Summary

From precision demands to neck and upper extremity pain

From precision demands to neck and upper extremity pain

Summary

Despite a whole body of literature, the aetiology of neck and upper extremity pain, also referred to as RSI, Repetitive Strain Injury, is poorly understood. Besides repetitive movements, working in the same (awkward) posture for long periods of time and exerting high forces, working with high precision has been suggested as a risk factor for neck and upper extremity pain. In the introduction of this thesis a Precision-Pain Model (Figure 1) is proposed which hypothesises how precision demands could lead to neck and upper extremity pain. In the Precision-Pain Model it is hypothesised that with higher precision demands in a task, endpoint impedance (i.e. resistance against imposed motion) is increased through increased co-contraction and/or higher friction with the underlying substrate. According to the model, if the task is performed for a long duration, the higher muscle activity required to increase impedance will accelerate fatigue development. Fatigue has been shown to lead to impaired proprioception, i.e. the accuracy of perception of movement or position of body parts, and to increased force variability (= noise). Less accurate information on position and movement of body segments and increased noise will make it more difficult to perform precise movements and a further increase in impedance is expected to be necessary to achieve the required task precision. Increasing impedance is not the only way to deal with high precision demands. In addition, kinematics can be altered and higher external forces may be applied in case proprioceptive information provides insufficient guidance, such as excessive forces in keying or in handling small objects. Higher muscle activity to increase impedance and to generate higher external forces again will accelerate fatigue and close a vicious cycle. This vicious cycle may lead to the development of chronic pain, which may be accompanied by disability.

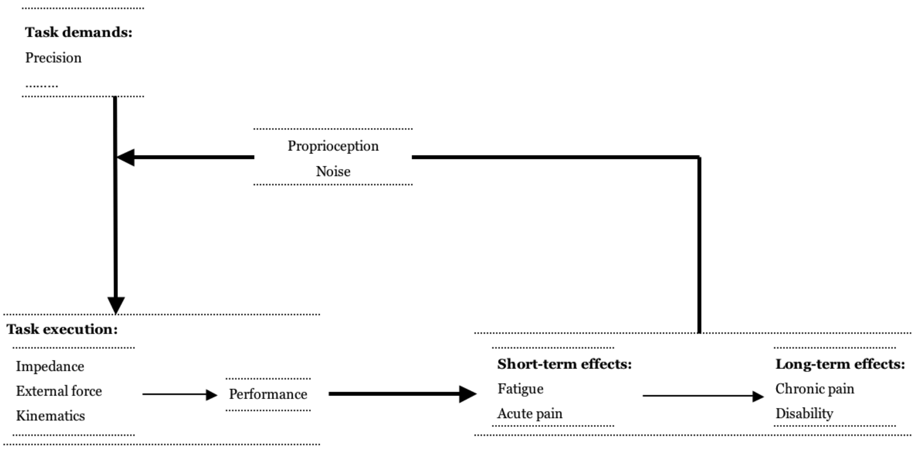

Figure 1
Precision-Pain Model

The present thesis aimed to scientifically verify the following steps of the Precision-Pain Model described above:

1. Precision demands affect task execution (Chapters 2 and 3)
2. Fatigue affects task execution (Chapter 4)
3. Pain affects proprioception (Chapter 5)
4. Pain affects task execution (Chapters 5 and 6)
5. Precision demands are related to chronic pain (Chapter 7)

Precision demands affect task execution

The study in **Chapter 2** was designed to determine the effect of precision demands on task performance and muscle activity in crane operators during a simulated crane task performed with a joystick. Furthermore, it was investigated whether joystick handle size and display-control gain could positively affect performance, muscle activity and wrist posture. Eight experienced crane operators performed a crane task in which they had to virtually move a load with the crane from one container into another on a computer screen by operating the joystick. The results of the study showed that higher task precision, i.e. using smaller containers, was associated with lower task performance (less repetitions were performed). The number of errors made remained the same. Muscle activity and wrist posture were not affected by task precision. Task performance improved when using a joystick with a short handle and when working at a higher display-control gain, while muscle activity was unaffected. The results of the study appear to contradict the Precision-Pain Model, since precision demands did not affect muscle activity in the simulated crane task. This could be explained by a change in the kinematics of the task, involving a decrease in task performance (productivity) in line with the speed-accuracy trade-off. Based on the results from this study we recommend a joystick with a short handle to practice. Furthermore, it is advised to optimise display-control gain settings of the machine in relation to the task constraints observed in practice.

In **Chapter 3** we investigated how task performance, kinematics, defined by organisation of sub-movements, and impedance, in terms of muscle activity and pen pressure, were affected by target size in a 2D tracking task performed with a pen on a digitiser tablet. Tracking does not allow a decrease in movement velocity to accommodate precision demands as was possible in the task studied in Chapter 2. Twenty-six healthy subjects performed the tracking task in which either a small or a large target was tracked, while it moved quasi-randomly across the computer screen. With the small target, mean distance to target and the standard deviation of this distance to target were significantly smaller and subjects trailed more behind the centre of target compared to tracking the large target. Subjects also changed pen kinematics, with larger velocity fluctuations of shorter duration, and increased pen pressure and co-contraction of forearm muscles with a smaller target. We concluded that increased precision demands are accommodated by a different organisation of sub-movements and an increased impedance.

Fatigue affects task execution

In **Chapter 4**, the same tracking task as in Chapter 3 was used to study the effects of local muscle fatigue on task performance and on muscle activity in the extensor muscle of the forearm. Eleven female participants performed a tracking task with a computer mouse, before and immediately after a fatigue protocol (wrist extension). After the fatigue protocol percentage time on target was significantly lower in the first half of the tracking task, but was unaffected in the latter half of the task. Mean distance to target and the standard deviation of the distance to target were both significantly larger after the fatigue protocol. The lower task performance was accompanied by higher peak amplitudes of muscle activity in the M. extensor carpi radialis, whereas the static and the median muscle activity levels were not affected. The results of this study showed that task execution was affected by fatigue. Contrary to what is hypothesised in the Precision-Pain Model, the negative effects of fatigue on task performance, i.e. positional precision, are not counteracted by an overall higher muscle activity, but lead to a selective increase in peak muscle activity levels of the forearm extensor muscle.

Pain affects proprioception and task execution

In the study of **Chapter 5**, twenty-three subjects with neck and upper extremity pain and twenty-six healthy control subjects participated in a 2D pointing task to investigate whether position sense acuity (as a measure for the quality of proprioception) differed between these groups. Furthermore, it was investigated whether task performance, kinematics (organisation of sub-movements), impedance (muscle activity and pen pressure) and perceived exertion are affected by neck and upper extremity pain in the 2D tracking task. In the pointing task, subjects were instructed to point at targets, without vision of their arm and hand. The tracking task was the same as used in Chapters 3 and 4 and was performed with a pen on a digitiser tablet. The results showed that position sense acuity and tracking performance were impaired in subjects with neck and upper extremity pain as compared to healthy controls. No differences were found in kinematics and muscle activity and pen pressure as indicators of impedance during tracking. Subjects with neck and upper extremity pain perceived the tracking task as physically more demanding than the healthy controls, whereas mental exertion was perceived similarly. Position sense acuity and tracking performance were correlated, implying that reduced proprioception underlies the reduced tracking performance in subjects with neck and upper extremity pain.

Chapter 6 concerns the effect of pain on the execution of a gripping task. Grip force control and adaptation of grip force were measured in eighty-one subjects with pain in neck and upper extremity, thirty-two subjects with a history of pain, and thirty-nine subjects without pain. The participants had to lift and hold an object (cup of 300 gram) five times with the dominant hand. Subjects with pain used significantly higher grip forces than subjects without pain, both during lifting and holding the object, while the vertical acceleration of the object during lifting was not different. After the initial lift, all subjects significantly reduced the maximum grip force during lifting, to keep it at a more or less constant level during the consecutive lifts, though grip force levels were still higher in the subjects with pain. The fact that subjects with pain adapted their grip forces after the initial lift indicates that there is no general deficit in sensory-motor integration. The higher grip forces observed in the subjects with pain seem more likely the consequence of reduced acuity of tactile information, which like proprioceptive information is used to guide motor behaviour and appears affected in people that report pain in the neck and upper extremity.

Precision demands are related to chronic pain

In **Chapter 7**, a systematic review was conducted to investigate the evidence for a relation between the duration of computer use, as an example of work requiring high precision, and the incidence of hand-arm and neck-shoulder pain. In the systematic review only articles were included that presented a risk estimate for the duration of computer use, included an outcome measure related to hand-arm or neck-shoulder symptoms or disorders, and had a longitudinal study design. Nine relevant articles were identified, of which six were rated as high quality. It was concluded that moderate evidence exists for a positive association between the duration of mouse use and hand-arm symptoms. For this association, indications of a dose-response relationship were found. For neck-shoulder pain, insufficient evidence is concluded for total duration of computer use, for duration of mouse use and for duration of keyboard use. Risk estimates are in general stronger for the hand-arm region than for the neck-shoulder region, and stronger for mouse use than for total computer use and keyboard use.

Conclusions

On basis of the results from the present thesis in combination with results from literature it is concluded that only partial support is found for the Precision-Pain Model. In line with the Precision-Pain Model, it is concluded that: 1) higher precision demands lead to higher impedance in combination with changes in kinematics, 2) proprioception and task performance in terms of positional precision are impaired in fatigued subjects and in subjects with neck and upper extremity pain, and 3) precision demands could be associated with arm-hand pain. The selective increase of peak muscle activity in fatigued subjects when performing precision tasks and the increased grip forces in a lift and hold task in subjects with neck and upper extremity pain could indicate the closure of a vicious cycle, as proposed by the Precision-Pain Model. However, a general increase of impedance in computer tasks with high precision demands was not found for these subject populations as compared to healthy controls. Therefore, the evidence for a vicious cycle is still inconsistent.

Implications for practice

Even though the role of precision demands in the development of neck and upper extremity pain is not exactly clear, it seems worthwhile to either strive to reduce precision demands in the task or to facilitate precision work. In **Chapter 9** several solutions to improve performance in precision tasks are given, most of which apply to human-computer interaction, but are also applicable in other work tasks in which input devices are used. For instance, in order to make (computer) precision work easier, larger or expanding targets or cursors can be used and input devices can be supplied with feedback mechanisms. In addition, performance in precision tasks can be improved by optimising display-control gain, the location of icons on the screen and physical characteristics of the input device.