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Short communication

The impact of prolonged experimental neck pain on walking stability and gait kinematics - A parallel-group study

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ABSTRACT

Background: Neck pain is a common problem in the general population, and movement adaptations are a natural response to pain. Previous studies have reported reduced trunk rotation during walking in those suffering from clinical neck pain. However, it is unknown how soon after the onset of pain, movement adaptations are adopted. This study investigated the effect of prolonged experimental neck pain four days after pain onset on gait kinematics during walking.

Methods: Forty healthy participants were randomized to receive injections of nerve-growth-factor or a control injection of isotonic saline into the right splenius capitis muscle at the end of days 0 and 2. Participants performed two walking tasks, walking and walking while reading on a smartphone, on days 0, 4, and 15. Gait kinematics, spatiotemporal parameters, and gait stability were measured using Xsens Awinda.

Findings: The nerve-growth-factor group reported increased neck pain intensity (median VAS 17.5 [IQR: 2.75–25.75]) on day 4 compared to day 0 and day 15. No pain intensity changes between days were reported for the isotonic-group. For gait kinematics, a main effect of the task was identified, showing that during the smartphone condition, participants had shorter stride lengths and reduced RoM for the trunk, hip, knee, and ankle compared to normal waking ($P < 0.006$).

Interpretation: Walking while reading on a smartphone, but not mild neck muscle pain, caused changes in the gait kinematics compared to normal walking without neck pain. This finding suggests that movement alterations during walking are not an early feature of prolonged experimental neck pain.

1. Introduction

Movement adaptations are a natural response to pain (Hodges and Tucker, 2011). Several studies have demonstrated that young people with ongoing neck pain walk with reduced trunk rotation, and these changes get more pronounced when walking with the head rotated or performing a dual-task (Alsultan et al., 2020; Falla and Dieterich, 2017; Uthaikhup et al., 2014). However, it remains unclear if the pain is causing these changes in trunk rotation and how soon these strategies are adopted after the onset of neck pain, as the previous studies tested people with ongoing neck pain. In a healthy population, reduced trunk rotations have been observed when given a dual-task with reading/typing on a smartphone while walking (5). This suggests that the allocation of cognitive resources may instantly impact locomotion.

One way of isolating the effects of pain on movement is to use experimental pain models (Christensen et al., 2022; Simonsen et al., 2019a). In recent years, intramuscular injection of nerve-growth-factor (NGF) has been used to cause muscle pain lasting for days, potentially mimicking the early phases of some painful musculoskeletal conditions (Christensen et al., 2022; Gerber et al., 2011; Schabrun et al., 2016). An intramuscular NGF injection causes muscle pain or soreness during muscle contractions for multiple days (Bergin et al., 2015; Christensen et al., 2022). This brief report aimed to investigate the effect of prolonged experimental neck pain on gait kinematics during walking and

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walking while reading on a smartphone. Two hypotheses were generated: (I) Trunk rotation would be reduced during walking with experimental neck pain compared to no pain, and (II) trunk rotation would be further reduced when walking while reading on a smartphone with experimental neck pain compared to no pain.

2. Methods

2.1. Participants

The present study was conducted alongside a 16-day, double-blinded study (Christensen et al., 2022). With forty healthy participants, two groups, and three test days with an alpha of 0.05 and 80% power, the study could detect an effect size of 0.24. Participants were randomized to receive injections of either NGF or a control injection of isotonic saline into a neck muscle at the end of day 0. A booster injection was given on day 2 to prolong any possible painful experience. The participants' gait was measured on days 0 (before the first injection), 4, and 15. Two gait tasks were performed: (a) walking with the head in a neutral position and (b) walking while reading a news article aloud from a smartphone. The news articles were topical and differed between days to avoid familiarization with the text. The North Denmark Region Committee on Health Research Ethics (N-20180063) granted ethical approval for this study. This study focusing on alterations in human kinematics during gait, is a part of a larger project (Clinicaltrial.gov: NCT03848247) investigating potential effects of prolonged experimental neck pain on pain sensitivity, cortical excitability, and alterations in human movement. All participants gave written and oral informed consent before commencing the study.

2.2. Gait kinematics

All participants repeated the two gait tasks three times at a self-selected speed. Xsens MVN Awinda (Xsens Technologies BV, Enschede, NL) was used to measure gait kinematics. A custom-made script for MATLAB (R2022a) (The MathWorks, Inc., Natick, Massachusetts, USA) was used to extract the sagittal ankle, knee, and hip joint angles, transverse trunk rotation, walking velocity, arm swing, and stride time variability (gait stability) (Beauchet et al., 2009; König et al., 2016; Walha et al., 2022). Further details are provided in the supplementary material. Each trial's first and last two steps were excluded for analysis (Simonsen et al., 2022) for all processing.

2.3. Experimental pain

Experimental neck pain was induced by injection of NGF (0.5 ml, 5 μg) into the right splenius capitis between the anterior border of the upper trapezius muscle and the posterior border of the sternocleidomastoid muscle at the level of C3 (Christensen et al., 2022). Isotonic saline (0.5 ml, 0.9%) was used as a control injection. Participants rated their perceived neck pain intensity at rest on a 0-100 mm (0 mm = no pain 100 mm = worst imaginable pain) visual analog scale (VAS) before the experiment started and immediately after the third gait trial of each task.

2.4. Statistics

All data were tested for normality using a Shapirio Wilk test. Pain intensity between days for the isotonic or NGF group was analyzed using Friedman tests at rest and, for both walking tasks, with Wilcoxon signed-rank, post-hoc tests. A three-way repeated measures analysis of variance (RM-ANOVA) was used to compare gait kinematics and spatiotemporal parameters with the factors: walking tasks (with and without using a smartphone), group (isotonic and NGF) and days (day 0, 4, and 15) as factors. Arm swing was only analyzed during normal walking with a two-way RM-ANOVA. Posthoc analyses were performed with Bonferroni corrections, and the alpha value was set to 0.05. Statistical analyses were performed in SPSS v27 (SPSS Inc., Chicago, USA).

3. Results

3.1. Participants

The isotonic group consisted of 20 participants (11 females) with a mean age and standard deviation of 26.6 ± 4.8 years, body height of 176.8 ± 11.4 cm, and a body weight of 75.4 ± 20.2 kg. The NGF group also consisted of 20 participants (11 females) with a mean age and standard deviation of 26.6 ± 5.1 years, body height of 171.8 ± 7.3 cm, and a body weight of 72.1 ± 11.6 kg.

3.2. Experimental neck pain

Table 1 presents the data for pain intensity. For the NGF group, the pain intensity was different between days during rest ($X2(2) = 29.7$, $P > 0.001$), with higher scores on day 4 compared to day 0 ($Z = -3.518$, $P > 0.001$) and day 15 ($Z = -3.519$, $P > 0.001$). A difference in pain intensity for the NGF group was also observed between days immediately after normal walking ($X2(2) = 22.2$ $P > 0.001$), with higher pain intensity on day 4 compared to day 0 ($Z = -3.064$, $P = 0.006$) and 15 ($Z = -3.065$, $P = 0.006$). Following walking, while reading, pain intensity was also different between days for the NGF group ($X2(2) = 21.12$ $P > 0.001$), with higher scores on day 4 compared to day 0 ($Z = -3.062$, $P = 0.006$) and day 15 ($Z = -3.064$, $P = 0.006$). The higher pain intensity reported by the NGF-group on day 4 was significantly higher when compared to the isotonic group at rest ($Z = -4.888$, $P > 0.001$), normal walking ($Z = -3.674$, $P > 0.001$), and walking while reading ($Z = -4.004$, $P > 0.001$). No between-day difference was found in pain intensity for the isotonic group.

3.3. Gait kinematics

During both walking tasks, no difference was observed between the NGF and the isotonic groups on any test days for gait velocity, step cycle length, gait stability, or RoM for the trunk, hip, knee, and ankle joints (Table 2). However, the participants in both groups walked slower (0.1 m/s slower, $F(1,38) = 10.457$, $P = 0.001$), with shorter step lengths (0.05 m shorter, $F(1,38) = 12.0$, $P = 0.001$), and with reduced RoM for the trunk (2.4° reduction, $F(1,38) = 30.6$, $P < 0.001$), hip (2.7° reduction, $F(1,38) = 35.3$, $P < 0.001$), knee (1.7° reduction, $F(1,38) = 19.7$, $P < 0.001$), and ankle (1.5° reduction, $F(1,38) = 7.93$, $p = 0.005$) when walking while reading compared to normal walking.

Table 1
Median (interquartile range: 25th and 75th percentile) pain scores using a 0-100 mm visual analog scale for both groups (Isotonic and nerve-growth-factor (NGF)) during rest, immediately after normal walking and walking while reading on a smartphone.

	Isotonic	NGF
VAS score at rest		
Day 0	0.0 [0.0–0.0]	0.0 (0.0–2.75)
Day 4	0.0 [0.0–0.0]	17.5 (2.75–25.75)*, †
Day 15	0.0 [0.0–0.0]	0.0 (0.0–0.0)
VAS score normal walking		
Day 0	0.0 [0.0–0.0]	0.0 (0.0–0.0)
Day 4	0.0 [0.0–0.0]	1.0 (0.0–9.5)*, †
Day 15	0.0 [0.0–0.0]	0.0 (0.0–0.0)
VAS score walking dual-task		
Day 0	0.0 [0.0–0.0]	0.0 (0.0–0.0)
Day 4	0.0 [0.0–0.0]	1.5 (0.0–13.5)*, †
Day 15	0.0 [0.0–0.0]	0.0 (0.0–0.0)

* Significant within-group difference compared with day 0 and day 15 (Wilcoxon's test: $P < 0.05$).
† Significant compared with the isotonic group (Mann-Whitney U: $P < 0.05$).

Table 2
Average ± standard deviation of the gait kinematics, spatiotemporal parameters, and gait stability for the nerve growth factor (NGF) and isotonic groups for all test days (0, 4 and 15).

	Day 0		Day 4		Day 15	
	Isotonic	NGF	Isotonic	NGF	Isotonic	NGF
Normal walking						
Velocity (m/s)	1.3 ± 0.1	1.3 ± 0.1	1.3 ± 0.1	1.3 ± 0.1	1.3 ± 0.1	1.3 ± 0.1
Step cycle length (m)	1.4 ± 0.1	1.40 ± 0.1	1.5 ± 0.1	1.50 ± 0.1	1.5 ± 0.1	1.5 ± 0.1
Hip RoM (°)	41.2 ± 5.7	40.2 ± 6.9	40.7 ± 5.6	41.4 ± 7.3	41.5 ± 5.3	40.6 ± 6.6
Knee RoM (°)	59.4 ± 9.1	60.6 ± 8.3	58.6 ± 9.1	60.2 ± 9.5	59.4 ± 9.3	58.9 ± 9.5
Ankle RoM (°)	35.1 ± 7.8	34.1 ± 7.6	35.6 ± 9.4	33.9 ± 8.1	36.6 ± 8.3	34.5 ± 9.3
Trunk rotation RoM (°)	12.1 ± 3.4	11.0 ± 4.0	12.6 ± 4.3	10.4 ± 3.4	13.4 ± 3.2	11.6 ± 3.5
Gait stability (%)	2.8 ± 0.8	2.8 ± 0.9	2.4 ± 0.6	2.6 ± 0.65	2.5 ± 0.6	2.6 ± 0.9
Left arm swing (m)	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1
Right arm swing (m)	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1
Walking dual-task						
Velocity (m/s)	1.2 ± 0.1	1.2 ± 0.1	1.2 ± 0.1	1.2 ± 0.1	1.3 ± 0.2	1.2 ± 0.1
Step cycle length (m)	1.4 ± 0.1	1.4 ± 0.1	1.4 ± 0.1	1.4 ± 0.1	1.4 ± 0.1	1.4 ± 0.1
Hip RoM (°)	37.5 ± 7.4	38.2 ± 7.1	38.4 ± 4.5	38.2 ± 7.8	39.0 ± 6.6	37.7 ± 7.5
Knee RoM (°)	56.2 ± 11.4	59.9 ± 9.2	58.1 ± 8.0	58.8 ± 9.5	57.4 ± 10.7	59.4 ± 9.0
Ankle RoM (°)	32.9 ± 10.0	33.2 ± 6.8	33.0 ± 8.5	33.2 ± 7.6	35.7 ± 9.5	32.8 ± 7.1
Trunk rotation RoM (°)	9.0 ± 2.8	8.9 ± 3.7	10.7 ± 3.8	8.8 ± 3.3	10.5 ± 3.0	8.7 ± 1.5
Gait stability (%)	2.4 ± 0.5	2.4 ± 0.5	2.6 ± 0.9	2.4 ± 0.5	2.3 ± 0.7	2.2 ± 0.4

4. Discussion

In the present study, the NGF group reported significantly increased pain intensity on day 4 compared to day 0 before returning to baseline values on day 15. However, the pain experienced on day 4 by the NGF group did not cause any changes in gait kinematics, spatiotemporal parameters, or gait stability within each gait task. The participants walked slower with reduced RoMs during the smartphone task compared to normal walking. The current finding shows altered gait kinematics, which aligns with previous studies showing that using a smartphone while walking results in reduced walking speed, kinematics, and awareness of the surroundings (Licence et al., 2015; Plummer et al., 2015; Schabrun et al., 2014). With the previous results in mind, it was expected that gait kinematics would not only be impacted by smartphone use but that the expected alteration would be further impacted by pain to reduce further pain while walking. However, the present findings did not support the latter. The pain intensity ratings were higher at the beginning of each test day than during the two gait activities. Another possible explanation could be that the participants had increased focus on the neck pain during rest as pain demands attention (Eccleston and Crombez, 1999), whereas during the walking tasks, participants were distracted, which in turn may decrease the experienced pain intensity (Eccleston and Crombez, 1999; Kohl et al., 2013) although this cannot be determined based on the current study.

The NGF pain model used in the present study has shown similarities to early neck pain according to the neck disability index and the words used by participants to describe their neck pain (e.g., "annoying," "tiring," or "nagging,") (Christensen et al., 2022). However, NGF-induced pain is most severe when the NGF-induced muscle is contracted (Graven-Nielsen, 2022). If the participants walked without activating the splenius capitis muscle, the effect of pain might be limited (Bergin et al., 2015). If only low pain intensity were present during the walking task, this could explain why no movement adaptations were identified, as observed in clinical neck pain populations (Alsultan et al., 2020; Falla and Dieterich, 2017; Uthaikhup et al., 2014). To the authors' best knowledge, a specific threshold of pain intensity where movement alterations occur does not exist. Hence, assessing whether the pain intensity has been insufficient to promote movement alterations is difficult.Furthermore, a previous study examining motor control deficits among patients with whiplash and chronic neck pain identified that altered movement patterns were not related to a history of neck trauma or current pain but more likely due to long-lasting pain (Woodhouse and Vasseljen, 2008). Therefore, it is unknown whether the NGF-induced pain would have detected movement alterations if the pain had lasted longer than four days, which was the case in the present study design. An alternative explanation could be that the central nervous system utilizes other muscle recruitment strategies to stabilize the head without changing the kinematics of the motion (Hirata et al., 2015; Hirata et al., 2022; Simonsen et al., 2019a, 2019b).

In summary, walking while reading on a smartphone but not prolonged experimental splenius capitis pain resulted in changes in the gait pattern among otherwise healthy adults compared to walking without pain. This finding suggests that movement alterations during walking are not an early feature of prolonged experimental neck pain. Further studies are required to understand when gait alteration strategies develop after the onset of neck pain.

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Author contribution

All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Ethical approval

Research involving human subjects complied with all relevant national regulations and institutional policies, is in accordance with the tenets of the Helsinki Declaration (as amended in 2013), and has been approved by The North Denmark Region Committee on Health Research Ethics (N-20180063) and the study was registered at Clinicaltrials.gov (NCT03848247).

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Declaration of Competing Interest

Authors state no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clinbiomech.2022.105869.

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