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A cognitive dual task affects gait variability in patients suffering from chronic low back pain

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Abstract Chronic pain and gait variability in a dual-task situation are both associated with higher risk of falling. Executive functions regulate (dual-task) gait variability. A possible cause explaining why chronic pain increases risk of falling in an everyday dual-task situation might be that pain interferes with executive functions and results in a diminished dual-task capability with performance decrements on the secondary task. The main goal of this experiment was to evaluate the specific effects of a cognitive dual task on gait variability in chronic low back pain (CLBP) patients. Twelve healthy participants and twelve patients suffering from CLBP were included. The subjects were asked to perform a cognitive single task, a walking single task and a motor-cognitive dual task. Stride variability of trunk movements was calculated. A two-way ANOVA was performed to compare single-task walking with dual-task walking and the single cognitive task performance with the motor-cognitive dual-task performance. We did not find any differences in both of the single-task performances between groups. However, regarding single-task walking and dual-task walking, we observed an interaction effect indicating that low back pain patients show significantly higher gait variability in the dual-task condition as compared to controls. Our data suggest that chronic pain reduces motor-cognitive dual-task performance capability. We postulate that the detrimental effects are caused by central mechanisms where pain interferes with executive functions which, in turn, might contribute to increased risk of falling.

Keywords Pain · Gait · Variability · Dual task

Introduction

Up to 76 % of older people experience pain (Abdulla et al. 2013) and older people suffering from chronic pain are at higher risk of falling (Stubbs et al. 2014a). Pain, however, is a fall risk factor which, as such, seems to be continually disregarded (Leveille et al. 2009; Muraki et al. 2011). Costs resulting from falls range between 0.85 and 1.5 percent of the overall healthcare expenses in the more industrialized nations (Heinrich et al. 2010). Approximately 40 % of all injury deaths (World Health 2008) and 81–98 percent of hip fractures are caused by falling (Parkkari et al. 1999) which shows how falls critically influence an individual's health status.

There are three possible reasons why pain increases fall risk: local joint pathology (like arthritis), neuromuscular effects of pain and central mechanisms where pain interferes with cognitive functions (Leveille et al. 2009). Neuromuscular effects are likely to result in muscle weakness or to slowed feedback relevant to prevent an impending fall (Leveille et al. 2009). Another reason could be that long-persisting inflammatory (chronic) pain after tissue damage causes nerve damage which is caused by the infiltration of inflammatory mediators (Marchand et al. 2005). Inflammatory activation of chemosensitive nerve endings in the joints and muscles might cause disturbed functioning of muscle spindles which, in turn, results in diminished proprioceptive feedback (Sjölander et al. 2002). Therefore, deficiencies in sensory-motor coordination are common symptoms in patients with chronic pain (Sjölander et al. 2002) which explains why chronic low back pain (CLBP) is associated with altered trunk muscle control and

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sensory-motor dysfunction (Brumagne et al. 2000, 2004; Mok et al. 2007). However, while sensory-motor dysfunction in CLBP patients has widely been investigated under static conditions (Gill and Callaghan 1998; Koumantakis et al. 2002; Brumagne et al. 2008a, b), which may not represent CLBP patients' daily-life routines, the assessment of motor control and the quantification of fall risk under dynamic conditions are lacking. One effective tool to estimate risk of falling under daily-life conditions is to measure gait variability (Hamacher et al. 2011).

Executive functions regulate gait variability and are associated with dual-task performance as well as risk of falling (Yogev-Seligmann et al. 2008). The brain's capacity is limited (Broadbent 1958) and information processing of motor systems and sensory systems is highly competitive (Miller and Cohen 2001). Dietrich (2003) suggested that this is presumably owing to the brain's limited resources coupled with the inability to sustained activation simultaneously in all neural structures. He observed that a certain level of exercise intensity enforces a redistribution of resources (sensory and motor systems) in the brain (Dietrich 2003). While taxing the higher centers with a certain intensity of cognitive load during walking, a sustained activation in structures of the brain of a given system could likely be accompanied by a loss of activation of other neural structures if according resources do not suffice (Dietrich and Sparling 2004). The third possible (and aforementioned) reason explaining why chronic pain increases risk of falling in an everyday situation is that pain interferes with executive functions (Leveille et al. 2009) and results in a diminished dual-task capability with performance decrements on the secondary task (Keogh et al. 2013). In a cognitive dual task, which is performed while walking, people prioritize either the maintenance of gait over the cognitive task ("posture first" strategy) or the cognitive task over walking performance ("posture second" strategy). However, dual-tasking challenges may well be met differently by different populations (e.g., depending on age, disease status) (Bloem et al. 2006; Rapp et al. 2006; Dumas et al. 2008; Simoneau et al. 2008). While (Bloem et al. 2006) found that the "posture first" strategy is typically realized by young and healthy individuals, and less frequently realized by older people and/or patients suffering from Parkinson's disease, other research groups suggested that the posture first strategy is particularly prevalent in older adults (Dumas et al. 2008; Simoneau et al. 2008). However, a posture second strategy would increase the individuals' variability (Schaafsma et al. 2003; Hamacher et al. 2011) and the increased relative number of falls.

The goal of this experiment is to evaluate differences in gait variability between CLBP patients and their healthy peers in normal walking and walking, while performing a cognitive dual task. Understanding the underlying

mechanisms elucidating the increased risk of falling caused by chronic pain might help to design more efficient fall prevention strategies for this particular cohort. We hypothesize (1) that gait variability in normal walking would be increased in CLBP patients and (2) that with a cognitive dual-task gait variability would increase to a higher extent in CLBP patients than in their healthy counterparts.

Methods

A cohort study with CLBP (self-reported pain lasting for three or more months) patients and their healthy counterparts has been designed. Twelve healthy participants (control group: 51 ± 11 years) not suffering from orthopedic or neurological diseases and twelve patients suffering from CLBP (CLBP group: 51 ± 10 years), which were recruited from a local health-orientated sports club, were included in the study. After signing the written informed consent, the subjects were asked to perform in a random order a cognitive single-task tests (Regensburger word fluency test (RWT) (Mitrushina et al. 1999), a walking single task and a motor-cognitive dual task (walking while performing the RWT). The RWT represents a verbal fluency task, which is used for neuropsychological screenings for executive functioning and linguistic skills (Ruff et al. 1997), where participants were asked to recite as many words as possible beginning with a given letter in a two-minute time period. For the walking trial, the patients walked on a 25-m-long track (back and forth for 2 min) at their preferred walking speeds. After 3 min of rest, they walked again performing simultaneously a verbal fluency task (motor-cognitive dual task). The stride-to-stride variability of the Euclidean norm of the three angular velocity trunk motion time-series was calculated using data derived from an inertial sensors (MTw, Xsens Technologies B.V., Enschede, The Netherlands) attached to each subjects' sternum. Each stride was time normalized, and the mean of the stride cycle of the standard deviation throughout all strides at each increment of normalized time was used (Dingwell et al. 2001). Data from the first and last 2.5 m every time the participants changed direction were extracted to insure steady-state walking. All data were checked for normal distribution (Kolmogorov–Smirnov). The Mann–Whitney *U* test for independent groups has been calculated to ensure that no differences exist regarding age, weight and attentive functions. A two-way ANOVA with repeated measures (IBM SPSS Statistics 20) has been performed to compare single-task walking with the motor-cognitive dual task and single-task verbal fluency performance with the motor-cognitive dual task. Partial eta squared (η^2) were calculated to indicate effect sizes and reported as small (≥ 0.01), medium (≥ 0.06) and large (≥ 0.14) (Sink and Stroh 2006).

Dual-task costs were calculated as the percentage change of gait variability as well as the percentage change of RWT performance from single-task walking to dual-task walking as described in (Hamilton et al. 2009). Here, differences between groups were checked using Student's *t* tests. The level of significance was set to $\alpha = .05$.

Results

Age ($p = .417$) and weight ($p = .230$) did not differ between groups. Regarding gait variability, we observed a group by condition interaction effect ($F_{1,22} = 11.506$, $p = .003$; $\eta^2 = 0.343$; Fig. 1b), a group effect in the dual-task condition ($F_{1,22} = 4.583$, $p = .044$; $\eta^2 = 0.172$; Fig. 1b) and a condition effect from single-task walking to dual-task walking in the CLBP group ($F_{1,11} = 16.041$, $p = .002$, $\eta^2 = 0.593$; Fig. 1b). Regarding RWT performance, no interaction effect, condition effects or group effects have been found (Fig. 1a). The dual-task costs for trunk variability were significantly higher in the CLBP group ($p = .001$; Fig. 1d). However, differences in RWT dual-task costs did not occur (Fig. 1c).

Discussion

The results of the current study show an effect of a cognitive dual task on gait variability in CLBP patients, but not in the healthy peers. We expected that, due to the sensory-motor dysfunction patients with CLBP exhibit (Brumagne et al. 2000, 2004; Mok et al. 2007), gait variability would be increased in that population. However, this has not been confirmed by our data. Furthermore, we expected an increase in gait variability in a dual-task situation in CLBP patients, but less in healthy individuals as pain leads to a decreased capability to multitask (Keogh et al. 2013). Our data show that individuals with CLBP apparently also choose a “wrong” priority. While cognitive performance does not decrease in the motor-cognitive dual-task situation, CLBP patients exhibit increased gait variability and, in turn, increased risk of falling. This concurs with already published work reporting that pain disrupts performance on the secondary task, but that performance remains undisturbed on the central task when using a basic dual-task paradigm (Keogh et al. 2013; Moore et al. 2013).

Not only sensory processes but also higher cognitive systems contribute to motor control (Woollacott and

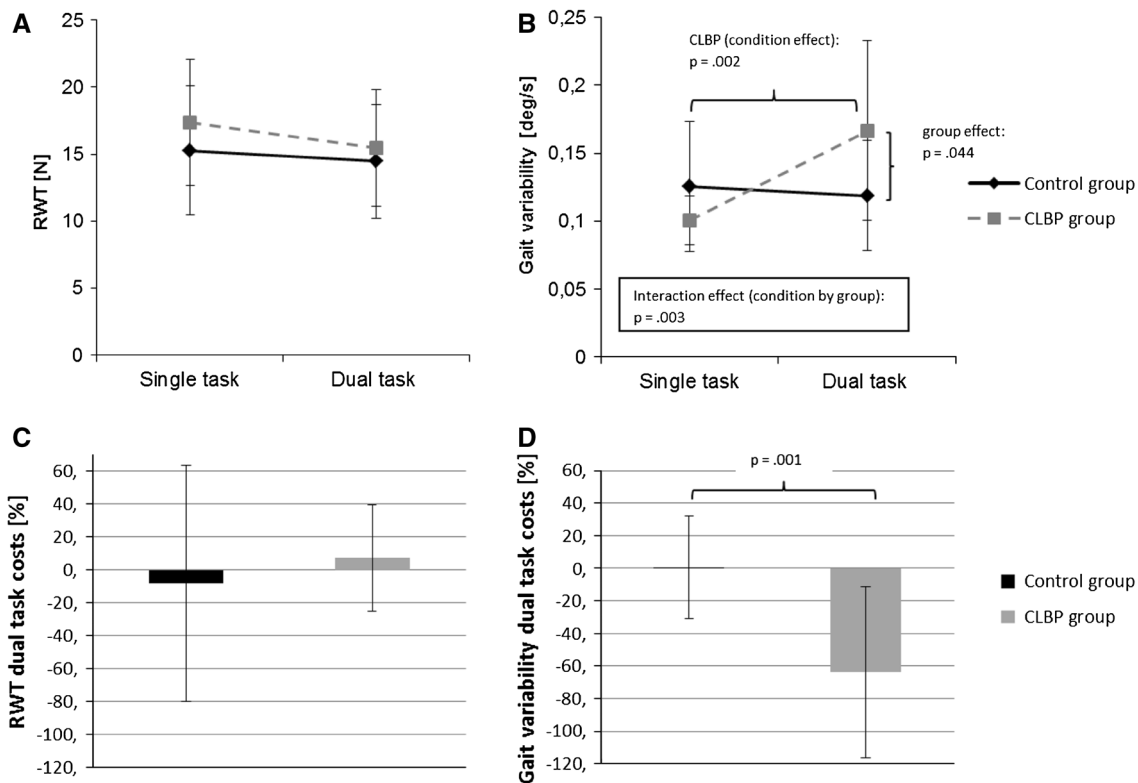


Fig. 1 Means and standard deviations (as indicated with error bars) are represented of gait variability (as quantified with the intra-individual standard deviations) of trunk motions and word fluency task performance (RWT) in single-task and dual-task walking conditions

(a, b). Dual-task costs (means and standard deviations) are represented in c and d. In each case, the control group and the chronic low back pain (CLBP) group are presented separately. Significant effects and differences are represented with according *p* values

Shumway-Cook 2002). As corrupted sensory processes are present in patients suffering from chronic pain, higher cognitive systems might aim to compensate this dysfunction (Van Daele et al. 2010). When, in addition, a cognitive dual task taxes the cognitive system, an increase in motor variability is expected as a loss of automatism of the sensory-motor control system requires more need of higher cognitive functions to control posture (Boisgontier et al. 2013) or walking. The altered sensorimotor mechanisms due to chronic pain might thus require increasing the level of control over gait as the degree of automaticity might have been reduced in the dual-task walking trial in the CLBP group. This phenomenon, in turn, could have caused the increased dual-task gait variability in the CLBP patients. Possibly, effects due to chronic pain resemble the influences of aging since an increase in control in older (vs. young) individuals causes a switch in the mode of control (from a continuous to an intermittent mode) resulting in greater performance variability (Collins et al. 1995; Boisgontier; and Nougier 2013).

Unlike other published work (Priest et al. 2008; Yogeve-Seligmann et al. 2010; Montero-Odasso et al. 2012), our healthy group did not show an increase in gait variability during dual-task walking. We have reason to suspect that the cognitive dual task chosen in current work was not complex enough to affect gait in the healthy subjects as opposed to the people of the CLBP group, which unfortunately limits the knowledge acquisition based on our data. However, it has been reported that young subjects did not suffer from a loss in serial three subtractions during walking, but in serial seven subtractions (Srygley et al. 2009) indicating that our healthy group, which comprised a mixture of only few older people but more subjects in middle age, would presumably increase their gait variability with a more complex cognitive task. It has also been reported that older (Priest et al. 2008; Srygley et al. 2009) or diseased [Parkinson's disease (Bloem et al. 2006) and multiple sclerosis (Hamilton et al. 2009)] subjects, do increase their gait variability in a higher extent in a cognitive dual-task situation, and our data complete the list of cohorts where this phenomenon occurs.

We have to acknowledge a few limitation of the study. The experimenter was not blinded with regards to the subjects' group affiliation (control group vs. CLBP group). Furthermore, the sample size was rather low and it remains unclear to what extent the present results are generalizable. To confirm this, future research is strongly needed. Lastly, recent work pointed out that patients with pain might be more susceptible to experiencing psychological concerns which may increase risk of falling (Stubbs et al. 2014b). For instance, people suffering from chronic pain may exhibit reduced balance confidence as compared to their pain-free counterparts (Stubbs et al. 2014b) which might display a confounder of our results.

In conclusion, our data suggest that chronic pain reduces motor-cognitive dual-task performance at the expense of the secondary task which in CLBP patients seems to be the motor task (walking). We postulate that the detrimental effects are caused by central mechanisms where pain interferes with executive functions (Leveille et al. 2009). This, in turn, might highly contribute to the increased risk of falling (Stubbs et al. 2014a). Based on our results, we concur with (Leveille et al. 2009) and (Stubbs et al. 2014a) and recommend clinicians to enclose chronic pain status in their falls risk assessment.

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