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Published in:
Proceedings of the 20th Congress of the International Ergonomics Association, IEA 2018

DOI (link to publication from Publisher):
10.1007/978-3-319-96065-4_9

Publication date:
2019

Document Version
Accepted author manuscript, peer reviewed version

Force Variability and Musculoskeletal Pain in Blue-Collar Workers

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Abstract. Blue-collar workers with physically demanding occupations have a high prevalence of musculoskeletal disorders accompanied by pain. Previous research has suggested that reduced motor variability may increase the risk of developing musculoskeletal disorders. Here we present preliminary data from an ongoing cross-sectional examination of physical performance in elderly manual workers. This paper includes data from 20 male workers (age 52-70 years). Handgrip force variability was measured using a digital hand dynamometer during an endurance trial where the workers exerted 30% of their maximal isometric contraction force until task failure. Absolute variability (standard deviation), relative variability (coefficient of variation), and the complexity of the force signal (sample entropy) were computed. The workers were dichotomized into two groups: no to mild pain/discomfort (No pain) and moderate to severe pain/discomfort (Pain) to investigate the effects of musculoskeletal pain on force variability. This dichotomy was done based on the rating of pain/discomfort within the last seven days, where workers reporting ≥3 score in the upper extremities were allocated to the pain group (Pain, n = 9, No pain, n = 11). No significant between-group differences in force variability during the endurance trial were found. Both absolute and relative variability increased significantly over time. These preliminary data do not support a difference in force variability between blue-collar workers with or without musculoskeletal pain or discomfort in the upper extremities.

Keywords: Handgrip Strength, Endurance, Motor Control, Discomfort

1 Introduction

Labor force participation of elderly workers is expected to increase in the coming years [1]. Workers with physically demanding occupations, such as construction workers and electricians, have a high prevalence of musculoskeletal disorders [2] and pain [3-4]. Consequently, blue-collar workers may not be able to keep up with the trend in prolonged labor market participation.

Work involving repetitive movements have been associated with pain and discomfort [5]. It is therefore of interest to study how 'variation' in motor output is associated with pain. Indeed, previous research has suggested that reduced motor variability may increase the risk of developing musculoskeletal disorders [6]. Moreover, low signal complexity (i.e. the structure of variability) has been related to musculoskeletal discomfort and pain [7]. Although healthy elderly may be able to continue working until normal retirement age, those with musculoskeletal discomfort or pain may be forced to withdraw from the labor market prematurely. This is especially problematic for manual workers, who are dependent of their strength and endurance capacity to adequately perform their work [2].

The present study aims to investigate the association between handgrip force variability and musculoskeletal pain or discomfort in blue-collar workers. We hypothesize that low force variability and signal complexity are associated with pain.

2 Methods

2.1 Participants

Here we present preliminary data from an ongoing cross-sectional examination of physical performance in elderly (age 50-70 years) blue-collar workers, which has been described in detail previously [8]. This conference paper includes the first 20 male workers that have been tested. Participants were informed about the purpose of the study and gave oral and written informed consent to participate. The study was carried out in accordance to the Helsinki declaration and is approved by the ethics committee of region North Jutland (N-20160023).

2.2 Musculoskeletal Pain

Musculoskeletal pain/discomfort was assessed using a modified Danish version of the Standardized Nordic Questionnaire [9]. It included questions about days with pain or discomfort within the last 12 months in the following regions: neck/shoulder, arms (elbow, wrist and hand), lower back, hips, and knees. Each region is graded on a 6-point scale (1 = 0 days, 2 = 1-7 days, 3 = 8-30 days, 4 = 31-90 days, 5 = >90 days, 6 = every day). In addition, the degree of pain in these areas within the last seven days was graded on an 11-point scale from 0 (no pain/discomfort) to 10 (most pain/discomfort imaginable). To investigate the effects of musculoskeletal pain on force variability, the tested workers were dichotomized into two groups: no to mild pain/discomfort (hereby referred to as "No pain") and moderate to severe pain/discomfort (hereby referred to as "Pain"). This was done based on the rating of pain/discomfort within the last seven days, where workers reporting ≥3 score [10-11] in the neck/shoulder or arm regions (upper extremities) were allocated to the Pain-group.

2.3 Force Variability

Handgrip force variability was measured using a digital hand dynamometer (Model G100, Biometrics Ltd, Gwent, UK) during an endurance trial, as described previously [8]. Briefly, the participants began by completing three trials (separated by 2 min) to measure their isometric maximal voluntary contraction (MVC) force. MVC was measured as a moving average over 100 ms. Then, in an endurance trial, the participants exerted 30% of their MVC force until task failure (Fig. 1). The test was terminated when the force dropped below 28% MVC for more than 5 consecutive seconds. To measure absolute and relative variability from the force signal, we calculated standard deviation (SD) and coefficient of variation (CV), respectively. Sample entropy (SaEn) was computed using a fixed embedding dimension $m = 2$ and a tolerance distance $r = 0.2\times SD$ to measure the complexity of the force signal [12]. After discarding the first and the last five seconds of each trial, total endurance time was normalized between workers by extracting seven epochs of 3 sec in steps of 16.7% (i.e. from 0 to 100%). SD, CV and SaEn were then calculated over these seven epochs. All data processing was conducted using Matlab 2017b® (Mathworks, USA).

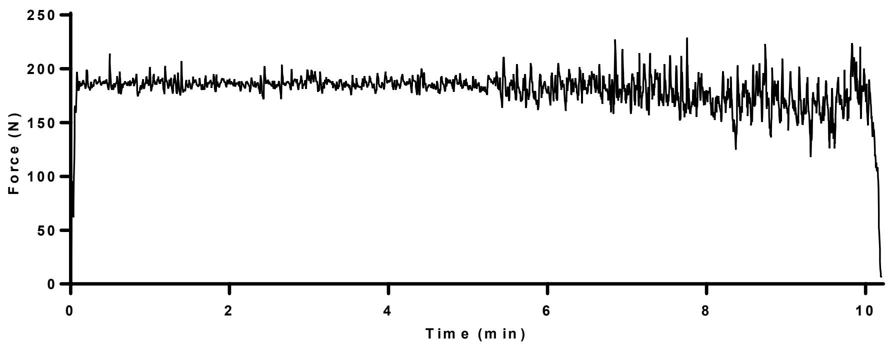

Fig. 1. Sample plot of an endurance trial from one worker from the No pain-group, for whom the target force of 30% maximal voluntary contraction was 189 Newton.

2.4 Statistics

A factorial repeated measures ANOVA was used to determine the effect of group (between-subjects factor) and time (within-subjects factor, 7 time epochs) on the dependent variables force variability and complexity during the endurance trial. To test the robustness of the group dichotomy (i.e. ≥3 pain), we investigated one lower and two higher cut-off values (≥2, ≥4 and ≥5). It has previously been suggested that motor variability in the pre-fatigued state may predict the development of muscle fatigue [13-14]. Therefore, a multiple regression was run to predict endurance time from SD, CV and SaEn measured from the first epoch, in addition to MVC, age, BMI and group (coded as Pain = 1 and No pain = 2). Variables were excluded from the model by stepwise elimination. Statistical analyses were carried out using SPSS 25.0 (SPSS Inc., Chicago, Illinois, USA). Mean (SEM) is reported and statistical significance set to $p < 0.05$.

3 Results

3.1 Participants

Out of the 20 included workers (age 52-70 years), half (i.e. 10) where still currently working full-time jobs. However, all workers had worked or were working in a manual job: mostly as construction workers (n=12), but also electricians (n=5) and other manual professions (n=3).

3.2 Musculoskeletal Pain

Characteristics of the workers in the Pain and No pain-group are presented in Table 1. There were no significant between-group differences in age or BMI. Self-reported levels of pain/discomfort during the last seven days were significantly different between groups in the neck/shoulder and arm regions. Regarding musculoskeletal pain/discomfort within the last year, workers reporting having had more than 90 days of pain/discomfort within the last 12 month were as follows: neck/shoulder (Pain: n=4), arms (Pain: n=1, No pain: n=1), lower back (Pain: n=3, No pain: n=1), hips (Pain: n=1), and knees (Pain: n=3, No pain: n=2). Five workers in each group were still currently working.

Table 1. Characteristics of included workers.

	Pain (n = 9)	**No pain (n = 11)**
Age (years)	62.6 (2.1)	62.2 (1.8)
BMI (kg/m^2)	28.8 (0.7)	27.9 (1.3)
Pain/discomfort last 7 days (degree)		
Neck/shoulder	4.6 (1.0)*	0.7 (0.2)
Arms (elbow, wrist, hand)	2.7 (0.9)*	0.4 (0.2)
Lower back	3.3 (0.5)	1.9 (0.7)
Hips	1.3 (0.6)	0.7 (0.3)
Knees	2.9 (1.1)	2.8 (0.9)

*Significant differences between groups, $p < 0.05$.

3.3 Force Variability

There was no significant difference in maximal voluntary contraction force between the Pain and No pain-group (461 (26) N vs 504 (23) N, $p = 0.228$, respectively), whereas endurance time was significantly shorter for the Pain-group compared to the No pain-group (228 (12) s vs 284 (20) s, $p = 0.035$, respectively). No between-group difference could be detected in force variability (SD and CV), nor signal complexity (SaEn) during the endurance trial (SD: $p = 0.879$, CV: $p = 0.906$, SaEn: $p = 0.224$, Fig. 2). However, a significant main-effect of time was found for all three outcomes (all $p < 0.01$). Pairwise comparisons revealed significant changes over time as illustrated in Figure 2. The sensitivity analyses with two higher cut-off scores for the group dichotomy (≥4 and ≥5) resulted in similar results as in the main analysis (data not shown). Contrary, using a lower cut-off (≥2), we found a significant group-effect for SaEn ($p = 0.033$), wherein the Pain-group (now n=12) had lower signal complexity during the endurance trial.

Regarding the multivariate regression analysis, group and SaEn was found to significantly predict endurance time, $F(2,17) = 6.356$, $p = 0.009$, $R^2 = 0.428$, adjusted $R^2 = 0.361$ (endurance time [s] = 222.9 + 60.6 × group – 265.9 × SaEn). SD, CV, MVC and age did not significantly contribute to the regression model.

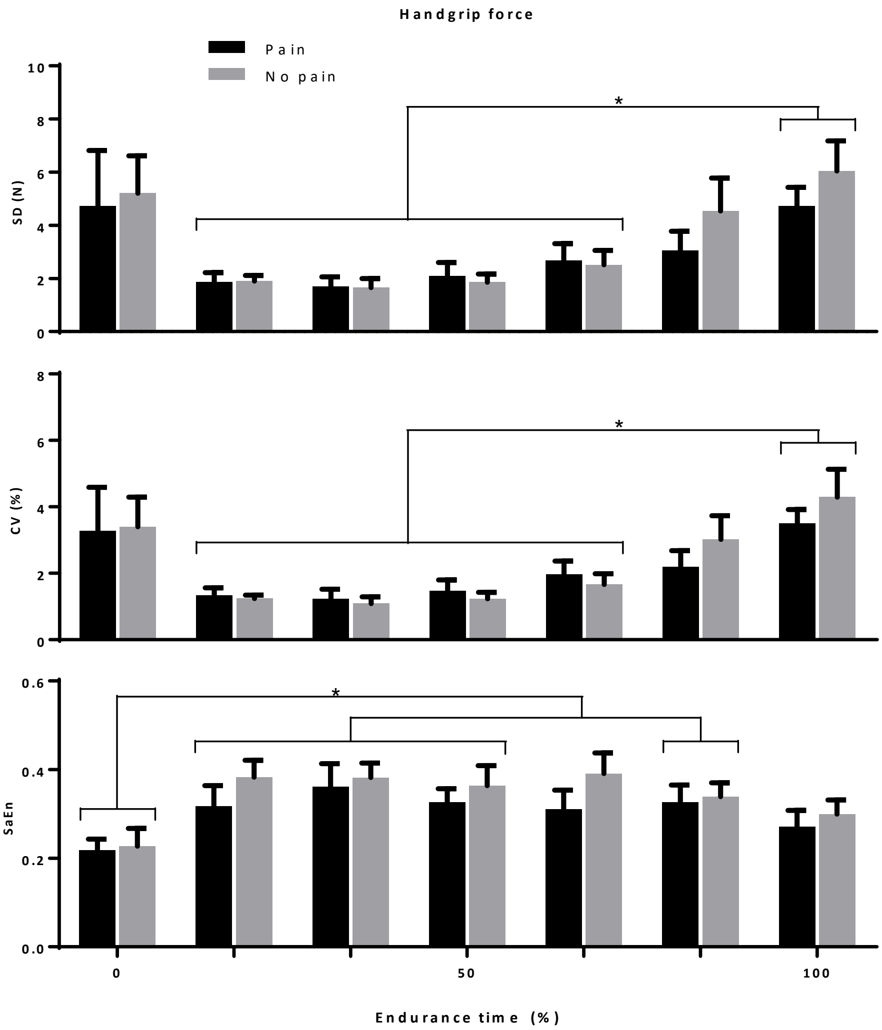

Fig. 2. Mean + SEM for standard deviation (SD, N), coefficient of variation (CV, %) and sample entropy (SaEn) during the endurance trial. *Significant differences between epochs (*$p < .05$*).*

4 Discussion

The aim of the present study was to investigate the association between handgrip force variability and musculoskeletal pain or discomfort in blue-collar workers. Contrary to our hypothesis, no difference in neither force variability, nor signal complexity, could be detected between workers with or without pain or discomfort in the upper extremities.

The concept of motor variability has received increasing attention over the last decade and has been associated with pain, fatigue, performance and task-related skill [13]. Acute experimental pain during a simulated cutting task was found to increase the size of movement variability of the arm, whereas the latter decrease in chronic pain conditions [6]. Seemingly, there is a difference in the amount of motor variability, depending on whether pain is felt as discomfort and the stage of pain (e.g. acute and chronic) [15]. In the present study, we expected force variability to be lower in the group reporting moderate to severe pain or discomfort in the upper extremities. However, due to the low sample size and the preliminary nature of our data, we were unable to group the workers based on pain stages.

We found significant effects of time for both force variability (SD and CV) and signal complexity (SaEn) during the endurance trial in line with previous studies, e.g. [12]. Both SD and CV were higher in the last epoch compared to epochs two through five, whereas SaEn was lower in the first epoch compared to the second, third, fourth and sixth. A similar temporal pattern was found in a study investigating force variability and complexity during isometric elbow flexion at 20% MVC in healthy young participants [12]. Contrary to that study, however, we found a u-shaped change in variability starting from the first epoch. This could be due to the difference in muscle groups investigated, or possibly the difference in age, i.e., elderly workers may need more time to familiarize with a given task.

Multivariate regression analysis revealed that SaEn (measured during the first epoch) and group described about 43% of variance in endurance time. Force variability (i.e. SD and CV), MVC force and age, however, did not significantly contribute to the model. A previous study found 50% of the variance in dorsiflexion endurance time to be explained by age, knee extensor strength, and steadiness (CV) during 60-s isometric dorsiflexion contraction at 20% 1-repetition maximum [16]. The reason for age and MVC not being significant predictors in the present study could partly be explained by the homogeneity of both age and MVC. Alternatively, task differences i.e., pushing against a force transducer (as in the present study) versus supporting an inertial load (as in the aforementioned study), have been shown to affect endurance time [17]. Thus, the results cannot be readily compared.

Interestingly, the complexity of the force signal (SaEn) was a significant predictor of performance, so that a 0.1 increase in SaEn would reduce endurance time by 27 s. In other words, the more complexity and randomness in the beginning of the endurance trial, the poorer the performance. Sensitivity analysis of the group-dichotomization also revealed a significant group-difference for SaEn when the dichotomy was made at ≥2 pain (on the 0-10 scale). This indicated, as hypothesized, that a lower signal complexity was associated with pain, and possibly that the null-finding in the main analyses was due to a type I error.

In previous studies, no difference was found in force steadiness (SD) during isometric wrist extension between patients with elbow pain and healthy controls [18], whereas force steadiness (CV) has been shown to decrease during experimental muscle pain (hypertonic saline injection) [19]. Contrary, a study investigating discomfort during 96 minutes of sitting on a force platform found that an increase in variability (SD) and a decrease in complexity (SaEn) of the center of pressure signal was associated with increased discomfort [7]. These findings, coupled with those of the present study, suggest a relationship between motor control patterns, pain/discomfort, and subsequently performance. However, whether one precedes the others is still uncertain [15], and its relevance in changes in pain stages warrants further research; specifically, whether motor variability and complexity can be manipulated to reduce the risk of musculoskeletal discomfort or pain. Although some studies have shown promise using biofeedback systems to manipulate motor variability [20-21], it is a field still in its infancy.

The present study was limited by its small sample size. Moreover, fatigue is a multifaceted phenomenon which can be attributed to muscular or peripheral factors, but also psychological aspects such as motivation and mood [22]. Although identical strong verbal encouragement was provided during the endurance trial, these factors are difficult to account for and could potentially have affected our results. Lastly, the cross-sectional design limits the interpretation of our results to investigate associations without inferring causality. Nonetheless, this design still enables us to benchmark important effects of pain and discomfort on motor control.

In summary, no significant difference in force variability during the endurance trial could be found between the Pain and No pain-group in a subsample population. Thus, these preliminary data do not support a difference in force variability between blue-collar workers with or without musculoskeletal pain or discomfort in the upper extremities; however, a larger sample size would enable comparisons between different pain stages (e.g. acute and chronic) and thereby reveal important information about the association between pain and force variability.

Acknowledgements. The project is funded by Arbejdsmiljøforskningsfonden (project number 20140072843). Also, the authors would like to thank the rest of the ALFA-group, which includes Kirsten Fonager, Henrik Bøggild, Johan Hviid Andersen, and Claus Dalsgaard Hansen.

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