PHYSICAL EDUCATION OF STUDENTS

ORIGINAL ARTICLE

Gait performance changes after ten cervical retractions

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Abstract

Background and Study Aim Students are prone to spine overloading, as they often spend prolonged periods in unfavorable postures. They tend to struggle with balancing study time and leisure physical activity. The head and neck regions are particularly rich in proprioceptors. Prolonged forward head posture (protraction) can lead to balance disturbances. This, in turn, affects gait and overall body posture. The aim of this study was to examine the effects of a series of corrective active head exercises on gait, a fundamental form of movement, in a group of healthy university students.

Material and Methods Gait patterns were assessed in 10 healthy male full-time students with an average age of 22.8 years (SD = 1.1). The assessment was based on the regional distribution of plantar pressure across two measurement sessions. One session was conducted before, and one after performing 10 active head retractions. Gait changes were analyzed in ten foot regions for 200 steps of each participant.

Results After 10 cervical retractions, a decrease in pressure, ground reaction force, contact time, and area values was observed in the 1st metatarsal head (1MTH). Conversely, an increase in these quantities was found in the toes. Additionally, there was a tendency toward a decrease in the contact area of the heel and 3rd metatarsal head (3MTH), along with increased contact time in the midfoot. Performing 10 neck retractions altered gait by inducing heel supination. It also increased hallux involvement in propulsion and widened the base of toe support.

Conclusions Even a few movements that correct head protraction have an immediate effect on whole-body movement. This effect suggests potential benefits of incorporating neck retractions into physical education programs for students. Even when time-consuming forms of regular exercise are not feasible, performing just a few neck-correcting movements can positively impact overall body movement.

Keywords: students, gait, neck, proprioception, motor control

Introduction

Prolonged periods of sitting are a common issue among students. Poor posture, associated with extended sitting, can lead to significant musculoskeletal problems over time. Students have always been prone to maintaining unfavorable spine positions for extended periods. This posture is dictated by the need to use visual learning resources and process written information [1]. Recently, this problem has attracted greater attention due to the widespread use of smartphones for both productivity and entertainment [2]. As a result, efforts are being made to promote physical activity through sports and multidirectional therapeutic training within this social group [3, 4]. Unfortunately, not everyone is able to find time for regular training [5, 6]. Therefore, alternatives that require minimal time could provide an effective solution [7, 8, 9]. Nevertheless, most interventions aimed at increasing muscle mass or improving spine posture through body movements are typically evaluated based on repetitive training.

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Evidence shows that correcting posture and reducing the symptoms of posture-related defects is possible by regularly performing specific short movements over an extended period [10, 11]. However, no studies have examined the immediate effects of a few active movements that correct head and neck posture on the overall movement system. Despite the importance of such research for developing guidelines for effective interventions, the influence on the entire body remains unstudied.

Head position and the shape of the cervical spine are important factors in the pathogenesis of discopathy and undiagnosed neck or head pain. These conditions are often associated with the loss of cervical lordosis [12, 13, 14, 15]. Patients with decreased cervical lordosis tend to experience longer episodes of headaches compared to those without this postural disturbance [16]. The reading position significantly influences the alignment of all sections of the spine in the sagittal plane [2]. Therefore, various therapeutic and preventive interventions are recommended. Since it has been emphasized that repetitive movements influence muscle development, studies have examined the outcomes of long-term programs aimed at correcting head

posture [17]. It has been found that regularly repeated movements to correct head posture have a positive effect [18]. Many therapeutic techniques involve passive movements of the patient's neck, aiming to produce immediate changes in pain perception and body control. Some of these techniques, like Glisson's cervical traction belt, have been used for a long time. Others, such as suboccipital muscle traction [8, 19] or various massage methods, including the suboccipital muscle inhibition technique, were introduced more recently. Only the "Mechanical Diagnosis and Therapy" method, known as the McKenzie method, uses repeated cervical retractions to treat and diagnose neck pain. The rationale for using repetition is based solely on the local modification of pressure distribution in the intervertebral discs [20, 21, 22]. However, the effects of these interventions in previous studies were assessed after multiple repeated movement sessions. Successful application of these methods requires that subjects allocate sufficient time for the exercises.

Meanwhile, it has been noted that even temporary increases in head load caused by forward head posture can disrupt proprioception. This disruption contributes to difficulties in correcting head posture, especially in individuals with more pronounced forward head protraction [4]. This phenomenon is unique to the neck, explained by the higher spindle density in neck muscles, which allows them to receive a greater number of proprioceptive signals [23]. Head position affects balance [24]. It influences overall posture through multisensory contributions to visuospatial orientation, as the interaction between neck and trunk proprioception has been confirmed [25]. The mutual dependence between gait motor control and head position has been established in only a few studies and remains unclear [26]. This dependence is demonstrated by changes in gait caused by uneven ground, which lead to the stabilization of head position during walking [27]. Additionally, changes in gait have been observed in specific head positions [28]. Therefore, movements that correct neck alignment are likely to reduce the strain imposed on the spine by maintaining unfavorable long-term positions. This observation may also explain the immediate relief experienced after various physiotherapeutic interventions targeting the neck.

Taken together, prophylactic solutions that require little time are highly sought-after. The heretofore proposed recommendations are time-consuming and, as a result, not widely followed by busy students. Despite numerous studies highlighting the benefits of regular physical activity and posture correction exercises, the challenge remains in developing interventions that are both effective and feasible for students. Many existing therapeutic approaches, while beneficial, require sustained effort and regular practice over long periods. This limits their widespread adoption. Therefore, there is a clear need for simpler, more time-efficient methods. Such methods should provide both immediate and long-term relief from the negative effects of prolonged poor posture, particularly in the student population.

Analysis of research findings allows us to propose the following hypothesis: Performing even a few movements that correct head posture has an immediate effect on body alignment. This leads to improved posture, which, in turn, affects walking conditions and gait performance.

The aim of this study was to examine the effects of a series of corrective active head exercises on gait, a fundamental form of movement, in a group of healthy university students.

Materials and Methods

Participants

Ten male full-time university students participated in the study. The participants reported no health issues and showed no visible signs of conditions that could affect musculoskeletal function. The group was characterized by the following parameters: age – 22.8 (SD = 1.1) years, mass – 76.75 (SD = 6.81) kg, height – 179.6 (SD = 0.04) cm, and BMI – 21.58 (SD = 2.44) kg/m^2.

Each participant provided informed consent prior to the study, which was conducted in accordance with the guidelines of the Declaration of Helsinki. The study protocol was approved by the institutional review boards of the Ethics Committee of the Poznan University of Medical Sciences (Act 1068/16, Archived Number 10/November/2016).

Study Design

To assess the impact of a series of cervical spine extension movements on gait, individual walking patterns were compared before and after performing a few movements aimed at straightening the cervical spine. The interactions between different anatomical-functional areas of the foot and the ground during weight shifting in free gait were measured for comparison.

Equipment. To measure changes in plantar pressure, an emed-m pedobarometric platform (Novel, Munich, Germany) was used. The platform, with an active area of 395 × 240 mm, was equipped with 3792 capacitance-based force transducers, providing a resolution of 4 sensors/cm^2. It was embedded in a 5-meter walkway. The platform was paired with Novel software, which collected measurement data at a frequency of 100 Hz and performed preliminary analysis of the temporal-spatial distribution of foot plantar pressures.

Measurement protocol. The measurements were conducted between 8 AM and 1 PM. The course of the experiment is presented in Figure 1. The experiment consisted of four stages:

1. The initial stage, including introductory and instructional activities,
2. The first measurement session,
3. Performing a series of cervical spine extension movements,
4. The second measurement session.

At the initial stage, all participants were thoroughly instructed on how to enable data collection. They performed several practice walk-throughs to master the second-step method [29]. According to this method, the participant takes the first step in front of the platform and the second step onto the platform, where the pressure characteristics are recorded. Participants were also guided on how to arrange the optimal starting distance from the platform, which is essential for executing the second-step protocol correctly. This process familiarized the participants with an optimal walking rhythm [30], which minimized measurement errors caused by the tendency to place greater load on the first step. All participants took part in both measurement sessions. In each session, every participant completed 100 passes over the measuring platform - 50 passes with the right foot and 50 with the left foot, alternating between the two. Before the second session, each participant performed 10 cervical spine retractions in a seated position (Figure 2).

Data extraction. The artificial intelligence algorithms in the Novel emed-m software automatically identified specific anatomically functional areas of the foot from the plantar images. These areas, referred to as "masks," were generated based on the distribution of plantar pressures in each measurement. The Novel software, integrated with the platform, isolated ten such masks, corresponding to: 1 - heel (H), 2 - midfoot (MF), 3-7 - the five metatarsal heads (MTH1–MTH5), 8 - hallux (first toe), 9 - second toe, 10 - third to fifth toes, and 0 - the entire foot surface. Files generated by the measuring system were processed using Novel's Multimask and Groupmask Evaluation programs, allowing for preliminary statistical and numerical analysis.

The text files representing the measurement results, generated by the system, were processed using the AWK programming language. The program was used to extract the desired index values in a format suitable for subsequent numerical processing. The extracted values included maximal (*mxa*) and mean (*mea*) contact area [cm^2], mean force (*mef*) [N], contact time (*ctm*) [s], and percentage of contact time (*ctp*) [%], which

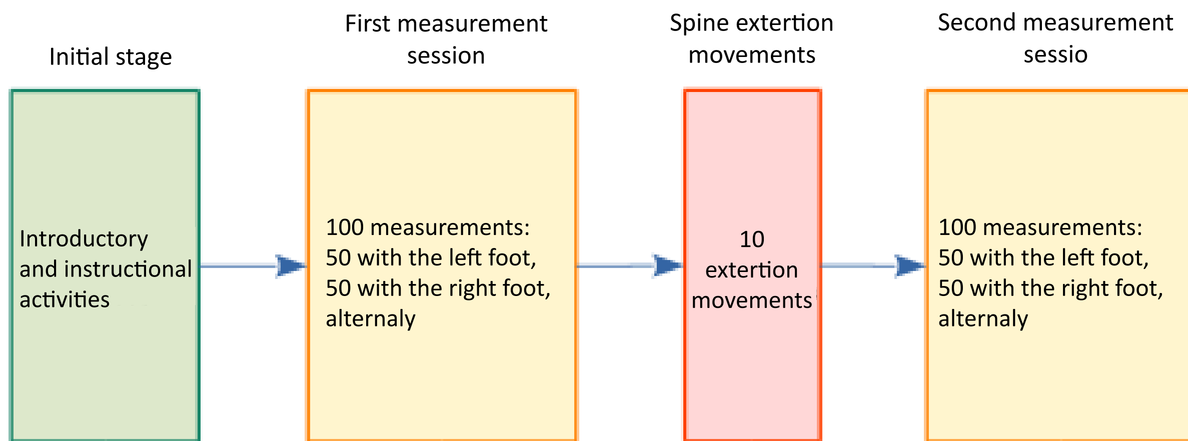

Figure 1. The course of the experiment.

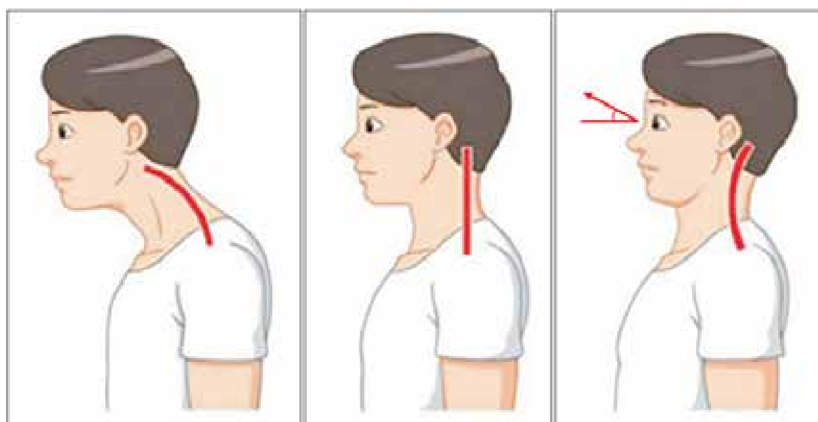

Figure 2. Cervical spine retraction movement [31].

represents the ratio of the *ctm* of a single mask to the *ctm* of the entire foot.

Statistical Analysis

The analyses and charts were developed using the R Language and Environment for Statistical Computing [32]. Initial results were assessed qualitatively before the measurement data underwent statistical description and further analysis. The statistical tests applied included the Kendall rank correlation test and the Shapiro–Wilk test.

A Kendall rank correlation test of the measured values, conducted across 400 50-sample sets of measurements (10 participants × 2 feet × 10 masks, tested twice), showed no observable learning effect. The extreme mean value of Kendall's Tau coefficients for these sets, grouped by individual masks, was -0.1 [-0.15, -0.04]. Additionally, a Kendall rank correlation test of stance phase time with other measured quantities indicated no significant influence of gait velocity on the measured parameters. A Shapiro–Wilk test for normality did not reveal strong deviations from a normal distribution in the measurement data.

To enable proper comparison of parameter values across different individuals, the collected data was normalized, and the percentage mean pressure (*pmp*) index was calculated [33]. This index is defined as the percentage ratio between the mean pressure values for specific masks and the total value for all recorded areas of plantar pressure, as described by the following formula (1), with the abbreviations:

mef_n – mean force for mask n,
mef_0 – mean force for the entire foot,
mxa_n – maximal area for mask n,
mxa_0 – maximal area for the entire foot.

$$pmp_n = 100 \cdot \frac{\frac{mef_n}{mxa_n}}{\frac{mef_0}{mxa_0}} = 100 \cdot \frac{mef_n \cdot mxa_0}{mef_0 \cdot mxa_n} \tag{1}$$

This index represents the contribution of different foot parts to body weight shifting during each step. For the assessment of mean area (*mea*), normalization was performed using formula (2), with the following abbreviations:

mea_n – mean area for mask n,
mea_0 – mean area for the entire foot.

$$pa_n = 100 \cdot \frac{mea_0}{mea_n} \tag{2}$$

To minimize the effects of outliers that could occur due to non-standard events, which may have been missed during the measurement, all datasets were subjected to adaptive winsorisation. This procedure defines outliers as values outside the range between the lower limit, calculated as the difference between the first quartile and 1.5 times the interquartile range, and the upper limit, calculated as the sum of the third quartile and 1.5 times the interquartile range. The winsorisation process adjusts these outliers to the extreme values of the lower and upper limits of the defined interval. The relative change in the values of the analysed indices due to the retraction exercise was estimated using the following formula (3):

$$RC(x_1, x_2)\ [\%] = ln\left(\frac{x_2}{x_1}\right) \cdot 100 \tag{3}$$

where:

- x_1 – value from the first measurement session,
- x_2 – value from the second measurement session,

and these values were visualized using boxplots and point-and-whisker charts.

The Cliff's δ effect size [34] of this change was also calculated. Using the orddom function [35], the Cliff's δ effect size was determined according to the following formula (4):

$$\delta(x) = \frac{\sum_{i=1}^{n} sign\,(x_i)}{n} \tag{4}$$

where:

- sign – the sign function of a number,
- n – sample size, and the p-value of the null hypothesis for Cliff's δ.

All analyzed datasets were described by their means and 95% confidence intervals (CIs), with the interval boundaries presented in square brackets ([CIlower, CIupper]).

Results

For all the analyzed indices, namely pressure, force, area, and time, a consistent change in the gait pattern was observed. There was a decrease in values for the 1st metatarsal head (1MTH) and an increase in values across all the toes. A reduction occurred in the contact area of the heel and the 3rd metatarsal head (3MTH), while the contact time of the midfoot increased.

Pressure

The assessment of weight-shifting engagement showed a decrease for mask 3 (1MTH) and an increase for masks 6-10, which correspond to the 4th and 5th metatarsal heads (4MTH, 5MTH) and the toes (Figure 3). Figure 3 demonstrates: A notable decline in gait engagement is evident for the 1MTH (mask 3), while a modest enhancement in the engagement is observed for the 4-5 MTH and the third to fifth toes (mask 10).

Contact area

The area of contact decreased for masks 1, 2, 3, 6 and 7 (heel, midfoot, 1MTH, 4MTH and 5MTH), while it increased for masks 8 and 10 (hallux and toes 3-5), as shown in Figure 4. The contact area generally shifted to the toes. The absolute values (*mea*) decreased

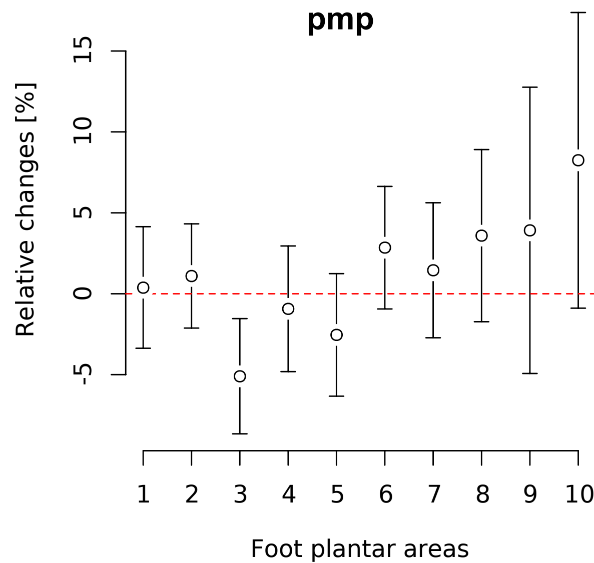

Figure 3. The effect of cervical retraction exercises on the pattern of weight shifting, as evidenced by alterations in the *pmp* index: The whiskers around each point represent 95% confidence intervals.

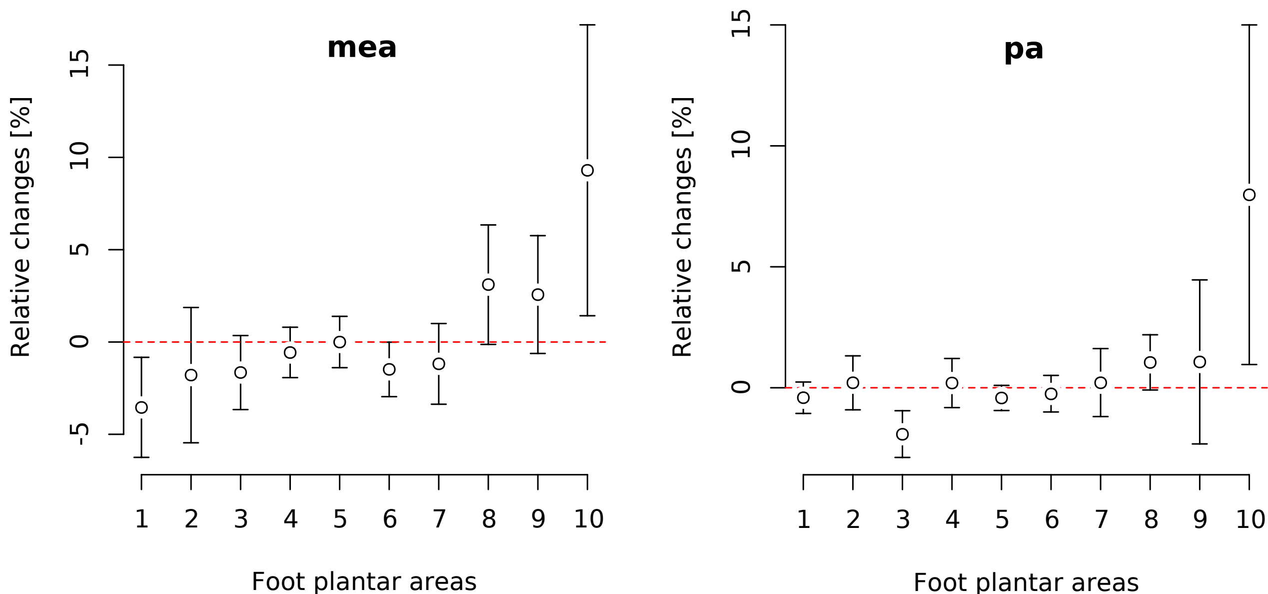

Figure 4. The effect of cervical retraction exercises on the pattern of weight shifting, as evidenced by alterations in the non-normalise *mea* and the normalised *pa* indices of the area of contact with the ground: The whiskers around each point represent 95% confidence intervals.

most prominently for the heel, but in the pattern expressed by relative values (*pa*) - the decrease was the most pronounced for mask 3 (1MTH). The contact area for the whole foot remained unchanged (*mea*) group mean difference 0.06[-0.59 0.71], δ= 0.1 [-0.35 0.512], (p = 0.666). Figure 4 demonstrates: A reduction in ground contact is evident for the 1MTH (mask 3), while a notable decline is observed for the heel (mask 1) and the 3MTH (mask 5). Conversely, there is an increase in the contact area for the hallux (mask 8) and the 3 -5 toes (mask 10).

Contact Time

The contact time increased for masks 2 and 7-10 (midfoot, 5MTH, and the toes) in both absolute (*ctm*) and relative values (*ctp*), as shown in Figure 5. Contact time for the whole foot remained unchanged (*ctm* group mean difference 1.8 [-0,2 3,79], δ = 0.2 [-0.24 0.57], p = 0.359). Figure 5 demonstrates: The increase in contact time is most evident for hallux (mask 8). Furthermore, a discernible enhancement in this interval is evident for midfoot (mask 2) and toes.

Ground reaction force

The ground reaction force (*mef*) decreased for masks 1 (-2,37 [-5,95 1,21] δ = -0,4 [-0,73 0,079] p = 0,072) and 3 (-6,8 [-11,3 -2,3] δ = -0,4 [-0,73 0,079] p = 0,072) and increased for masks 8, 9 and 10, as shown in Figure 6 meaning that the heel and 1MTH loads decreased and toes loads in the gait performance increased. For the whole foot, *mef*

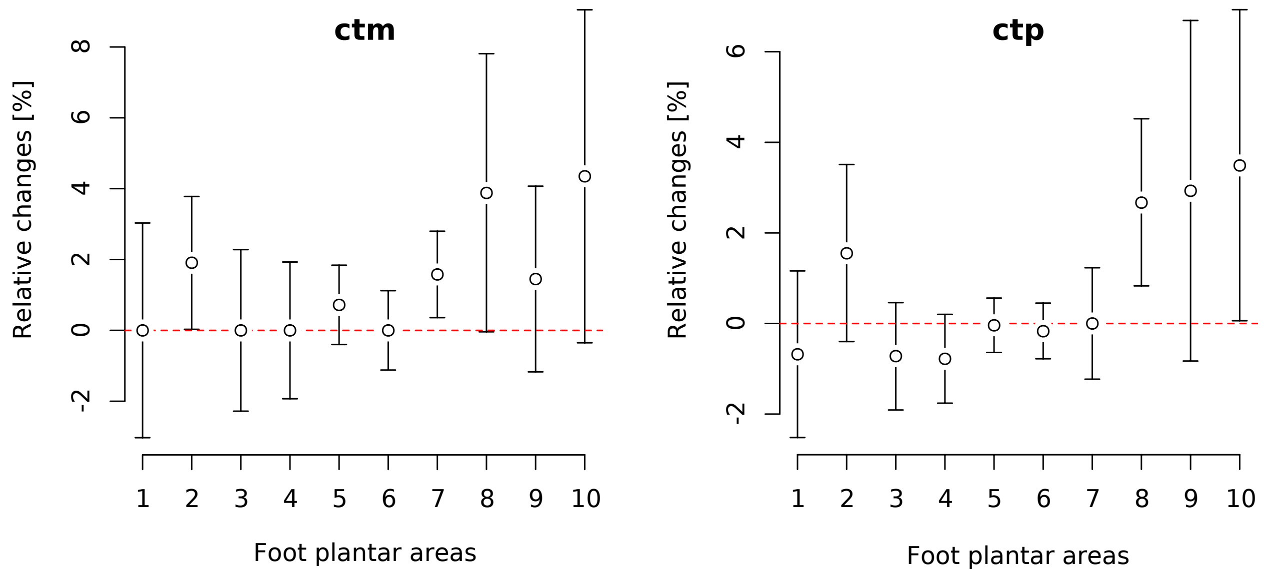

Figure 5. The effect of cervical retraction exercises on the pattern of weight shifting (alterations in the non-normalised *ctm* and the normalised *ctp* indices of time of contact with the ground): The whiskers around each point represent 95% confidence intervals.

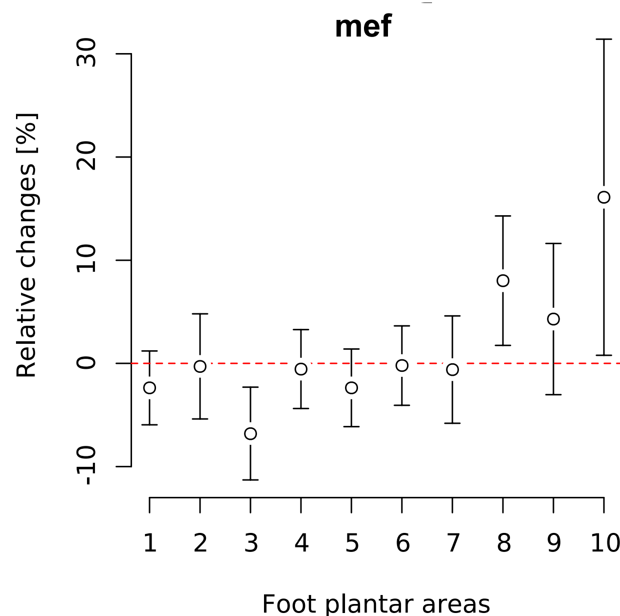

Figure 6. The effect of cervical retraction exercises on the pattern of weight shifting (alterations in the non-normalised *mef* index of the force of interaction with the ground): The whiskers around each point represent 95% confidence intervals.

remained unchanged (*mef* group mean difference 0.02 [-0.42 0.47], δ = 0 [-0.43 0.43], p = 1). Figure 6 demonstrates: The increase of the contact time is most evident for 1MTH (mask 3). A discernible enhancement in the force is also evident for toes.

The numerical analysis of the effect of retractions on the relative changes was performed on normalised indices *pmp*, *ctp*, and *pa* (Table 1). Table 1 demonstrates: The most prominent positive changes were seen for mask 3 (1MTH), while the most notable negative changes were found for mask 10 (3-5 toes) across all normalised indices. Although less evident, consistent growth was observed for masks 8 (halux) and 9 (second toe).

Discussion

To promote the prevention of posture disturbances among students, it is essential to conduct studies that assess the effectiveness of a few movements aimed at correcting protracted head posture, which often results from non-ergonomic positions during computer use, reading, or writing. Given the influence of head position on proprioception, it was hypothesized that even a small number of neck retraction repetitions would affect the gait pattern. After performing 10 neck retractions, gait assessment in a group of students revealed a multidimensional decrease in values at

Table 1. The effect of the retraction exercises in relative changes of the values of the normalized indices: *pmp*, *ctp* and *pa*. 95% confidence intervals (CIs) are presented in square brackets [CI_{lower} CI_{upper}].

	pmp			**ctp**			**pa**		
m	**Mean**	**δ**	**p**	**Mean**	**δ**	**p**	**Mean**	**δ**	**p**
1	0.38 [-3.37 4.14]	0.1 [-0.35 0.51]	0.67	-0.68 [-2.52 1.16]	-0.15 [-0.543 0.30]	0.51	-0.41 [-1.06 0.24]	-0.2 [-0.59 0.26]	0.39
2	1.1 [-2.12 4.32]	0 [-0.433 0.43]	1	1.55 [-0.40 3.51]	0.25 [-0.207 0.62]	0.26	0.21 [-0.91 1.32]	0.1 [-0.35 0.512]	0.67
3	-5.1 [-8.66 -1.54]	-0.5 [-0.793 -0.02]	0.02	-0.72 [-1.91 0.46]	-0.3 [-0.661 0.17]	0.19	-1.92 [-2.88 -0.95]	-0.5 [-0.79 -0.02]	0.02
4	-0.93 [-4.81 2.95]	-0.3 [-0.661 0.17]	0.19	-0.78 [-1.76 0.2]	-0.25 [-0.617 0.21]	0.26	0.2 [-0.82 1.21]	0.1 [-0.35 0.51]	0.67
5	-2.54 [-6.33 1.24]	-0.2 [-0.588 0.26]	0.39	-0.04 [-0.64 0.56]	-0.05 [-0.464 0.38]	0.83	-0.42 [-0.94 0.1]	-0.3 [-0.66 0.17]	0.19
6	2.85 [-0.94 6.63]	0.2 [-0.263 0.59]	0.39	-0.17 [-0.78 0.45]	-0.15 [-0.543 0.30]	0.51	-0.25 [-1 0.51]	-0.2 [-0.59 0.26]	0.39
7	1.45 [-2.72 5.62]	0.2 [-0.263 0.59]	0.39	0 [-1.23 1.23]	-0.05 [-0.45 0.36]	0.82	0.21 [-1.19 1.62]	0.2 [-0.26 0.59]	0.39
8	3.59 [-1.73 8.91]	0.3 [-0.173 0.66]	0.19	2.67 [0.83 4.52]	0.55 [0.09 0.82]	0.01	1.05 [-0.09 2.19]	0.3 [-0.17 0.66]	0.19
9	3.92 [-4.93 12.76]	0.1 [-0.35 0.51]	0.67	2.93 [-0.83 6.69]	0.2 [-0.26 0.59]	0.39	1.07 [-2.32 4.46]	0.2 [-0.26 0.59]	0.39
10	8.25 [-0.89 17.38]	0.5 [0.02 0.79]	0.02	3.49 [0.06 6.93]	0.4 [-0.08 0.73]	0.07	7.98 [0.96 15]	0.4 [-0.08 0.73]	0.07

the 1st metatarsal head (1MTH) and an increase in values at the toes. Additionally, the performance of these movements led to a reduced contact area in the heel and 3rd metatarsal head (3MTH), along with an extension of contact time in the midfoot.

A decrease of approximately 5% in 1MTH engagement in weight-shifting ($\delta = 0.5$, $p = 0.02$) was recorded, along with a tendency for increased engagement of the lateral metatarsal heads (MTHs) and all toes in this process (for toes 3-5, $\delta = 0.5$, $p = 0.02$) (Table 1). These changes were associated with a shift of approximately 5% in ground reaction force (mef) from 1MTH to the hallux and toes 3-5. Additionally, a decrease in the contact area by several percent (mea, pa) was observed in masks 1 (heel), 3 (1MTH), and 5 (3MTH), while an increase occurred in masks 8 (hallux) and 10 (toes 3-5). These dynamics indicate that changes in pressure and force were accompanied by a shift in foot positioning on the ground. As the contact area of the heel decreased without a corresponding reduction in load, this change was attributed to a more supine position of the calcaneal tuberosity. The increased contact time in the midfoot and across the entire foot supports the idea of a more supine weight transfer through the foot after performing cervical extensions. The plantar pressure distribution analysis suggests a shift towards a more supine foot position, increased hallux engagement in propulsion, and greater reliance on the toes for support. These outcomes suggest that even a brief deepening of cervical lordosis during extension can alter gait patterns.

This study is the first to demonstrate immediate changes in gait resulting from just a few corrective head movements. Similar analyses have not been conducted to date [26], which is why the observed gait pattern changes can only be compared to the effects reported in studies focusing on regularly repeated training targeting the neck region [17]. As in those studies, the intervention involving the neck led to expected changes. However, it is surprising that alterations in plantar pressure distribution occurred after only a few corrective movements. Considering the existing reports on the influence of neck and head alignment on proprioception and balance [24], these observed changes become more comprehensible. The results indicate that even a brief deepening of cervical lordosis during extension can immediately alter proprioceptive conditions, affecting motor control processes. Thus, it was found that performing just a few movements to correct head position has an impact on the entire body, leading to changes in gait.

The existing evidence supports the direction of the observed changes. Heel positioning is considered a critical factor in influencing the conditions of propulsion [36]. The midfoot plays a significant role in power generation during walking. Pronation and plantarflexion moments in this area are related to the foot's resistance to supination. Lower resistance to supination, in turn, enhances the midfoot's power generation capacity. Given this, the observed

effect of achieving a more supine heel position through head alignment correction likely creates more favorable conditions during the stance phase of gait. This is especially relevant in the context of ankle joint stability, which, when compromised, can lead to injuries.

The observed shift in load toward the toes, particularly the hallux, aligns with recent studies investigating the "windlass mechanism" in foot function. These studies highlight the importance of dorsiflexion at the intermetatarsal joint (IMTJ) for effective propulsion [37]. However, adequate force generation under the hallux is crucial for this flexion to contribute to propulsion. We observed an increase in this force generation ability after performing neck extensions. This result underscores the significant role of the neck region in regulating propulsion conditions. It is consistent with findings from a study showing that a lateral head position reduced propulsion efficiency on the side toward which the head was leaned [28]. The results presented here suggest that performing just a few neck posture correction movements creates favorable conditions for subsequent movement activities. In gait, these movements enhance weight-shift efficiency, leading to a more supine heel position and greater hallux engagement in propulsion. Thus, we found that even a small number of neck posture correction movements can positively influence locomotion dynamics.

In our study, the benefits of performing even a few head and neck posture-correcting movements highlight their usefulness during periods of excessive loading, such as those caused by forward head posture. The fact that the corrective effect occurs immediately after just a few movements helps explain the instant benefits of therapeutic techniques that involve or facilitate neck extension, such as muscle relaxation. Therefore, studies on therapeutic interventions should prioritize neck extensions before considering other techniques to avoid overlapping effects. For individuals who spend hours working or studying at a desk, performing neck extensions throughout the day should become a routine practice, not only for its positive impact on the structural elements of the neck but also for the significant influence it has on the motor control of the entire body, as demonstrated in our findings.

While this study demonstrated the immediate benefits of neck posture-correcting movements on gait and motor control, certain limitations should be acknowledged. The sample size was relatively small and limited to healthy university students, which may affect the generalizability of the findings. Future research should involve larger, more diverse populations and investigate the long-term effects of these corrective movements. Additionally, further studies are needed to explore the interaction between neck extensions and other therapeutic techniques to better understand their combined impact on posture and movement control.

Conclusions

Performing just a few neck movements, such as retractions, significantly alters gait and has a direct impact on the overall condition of the body. This simple intervention is sufficient to induce heel supination, increase hallux engagement in propulsion, and widen the base of foot support through greater toe involvement. Therefore, even a small number of corrective head movements have therapeutic benefits and contribute to the prevention of postural-related disorders by influencing whole-body movement. Short sequences of neck-extension movements, even when performed occasionally, should be incorporated into students' physical education programs. These exercises have the potential to benefit individuals who are prone to overloading due to prolonged periods of forward head posture during computer use or reading.

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