best possible vestibular and optical conditions when moving (7, 8). Furthermore, healthy individuals retain a high level of head stability during normal gait by using compensatory mechanisms including head pitch adjustments that oppose the angular and linear motions imposed by the entire body (8, 9).

The frequency and velocity of head movements are key determinants of head stability during gait (10). Gait analysis has extensively documented how various lower limb movements influence head movement frequency, depending on walking speed, stride rate, and step length (11, 12). A recent study specifically investigated the relationship between head posture displacements and gait parameters in healthy college students during overground walking. The results demonstrated that spatiotemporal gait parameters (e.g., cadence, speed, and stride length) have a moderate positive correlation with cranio-vertebral angle (CVA) and a moderate negative correlation with anterior head translation. These results indicate that people with more significant FHP — defined by a reduced CVA or elevated anterior head translation — tend to display shorter stride lengths, slower gait speed, and reduced cadence (13).

Head stability is also linked to upper limb movements such as arm swing and trunk rotation (14, 15). Gait asymmetry is frequently viewed as abnormal and is regarded as a significant therapeutic concern that needs to be addressed. Cyclic activities, like walking and running, are thought to be naturally symmetrical (16).

Studies over the past two decades have provided important information on postural control (17, 18). FHP causes sternocleidomastoid muscle thickness, increased lower cervical spine lordosis, weakness of the deep cervical flexors, neck muscle imbalance, shortening of cervical extensors (19-22), increased upper and lower trapezius activity and lower serratus anterior muscle activity (23, 24). Although there is a lack of empirical evidence to support the impact of FHP on spatiotemporal gait characteristics, a significant correlation has been found between FHP and limitations in cervical proprioception, stability, and performance-based balance. Additionally, there are conflicting findings among the limited reports on FHP and poor postural control and walking. Some studies in the literature argue that FHP changes walking parameters, while others argue that it does not cause changes in walking and balance (25).

In the light of the above-mentioned evidence, deviations in head posture may affect both postural control and proprioception and thus gait symmetry. Not withstanding the importance of this possible relationship, to date, only a limited number of studies have identified the relationship between gait parameters and FHP in young adults (13). Thus, the purpose of this comparative cross sectional study is to assess how FHP affected young adults' gait characteristics. Given that forward head posture (FHP) affects head positioning in the sagittal plane, we hypothesized that there may be a relationship between spatiotemporal gait parameters, gait symmetry, and head posture.

2. Material and Method

2.1. Research Type and Sample of the Research

Sixty-six volunteers aged between 17 and 35 years were included in this cross-sectional observational study, which was conducted at the Atılım University Physiotherapy and Rehabilitation Laboratory in Ankara.

All subjects were evaluated according to the following exclusion criteria: (1) inflammatory joint disease or other systemic diseases; (2) a history of acute musculoskeletal pain, or injuries and surgeries (3) neurological conditions; and (5) vision impairments. Prior to data collection, the eligible participants signed an informed consent form and consented to participate in the study. The study included 35 controls with normal head alignment and 31 subjects with FHP matched with regard to age, gender, and body mass index (BMI).

2.2. Data Collection

2.1.1. Head Posture Assessment

In this study, CVA, cranial rotation angle, and craniohorizontal angle were calculated to determine the head posture of the participants. The measurements were performed while the participants were in standing position.

For the measurements, the C7 vertebra, the tragus of the ear, and the lateral canthus of the eye were identified and marked by a physiotherapist. Subsequently, lateral photographs were taken using a digital camera mounted on a tripod, positioned 200 cm away from the participant at shoulder level. The captured images were analyzed using MB-Ruler 5.4 and the angles were calculated accordingly. CVA is defined as the angle formed by the intersection of a line connecting the C7 vertebra to the tragus and a horizontal line (Figure 1). Based on CVA, participants were divided into two groups: normal posture and FHP. A CVA angle ≥48° was classified as normal posture, while an angle <48° was classified as forward head posture (26).

The cranial rotation angle is defined as the angle formed by the intersection of a line connecting the C7 vertebra to the tragus and a line connecting the tragus to the lateral canthus of the eye (27) (Figure 1-A).

The craniohorizontal angle is defined as the angle formed by the intersection of a horizontal line and a line connecting the tragus to the lateral canthus of the eye (28, 29) (Figure 1-B).

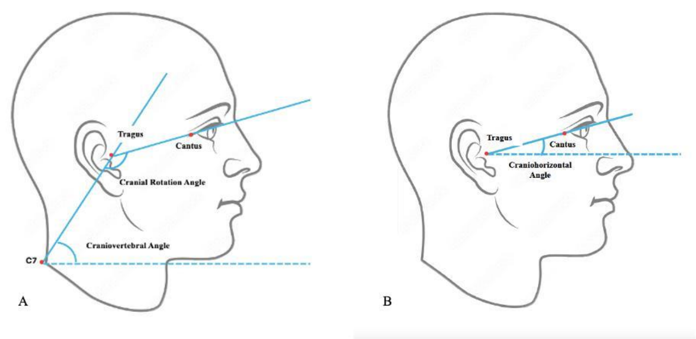

Figure 1. Cranial Angles. A: Craniovertebral and Cranial Rotation Angles, B: Craninohorizontal Angle

2.1.2. Gait Analysis

Gait analysis was performed using the FreeMed baropodometry platform (FreeStep v.1.0.3.88 software, Sensor Medica, Guidonia Montecelio, Rome, Italy) (30). Initially, demographic characteristics, including gender, age, height, and weight, were recorded. Subsequently, the FreeMED force platform was used to assess gait trials over a 6-meter straight path, with participants walking barefoot at their self-selected natural speed.

Each participant was instructed to maintain a normal gait pattern while walking over the force plate. Following a familiarization trial, three gait cycles were recorded for analysis. To minimize the potential influence of fatigue on the measured parameters, all experimental sessions were conducted in the morning. Participants wore comfortable clothes, consisting of shorts and a t-shirt. At the end of the assessment, the device generated a software report containing detailed gait analysis data for each participant.

The recorded parameters included initial contact phase, support phase, swing phase, step cycle, pressure metrics, and surface metrics. Additionally, gait symmetry was analyzed. The symmetry index was used to quantify the degree of symmetry between the anterior and posterior acceleration curves throughout the left and right gait cycles. [(xright − xleft)/0.5*(xright + xleft)*100%], where "x" represents a given parameter being calculated. A value of 0 indicates a perfectly symmetrical gait, while higher positive or negative values indicate a greater degree of asymmetry (31).

2.3. Implementation of the Research

2.3.1. Analysis of Research Data

Sample size calculation was performed with the G*Power 3.1.9.7 software, with 0.8 effect size at %5 significance level, power of 0.80 at a confidence level of 95%. Total 66 participants included the study. The analyses were conducted using IBM SPSS Statistics 23 software. The normality of the variables was assessed using visual methods (histogram and probability plots) and analytical tests (Kolmogorov-Smirnov and Shapiro-Wilk tests). The results indicated that the variables did not follow a normal distribution and met the non-parametric conditions. In the descriptive statistical analysis, numerical variables were reported as the median and interquartile range (IQR) under non-parametric conditions.

The normal posture and forward head posture (FHP) groups were compared using the Mann-Whitney U test. The relationships between head posture, gait parameters, and gait asymmetry were analyzed using Spearman correlation analysis. The correlation coefficients were classified as weak (0–0.30), moderate (0.40–0.60), strong (0.70–0.89), and very strong (0.90–1.00). The statistical significance level was set at p<0.05 (32).

2.4. Ethical Aspects of the Research

This research was conducted in accordance with the principles of the Declaration of Helsinki. This study was approved by the Ethics Committee of Atılım University (Approval No: E-59394181-604.01.02-58808, Date: 24.03.2023). Institutional permission was also obtained prior to data collection. All participants were informed about the study's purpose, procedures, and written informed consent was obtained from each participant.

3. Results

A total of 66 participants, consisting of 41 females and 25 males aged 23 (22-23 IQR) years, were included in the study. The participants were divided into two groups based on CVA: normal posture and FHP. Descriptive findings of the groups are presented in Table 1.

Table 1. Descriptive information

	Normal Posture (n= 35)		Forward Head Posture (n= 31)		p
Gender	**n**	**%**	**n**	**%**	
Female	20	57.14	21	67.74	0.683
Male	15	42.86	10	32.26	
	Median	**IQR**	**Median**	**IQR**	
Age (year)	23	22–23	23	22–23	0.341
Weight (kg)	65	52–75	66	55–76	0.477
Height (m)	1.70	1.64-1.79	1.68	1.64-1.75	0.421

The study examined the relationship between gait symmetry data, including CVA, cranial rotation angle, and the craniohorizontal angle. As a result of the analysis, a moderate positive correlation was found between the left step cycle length and the cranial rotation angle (r=0.316, p=0.024) (Table 2).

Additionally, the relationship between gait symmetry data was examined, no significant correlation was found (p>0.05) (Table 3). Normal posture and FHP groups were compared in terms of gait spatio-temporal parameters, no significant differences were found between the groups (p>0.05) (Table 4).

Table 2. Relationship between head posture angles and gait parameters

		Craniovertebral Angle		Cranial Rotation Angle		Craniohorizontal Angle	
		r	**p**	**r**	**p**	**r**	**p**
Initial Contact Phase							
Initial Contact	R	0.144	0.307	-0.098	0.487	0.045	0.751
	L	0.092	0.515	-0.121	0.394	0.030	0.830
Loading Response	R	0.147	0.299	-0.099	0.485	0.052	0.714
	L	0.110	0.436	-0.131	0.356	0.022	0.877
Support Phase							
Double Support Duration	R	0.095	0.477	-0.076	0.569	0.077	0.563
	L	0.074	0.579	-0.064	0.634	0.110	0.412
Mid Stance	R	0.147	0.300	-0.101	0.478	0.048	0.738
	L	0.111	0.432	-0.127	0.371	0.034	0.811
Terminal Stance	R	0.142	0.315	-0.096	0.500	0.056	0.691
	L	0.104	0.464	-0.128	0.367	0.026	0.855
Swing Phase							
Swing Duration	R	0.073	0.605	-0.067	0.635	0.078	0.581
	L	0.158	0.267	-0.130	0.362	-0.061	0.673
Step Cycle							
Step Cycle Duration	R	0.300	0.060	-0.086	0.599	0.087	0.594
	L	0.091	0.596	-0.213	0.211	-0.086	0.619
Step Cycle Length	R	-0.086	0.550	0.072	0.615	-0.137	0.339
	L	-0.097	0.500	0.316*	0.024	-0.037	0.797
Time of contact	R	0.136	0.337	-0.094	0.506	0.046	0.745
	L	0.102	0.470	-0.125	0.378	0.025	0.861
Pressure and Surface Metrics							
Dynamic Surface	R	0.231	0.082	-0.101	0.452	0.043	0.751
	L	0.111	0.406	-0.042	0.755	0.059	0.660

Table 3. Relationship between head posture and gait symmetry

Symmetry Indexes	Craniovertebral Angle		Cranial Rotation Angle		Craniohorizontal Angle	
	r	**p**	**r**	**p**	**r**	**p**
Initial Contact	0.011	0.941	0.001	0.993	-0.030	0.831
Loading Response	0.009	0.950	-0.013	0.929	-0.045	0.752
Double Support Duration	0.103	0.442	-0.148	0.268	-0.126	0.346
Mid Stance	0.000	1.000	0.011	0.936	-0.035	0.804
Terminal Stance	-0.010	0.945	0.017	0.906	-0.016	0.910
Swing Duration	-0.158	0.278	0.079	0.589	0.260	0.071
Step Cycle Duration	0.004	0.981	0.028	0.883	-0.097	0.604
Step Cycle Length	-0.123	0.404	-0.158	0.282	-0.138	0.351
Time Of Contact	-0.024	0.867	0.007	0.961	-0.051	0.718
Dynamic Surface	0.079	0.553	0.027	0.843	0.013	0.920

Table 4. Comparison of groups in terms of gait parameters

		Normal Posture (n= 35)		Forward Head Posture (n= 31)		
		Median	IQR	Median	IQR	p
Initial Contact Phase						
Initial Contact	R	19	17–21	20	16–21	0.983
	L	17	16–19	20	16–23	0.203
Loading Response	R	93	85–104	99	79–106	0.942
	L	88	79–96	97	81–112	0.315
Support Phase						
Double Support Duration	R	1224	1040–1343	1283	1180–1401	0.389
	L	1225	1008–1325	1296	1042–1367	0.660
Mid Stance	R	277	255–318	298	238–317	0.990
	L	264	237–288	292	245–335	0.242
Terminal Stance	R	466	425–520	495	396–528	0.917
	L	433	395–478	487	407–557	0.191
Swing Phase						
Swing Duration	R	1263	1148–1564	1271	1030–1452	0.526
	L	1078	915–1418	1238	884–1324	0.893
Step Cycle						
Step Cycle Duration	R	628	521–692	594	503–656	0.386
	L	594	564–671	613	520–718	0.973
Step Cycle Length	R	682	649–730	702	673–735	0.422
	L	673	629–718	645	627–680	0.224
Time of contact	R	924	831–1047	991	792–1057	0.933
	L	874	790–955	973	815–1114	0.210
Pressure and Surface Metrics						
Dynamic Surface	R	155	137–186	154	139–169	0.688
	L	155	137–178	156	141–181	0.818

4. Discussion

In our study investigating the relationship between head posture and gait parameters and symmetry in young adults with forward head posture, we found that head posture did not affect gait parameters and symmetry.

This outcome aligns with existing research suggesting that variations in head and neck posture, as quantified by postural angles, may not substantially influence gait mechanics in asymptomatic individuals (26). The angle formed by a line passing between the spinous process of the C7 and a line joining the C7 to the tragus of the ear is known as the CVA, and it is a recognized measure of for FHP. A decreased CVA indicates increased FHP, which has been linked to musculoskeletal pain, especially neck pain (33). However, its direct impact on dynamic activities such as walking remains unclear. For instance, Lin et al., found no significant differences in kinematic gait parameters between individuals with varying CVAs, suggesting that mild postural deviations may not affect functional movements like gait (34). Similarly, craniohorizontal angle and cranial rotation angle have primarily been studied in static postural assessments rather than dynamic gait analysis (35-37).

According to the results of a previous study, in contrast to our findings; changes in cervical posture following the exercise program led to alterations in the participants' gait parameters (38). The association between head posture and biomechanical parameters during young adults' walking and jumping was investigated in a study by Saad et al. The results showed that several gait and jump metrics had moderate-to-high associations with head posture, such as the craniovertebral angle and anterior head translation. However, these correlations are insufficient to explain the overall effect of FHP on gait mechanics (39).

To date, the only study that has directly compared gait variables between children with FHP and healthy controls reported that children with FHP exhibited greater mediolateral ground reaction force (GRF) during the push-off phase of the non-dominant limb, shorter time to peak vertical GRF, and reduced mediolateral GRF during heel contact and push-off phases of the dominant limb (40).

In this study, a moderate positive correlation was found only between left step cycle length and cranial rotation angle. Since the cranial rotation angle may be related to the allignment of the upper cervical (C0-C2) spine, our study showed that changes in this angle may affect the step length cycle of the gait (41).

Another important research question of this study was the relationship between FHP and gait symmetry, which refers to the balanced and coordinated movement of the legs during walking. As a result of the study, no significant correlation was found between the two variables. This finding stands in contrast to previous studies that have suggested a link between postural abnormalities, such as FHP, and gait abnormalities, including asymmetry (25). The lack of a correlation in our findings calls for a deeper examination of the complex interplay between head posture and gait. This finding aligns with existing literature that suggests the impact of FHP on gait kinematics may be minimal or depending on different variables. Another explanation could be that the system responsible for maintaining posture in young, healthy subjects can adjust to the demands of amplified FHP.

Previous literature has reported that abnormal postural alignments, such as FHP, could influence the biomechanics of movement, including gait (25). The GRF was the only metric used to collect data on the gait abnormalities of people with FHP in children. According to a study's findings, a healthy person's mediolateral ground response force may differ depending on their muscle contributions (42). However, our results suggest that individuals with FHP may not exhibit asymmetry in their gait patterns. One possible explanation could be the independence of head and limb movements. While FHP reflects a misalignment of the cervical spine and head, gait is primarily governed by the coordination of the lower limbs and pelvis. As such, any postural dysfunction in the upper body may not directly influence the symmetry of lower body movements (25, 43).

Another potential factor is the existence of compensatory mechanisms in the musculoskeletal system. These compensations could help maintain gait symmetry despite the postural deviation in the head and neck. In fact, studies have shown that individuals with postural abnormalities often develop adaptive strategies that allow for functional movement without significant alterations to gait symmetry (44). It is also important to consider other factors that may influence gait symmetry—such as age, lower limb muscle strength, and core muscle strength contributing to coordination and gait performance—which may not have been fully accounted for in this study. Therefore, it is possible that these variables, rather than FHP alone, have a more substantial effect on gait symmetry. Furthermore, it would be beneficial to investigate the role of other postural deviations, such as scoliosis or pelvic tilt, in relation to gait symmetry.

5. Conclusion and Recommendations

In conclusion, the findings of this study suggest no significant correlation between FHP and gait parameters and symmetry. The lack of correlation emphasizes the complexity of the relationship between posture and gait and suggests that factors beyond head posture may play a more important role in determining gait symmetry. These findings suggest that although FHP is associated with certain postural and balance disorders, its direct influence on kinematic gait parameters in young adults may be limited. Further research examining the relationship between head posture and gait in individuals with severe head-forward posture is needed.

The measurement of FHP in this study may not have fully captured the variations in posture that could impact gait. Since our study was cross-sectional and the sample consisted of young participants, the effects of FHP on walking were not found to be significant. Future studies should consider using more precise tools to assess the degree of FHP and its potential effects on gait. Additionally, lack of use of a three-dimensional motion analysis system—a contemporary scientific technique frequently used for movement evaluations in clinical and research settings—could be one of the study's drawbacks.

6. Contribution to the Field

This study contributes to literature examining the biomechanical implications of postural deviations by specifically evaluating the relationship between FHP and gait parameters in young adults. Unlike prior research that often-lacked quantitative gait assessment or focused on broader postural issues, this study employs objective spatiotemporal gait analysis and postural metrics to clarify the impact of FHP on dynamic function. The results showed that FHP did not have a significant impact on gait, a functional task, in the young population.

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None.

Conflict of Interest

There is no conflict of interest with any person and/or institution.

Authorship Contribution

Concept: NU; Design: NU; Supervision: NU, ZCK, SY; Data Collection/ Processing: SNB; Analysis/Interpretation: SNB, NU, ZCK; Literature Review: ZCK, SY; Manuscript Writing: NU, SNB; Critical Review: ZCK, SY.

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References

1. Griegel-Morris P, Larson K, Mueller-Klaus K, Oatis CA. Incidence of common postural abnormalities in the cervical, shoulder, and thoracic regions and their association with pain in two age groups of healthy subjects. Phys Ther. 1992 Jun;72(6):425–31. DOI: 10.1093/ptj/72.6.425.
2. Magnani RM, Bruijn SM, van Dieën JH, Vieira MF. Head orientation and gait stability in young adults, dancers and older adults. Gait Posture. 2020;80:68–73. DOI: 10.1016/j.gaitpost.2020.05.035.
3. Abdulwahab SS, Sabbahi M. Neck retractions, cervical root decompression, and radicular pain. J Orthop Sports Phys Ther. 2000;30(1):4. DOI: 10.2519/jospt.2000.30.1.4.
4. Diab AA, Moustafa IM. The efficacy of forward head correction on nerve root function and pain in cervical spondylotic radiculopathy: a randomized trial. Clin Rehabil. 2012;26(4):351–61. DOI: 10.1177/0269215511419536.
5. Moustafa IM, Diab AA. The effect of adding forward head posture corrective exercises in the management of lumbosacral radiculopathy: a randomized controlled study. J Manipulative Physiol Ther. 2015;38(3):167–78. DOI: 10.1016/j.jmpt.2014.11.009.
6. Falla D, O'Leary S, Fagan A, Jull G. Recruitment of the deep cervical flexor muscles during a postural-correction exercise performed in sitting. Man Ther. 2007;12(2):139–43.
7. Keshner EA, Cromwell RL, Peterson BW. Mechanisms controlling human head stabilization. II. Head-neck characteristics during random rotations in the vertical plane. J Neurophysiol. 1995;73(6):2302–12.
8. Pozzo T, Berthoz A, Lefort L. Head stabilization during various locomotor tasks in humans. Exp Brain Res. 1990;82(1):97–106.
9. Grossman GE, Leigh RJ, Abel LA, Lanska DJ, Thurston SE. Frequency and velocity of rotational head perturbations during locomotion. Exp Brain Res. 1988;70(3):470–6.
10. Hirasaki E, Moore ST, Raphan T, Cohen B. Effects of walking velocity on vertical head and body movements during locomotion. Exp Brain Res. 1999;127(2):117–30.
11. Latt MD, Menz HB, Fung VS, Lord SR. Walking speed, cadence and step length are selected to optimize the stability of head and pelvis accelerations. Exp Brain Res. 2008;184(2):201–9.
12. Holt KJ, Jeng SF, Ratcliffe R, Hamill J. Energetic cost and stability during human walking at the preferred stride frequency. J Mot Behav. 1995;27(2):164–78.
13. Yun SH, Lee YM, Kwon JW. Spatiotemporal and kinematic parameters during uphill, downhill, and overground walking in forward head posture: a preliminary study. J Biomech. 2025 Jul 11;190:112866. DOI: 10.1016/j.jbiomech.2025.112866. Epub ahead of print.
14. Cromwell R, Schurter J, Shelton S, Vora S. Head stabilization strategies in the sagittal plane during locomotor tasks. Physiother Res Int. 2004;9(1):33–42.
15. Cromwell RL, Newton RA, Carlton LG. Horizontal plane head stabilization during locomotor tasks. J Mot Behav. 2001;33(1):49–58.
16. Sadeghi H, Allard P, Prince F, Labelle H. Symmetry and limb dominance in able-bodied gait - a review. Gait Posture. 2000;12(1):34–45.
17. Kogler A, Lindfors J, Ödkvist LM, Ledin T. Postural stability using different neck positions in normal subjects and patients with neck trauma. Acta Otolaryngol. 2000;120(2):151–5.
18. Vuillerme N, Rougier P. Effects of head extension on undisturbed upright stance control in humans. Gait Posture. 2005;21(3):318–25.
19. Harman K, Hubley-Kozey CL, Butler H. Effectiveness of an exercise program to improve forward head posture in normal adults: a randomized, controlled 10-week trial. J Man Manip Ther. 2005;13(3):163–76.
20. Bokaee F, Rezasoltani A, Manshadi FD, Naimi SS, Baghban AA, Azimi H. Comparison of cervical muscle thickness between asymptomatic women with and without forward head posture. Braz J Phys Ther. 2017;21(3):206–11.
21. Yoo WG, An DH. The relationship between the active cervical range of motion and changes in head and neck posture after continuous VDT work. Ind Health. 2009;47(2):183–8.
22. Goodarzi F, Rahnama L, Karimi N, Baghi R, Jaberzadeh S. The effects of forward head posture on neck extensor muscle thickness: an ultrasonographic study. J Manipulative Physiol Ther. 2018;41(1):34–41.
23. Weon JH, Oh JS, Cynn HS, Kim YW, Kwon OY, Yi CH. Influence of forward head posture on scapular upward rotators during isometric shoulder flexion. J Bodyw Mov Ther. 2010;14(4):367–74.
24. Yip CH, Chiu TT, Poon AT. The relationship between head posture and severity and disability of patients with neck pain. Man Ther. 2008;13(2):148–54.
25. Lin G, Zhao X, Wang W, Wilkinson T. The relationship between forward head posture, postural control and gait: a systematic review. Gait Posture. 2022 Oct;98:316–29. DOI: 10.1016/j.gaitpost.2022.10.008.
26. Shaghayegh Fard B, Ahmadi A, Maroufi N, Sarrafzadeh J. Evaluation of forward head posture in sitting and standing positions. Eur Spine J. 2016 Nov;25(11):3577-3582. DOI: 10.1007/s00586-015-4254-x. Epub 2015 Oct 17. Erratum in: Eur Spine J. 2021 Oct;30(10):3135. DOI: 10.1007/s00586-021-06923-z.
27. Ha NR, Shin HM, Kim MC, Oh HJ. Effects of abdominal breathing and thoracic expansion exercises on head position and shoulder posture in patients with rotator cuff injury. Journal of the Korean society of physical medicine 2016;11(4):1-9.
28. Mo SW, Xu DQ, Li JX, Liu M. Effect of backpack load on the head, cervical spine and shoulder postures in children during gait termination. Ergonomics 2013;56(12):1908-16.

29. Diéguez-Pérez M, de Nova-García MJ, Mourelle-Martínez MR, González-Aranda C. The influence of crossbite in early development of mandibular bone asymmetries in paediatric patients. J Clin Exp Dent. 2017;9(9):e1115.

30. Correale L, Carnevale Pellino V, Marin L, Febbi M, Vandoni M. Comparison of an inertial measurement unit system and baropodometric platform for measuring spatiotemporal parameters and walking speed in healthy adults.Motor Control.2020;25(1):89–99. DOI:10.1123/mc.2020-0060.

31. Rožac D, Kasović M, Knjaz D. Spatiotemporal Gait Asymmetries Remain Unaffected by Increased Load Carriage in Professional Intervention Police Officers. Bioengineering 2024;11(11):1140.

32. Pallant J. SPSS survival manual: a step by step guide to data analysis using IBM SPSS. 7th ed. Routledge; 2020. ISBN: 1003117457.

33. Titcomb DA, Melton BF, Bland HW, Miyashita T. Evaluation of the Craniovertebral Angle in Standing versus Sitting Positions in Young Adults with and without Severe Forward Head Posture. International Journal of Exercise Science. 2024;17(1):73.

34. Kang FJ, Lin KY. Observing the effect of physical activity on forward head posture and rounded shoulder posture in young healthy adults.J Phys Ther Sci. 2023;35(8):564–7. DOI:10.1589/jpts.35.564.

35. Mahmoud NF, Hassan KA, Abdelmajeed SF, Moustafa IM, Silva AG. The relationship between forward head posture and neck pain: a systematic review and meta-analysis. Curr Rev Musculoskelet Med. 2019;12(4):562–77. DOI:10.1007/s12178-019-09594-y.

36. Lin G, Zhao X, Wang W, Wilkinson T. The relationship between forward head posture, postural control and gait: a systematic review.Gait Posture. 2022;98:316–29. DOI:10.1016/j.gaitpost.2022.10.008.

37. Mosaad DM, Abdel-aziem AA. The relationship between neck angles and ground reaction forces in school children during backpack carriage. Biomed Hum Kinet. 2020;12(1):1–9.

38. Latour E, Latour EE, Nowaszczuk J, Arlet J, Zavatska L. Gait performance changes after ten cervical retractions. Phys Educ Stud. 2024;28(5):286–95.

39. Saad N, Moustafa IM, Ahbouch A, Alsaafin NM, Oakley PA, Harrison DE. Are rotations and translations of head posture related to gait and jump parameters? J Clin Med. 2023;12(19):6211. DOI:10.3390/jcm12196211.

40. Jafarnezhadgero A, Sheikhalizade H. Gait ground reaction force characteristics in children with and without forward head posture. J Kerman Univ Med Sci. 2019;26(1):55–66.

41. Kawasaki T, Ohji S, Aizawa J, Sakai T, Hirohata K, Kuruma H, et al. Correlation between the Photographic Cranial Angles and Radiographic Cervical Spine Alignment. *International Journal of Environmental Research and Public Health,* 2022;*19*(10):6278. DOI: 10.3390/ijerph19106278.

42. John CT, Seth A, Schwartz MH, Delp SL. Contributions of muscles to mediolateral ground reaction force over a range of walking speeds. J Biomech. 2012;45(14):2438–43.

43. Lythgo N, Wilson C, Galea M. Basic gait and symmetry measures for primary school-aged children and young adults. II: walking at slow, free and fast speed. Gait Posture. 2011 Jan;33(1):29-35. DOI: 10.1016/j.gaitpost.2010.09.017.

44. Liu YT, Lin AC, Chen SF, Shih CJ, Kuo TY, Wang FC, et al. Superior gait performance and balance ability in Latin dancers. Front Med. 2022;9:834497.