Optimizing worksite exercise training – muscle physiological responses

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REPS 2012-05-23, University of Southern Denmark
Physical activity

Leisure time
- Home
- Sport
- Transport

Work/School
- Tasks
- Worksite Training/PE

Rehabilitation PA prescription

Musculoskeletal health
Cardiovascular health
Metabolic Health
Mental health
Well-being
Low sick-leave

Lancet 265: 1111-1120, 1953
Eur Heart J 28: 492-498, 2007
Work-related disorders in Denmark

- Musculoskeletal disorders: 50%
- Hud sygdomme: 11%
- Ikke allergiske lungelidelser: 3%
- Høreskader: 14%
- Hjerneskader etc.: 2%
- Ikke definerede: 7%
- Andre lidelser: 5%
- Cancer: 1%
- Mentale sygdomme: 5%
Musculoskeletal pain

self-reported frequency last week

- Neck: 17
- Shoulder: 12
- Elbow: 17
- Hand: 7
- Low back: 19
- Hip: 11
- Thigh: 11
- Knee: 11
- Lower leg: 11
- Feet: 11
Musculoskeletal pain

<table>
<thead>
<tr>
<th>Body Part</th>
<th>Self-reported frequency last week</th>
<th>Work-related reported claims</th>
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Musculoskeletal pain

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<tr>
<th>Body Part</th>
<th>Self-reported frequency last week</th>
<th>Work-related reported claims</th>
<th>Sports related relative to all injuries</th>
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<td>knee</td>
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<td>lower leg</td>
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<td>feet</td>
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Musculoskeletal pain

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<th>Location</th>
<th>Self-reported frequency last week</th>
<th>Work-related reported claims</th>
<th>Sports related relative to all injuries</th>
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<tr>
<td>Neck</td>
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<tr>
<td>Feet</td>
<td>30</td>
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<td>30</td>
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</table>
Musculoskeletal injuries/disorders in Denmark per year:

~ 500,000 sports injuries with medical care
   250,000 acute to hospital
   250,000 therapist, general practitioners, etc

~ 33,000 work injuries/disorders reported
   25,000 reported accidents
   8,000 reported disorders

Physical activity at work include all forms of activity contributing to the production

- Heavy lifting
- Pushing, pulling & carrying
- Awkward postures, twisting & bending
- Monotonous repetitive work
  - with small muscle groups

Workers with sedentary monotonous tasks (office/computer) who are
• physically active compared with those being inactive
• perceive less stress and more energy

These perceived differences are underlined by corresponding differences in physiological measures of cortisol (a stress-hormon)

Physical activity at leisure – physical exercise training (PET) include all forms of physical activity that improve

- fitness (oxygen uptake)
- muscle strength and endurance
- balance (coordination or motor control).

Intelligent physical exercise training IPET – based on sports science principles –

was introduced at work sites in terms of
  • all-round physical activities
  • strength training
  • bicycling

demonstrated to alleviate pain and improve muscle
  • mechanics
  • morphology
  • metabolism

Study design

Case – Control

Randomized Controlled intervention Trial

RCT
Questionnaire send to female workers, 30-60 years (n=812)

Neck/shoulder controls based on questionnaire (n=53)

Neck/shoulder cases based on questionnaire (n=147)

Controls Invited to full study (n=22)

Myalgia Invited to full study (n=48)

Cluster randomization, balanced design

Specific Resistance Training group (n=18)

Bicycle Exercise group (n=16)

Reference group (n=14) (end n=8)

Case-Control

No questionnaire replies Declined to participate or Neither neck/shoulder cases nor controls on questionnaire (n= 612)

Excluded due to lack of time Health conditions or Clinical diagnosis of trapezius myalgia (n= 130)
Trapezius myalgia

Myalgia: ICD-10 code number M60-63

Questionnaire for inclusion of MYA:

1) trouble (pain or discomfort) for more than 30 days during the last year in the neck/shoulder region
2) no more than three body regions with more than 30 days of trouble in order to exclude generalised MS diseases,
3) the trouble should be at least “quite a lot” on an ordinal 5-step scale ranging from “a little” to “very much”,
4) the trouble should be frequent (at least once a week), and
5) the intensity of the trouble should be at least 2 on a scale from 0 – 9, where 0 is no pain and 9 is the worst imaginable pain.
Clinical examination

2/3 of the non-specific selfreported NS cases had Trapezius Myalgia

3 main criteria:
• neck pain
• tightness of the muscles
• palpable tender spots in the muscles

same side or both sides

(Viikari-Juntura et al. 83; Ohlsson et al. 94; Sluiter et al. 01; Nordander, 04; Juul-Kristensen et al 06)
2 banks, 2 post office work places, 2 national administrative offices, and 1 industrial production unit

<table>
<thead>
<tr>
<th>Occupation (&gt;3/4 of time)</th>
<th>MYA</th>
<th>CON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work at the computer</td>
<td>82%</td>
<td>56%</td>
</tr>
<tr>
<td>Keyboard</td>
<td>79%</td>
<td>53%</td>
</tr>
<tr>
<td>Mouse</td>
<td>30%</td>
<td>29%</td>
</tr>
<tr>
<td>Sitting</td>
<td>68%</td>
<td>67%</td>
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<table>
<thead>
<tr>
<th>Leisure</th>
<th>MYA</th>
<th>CON</th>
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<tbody>
<tr>
<td>Moderate</td>
<td>2749 ± 2395</td>
<td>3156 ± 2036</td>
</tr>
<tr>
<td>Vigorous</td>
<td>670 ± 1586</td>
<td>1824 ± 1956a</td>
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</table>
Intervention

• 10 weeks
• 1 hr/week during working time

Training groups:
• Physical exercise training was performed
• 20 min 3 x per week - supervised

Reference group:
• Information on general health promotion and work environment was given on group or individual level
• 1-2 hrs every 1-2 weeks
REF

Reference group

• Information on general health promotion
  – and work environment,
• No physical activity counselling
BIC
bicycle exercise
50 – 70 %VO2max
Muscle Activation During Selected Strength Exercises in Women With Chronic Neck Muscle Pain

Lars L Andersen, Michael Kjær, Christoffer H Andersen, Peter B Hansen, Mette K Zebis, Klaus Hansen, Gisela Sjøgaard

Physical Therapy, 88: 703-711, 2008

SRT
Specific resistance training

12 - 10 - 8 RM

3 sets ~30 s
3 exercises
Muscle biochemistry, activity, blood flow and oxygenation measured simultaneously during stress and repetitive tasks.
MECHANICS
Kinematics and motor control
Function
Biodex Isokinetic Dynamometer

- **Slow Concentric, 60°.s⁻¹**
- **Fast Concentric 180°.s⁻¹**
- **Isometric, 0°.s⁻¹**
- **Slow Eccentric -60°.s⁻¹**
**Angular Velocity**

-60 0 60 120 180

**Torque**

0 10 20 30 40 50 60

---

**EMG**

**Trapezius EMG amplitude (V)**

0 200 400 600 800 1000

---

**Deltoid EMG amplitude (V)**

0 100 200 300 400 500

---

**Andersen LL et al. 2008, J Biomech**
**Function**

Isokinetic Strength

- **Angular velocity**
  - -60 0 60 120 180

- **Torque**
  - 0
  - 10
  - 20
  - 30
  - 40
  - 50
  - 60

***

Rate of Torque Development

- **RTD (Nm\cdot s^{-1})**
  - 0
  - 100
  - 200
  - 300
  - 400

§

- **Shoulder joint angle**
  - 35
  - 115

**Andersen LL 2008, J Biomech**

**Andersen LL 2008, Clin Biomech**

---

**Biodex dynamometer**
Pegboard

CON | MYA
--- | ---
EMG (%MVE) | 7.4 (9.09) | 11.7 (9.09) | p < 0.05
RCT - RESULTS

Physical Capacity

<table>
<thead>
<tr>
<th>Test</th>
<th>Change</th>
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<tr>
<td>VO2max</td>
<td>*</td>
</tr>
<tr>
<td>Shoulder elevation</td>
<td>*</td>
</tr>
<tr>
<td>Shoulder abduction</td>
<td>*</td>
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<td>Handgrip</td>
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* Indicates statistical significance.

Muscle activity (EMG) during PEG

Before

After

(\% MVE)
The case-control study demonstrated mechanical insufficiencies in the trapezius muscle of MYA compared with CON.

The RCT study demonstrated in MYA:
- full recovery in trapezius
  - muscle activation
  - muscle strength
  - rate of torque development
  - relative load during repetitive work

with SRT but not BIC.
MORPHOLOGY
Muscle disorders
Ultrasound measured trapezius thickness

CON: 10.7 (1.3) mm  MYA 11.8 (2.0) mm  (p< 0.05)

COX-negative fibers  
(Kadi 1998; Larsson B 2000)

Moth Eaten fibers  

Ragged Red Fibers  
## Fibertype and –size

### Traditional analysis

<table>
<thead>
<tr>
<th>Fibertype&amp; (%)</th>
<th>Fiber type</th>
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<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>CON</td>
<td>67 ± 11</td>
<td>33 ± 11</td>
<td></td>
</tr>
<tr>
<td>MYA</td>
<td>69 ± 11</td>
<td>31 ± 11</td>
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</table>

<table>
<thead>
<tr>
<th>CSA&amp; (μm(^2))</th>
<th>Fiber type</th>
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<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>CON</td>
<td>5057 ± 1120</td>
<td>4000 ± 1104</td>
<td></td>
</tr>
<tr>
<td>MYA</td>
<td>5193 ± 1110</td>
<td>3501 ± 977</td>
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<th>CAF&amp;</th>
<th>Fiber type</th>
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<td></td>
<td>I</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>CON</td>
<td>4.2 ± 0.74</td>
<td>3.2 ± 0.72</td>
<td></td>
</tr>
<tr>
<td>MYA</td>
<td>4.1 ± 0.87</td>
<td>2.8 ± 0.70</td>
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<th>CAFA</th>
<th>Fiber type</th>
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<tr>
<td></td>
<td>I</td>
<td>II</td>
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<tr>
<td>CON</td>
<td>0.89 ± 0.15</td>
<td>0.84 ± 0.17</td>
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</tr>
<tr>
<td>MYA</td>
<td>0.83 ± 0.14</td>
<td>0.86 ± 0.20</td>
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</table>

Frequency distribution
Fibersize around median

Type I fibre area distribution around median (μm²)
Megafiber

Average size > 10,000 μm²
~ 1% of all type I fibers in MYA
~ ½ of all subjects in MYA
CAFA ↓ 37 % ➔ less potential for oxidative metabolism
Macrophages

No signs of overall inflammation

Significantly higher number of biopsies with embryonic myosin in MYA compared with CON, indicating ongoing regenerative processes in MYA

Significantly higher number of myonuclei associated with type I fibres in MYA compared with CON, supporting heightened myogenic activity

Fibertype and –size

Case-Control

<table>
<thead>
<tr>
<th>Fibertype &amp; (%)</th>
<th>CON 67 ± 11</th>
<th>33 ± 11</th>
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<tr>
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<td>MYA 69 ± 11</td>
<td>31 ± 11</td>
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<tr>
<td>CSA &amp; (μm²)</td>
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RCT

Type II fiber area increase ~ 20% with SRT

Novel immunohistochemical staining developed for analysis of Satellite Cells, SC, the stem cell of the muscle

There was a significant group by fiber type interaction for PAX (F=12.3, P<0.001). Post hoc analyses showed higher PAX in type I fibers of MYA compared with CON (0.098 ± 0.039 vs 0.079 ± 0.031, P<0.05). Conversely, PAX was lower in type II fibers of MYA compared with CON (0.047 ± 0.017 vs 0.066 ± 0.035, P<0.05).

MYA demonstrated compared with CON:

19% more SCs per fibre associated with type I fibers (MYA 0.098 ± 0.039 vs. CON 0.079 ± 0.031; P<0.05)

40% fewer SCs associated with type II fibers (MYA 0.047 ± 0.017 vs. CON 0.066 ± 0.035; P<0.05).

**Figure 1.** Immunohistochemical detection of Pax7 cells, type I myosin, and laminin on a cross section of trapezius muscle from a patient suffering from myalgia, before (pre) and after (post) a period of specific strength training (SST).

In these image series, Pax7 cells are visible by light microscopy (brown), and fluorescent staining indicates whether they are associated with type I fibres (A4.951+; red) or type II fibres (unstained). Laminin staining (green) defines the fibre borders. Scale bars, 50 µm.
In response to the intervention there was a significant group by time interaction for PAX of both type I fibers ($F=5.3$, $P<0.05$) and type II fibers ($F=5.5$, $P<0.01$). Post hoc analyses showed increase in SRT of PAX in both type I fibers (from $0.083 \pm 0.042$ to $0.127 \pm 0.047$, $P<0.001$) and type II fibers (from $0.043 \pm 0.017$ to $0.098 \pm 0.046$, $P<0.001$). No significant change occurred in BIC and REF.

**Figure 3. Illustration of the change in satellite cell number per fibre (Pax7/F) in myalgic trapezius muscle with a period of general health information (REF), general fitness training (GFT), or specific strength training (SST)**

Data are expressed as percentage change from baseline.

$*P \leq 0.0001$ vs. pre from statistical analysis on absolute values.
The case-control study demonstrated:

morphological differences in the trapezius muscle of MYA and CON

- Megafibres
- Myonucei
- Embryonic myosin
- Satellite cells

The RCT-study showed morphological adaptation occurred in MYA with SRT but not with BIC

- Increased muscle cross section, specific type II
- Increased number of satellite cells in type I + II
- Decreased mRNA heat shock protein
Pegboard

40 min (8 x 5 min)

100 g load
1 movement per sec

Microdialysis
A 5 kDa microdialysis catheter was used to determine muscle interstitial concentrations

MYA compared with CON showed:
Lactate and pyruvate were elevated while blood flow was lower during PEG and STRESS
Algesics - Glutamate

OHb during PEG and Recovery

G. Sjogaard et al.
Muscle oxygenation and glycolysis in females with trapezius myalgia during stress and repetitive work using microdialysis and NIRS. 
Bicycle training improved significantly trapezius oxygenation during the repetitive task.

Changed activation, oxygenation, and pain response of chronically painful muscles to repetitive work after training interventions: a randomized controlled trial

Karen Søgaard · Anne Katrine Blangsted · Pernille Kofoed Nielsen · Lone Hansen · Lars L. Andersen · Pernille Vedsted · Gisela Sjøgaard
The present case-control study demonstrated metabolic differences in the trapezius muscle of MYA and CON

- Lactate
- Pyruvate
- Bloodflow
- Algesic substances
- Oxygenation
- nNOS dislocation to SR

The present RCT study demonstrated improved oxygenation in MYA during repetitive work with BIC but not with SRT and a decreased dislocation to SR of nNOS which is a sign for SRT and a tendency for BIC
MUSCLE PAIN
Acute Change in Pain with each training session

- BIC first half of the training period
- BIC second half of the training period
- SRT first half of the training period
- SRT second half of the training period

** immediately after
** 2 hrs after

<table>
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<tr>
<th>Group</th>
<th>Immediately after</th>
<th>2 Hours after</th>
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<td>BIC first half</td>
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<tr>
<td>BIC second half</td>
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<tr>
<td>SRT first half</td>
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<tr>
<td>SRT second half</td>
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</tbody>
</table>
Long-term change in pain with time of intervention duration

- SRT
- BIC
- REF

Worst Pain (mm)

Session

wks post-intervention

0 5 10 15 20 25

0 5 10 15 20 25

1 2 3 4 5 6 7 8 9 10

*  **
Pegboard

40 min (8 x 5 min)

100 g load
1 movement per sec

No Pain

Worst Pain Imaginable
PEG: VAS pain-score

![Graph showing VAS pain score over time for control and myalgia groups.](image-url)

- **VAS (0-100 mm)**
- **Minutes**

- **Control**
- **Myalgia**
PEG VAS score after intervention

![Graph showing VAS score changes over time for different interventions: BIC, REF, MYA, and CON. The x-axis represents minutes, and the y-axis represents VAS score (0-100 mm). Each intervention shows a distinct trend in the VAS score over time.]
<table>
<thead>
<tr>
<th></th>
<th>Rest value (mm)</th>
<th>Rate of pain development (mm/min)</th>
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<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>GFT</td>
<td>30.9 ± 22.5</td>
<td>26.5 ± 23.2</td>
</tr>
<tr>
<td>SST</td>
<td>23.2 ± 23.1</td>
<td>11.2 ± 11.8*</td>
</tr>
<tr>
<td>REF</td>
<td>25.6 ± 22.5</td>
<td>17.5 ± 16.9</td>
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Values are mean ± SD

GFT general fitness training (n = 15), SST specific strength training (n = 16), REF reference intervention without physical activity (n = 8)

* Significantly different from value before the intervention, p < 0.05

Conclusion 1

- The present study demonstrated differences in the trapezius muscle of MYA and CON in terms of:
  - Morphological
  - Mechanical
  - Metabolic
Conclusion 2

• SRT and BIC had beneficial effects on muscle in females with TM

• Mechanical
  – SRT increased muscle activation and force, and decreased relative load during PEG task

• Morphological
  – SRT increased muscle cross section, type II cross section, number satellite cells, decreased mRNA HSP (-BIC decreased HSP72)

• Metabolic
  – BIC improved oxygenation during PEG task
Conclusion 3

• SRT and BIC can have beneficial effects on muscle pain in females with TM
• The sites of pain alleviation differ:
  – BIC and SRT affect central mechanisms
  – SRT affect local muscle pain (increased PPT)
• The time course of these effects are different:
  – BIC decreased pain acutely after training sessions but not longitudinally
  – SRT increased pain acutely in the first part of the training period but showed a marked decrease over a prolonged period of time
Take home message

Painful muscles are trainable when muscle activity is based on sport science principles

Painful muscles can adapt to exercise training mechanically, morphologically and metabolic and reduce pain sensation

But

There is a long way to go before we have identified the optimal training schedules for the individual worker:

IPET
"Individually tailored multimodal Physical Exercise Training"
Acknowledgements

The study was undertaken in colobaration with the
• University of Southern Denmark, Odense
• National Research Center for the Working Environment, CPH
• Copenhagen Muscle Research Center, Denmark,
• Bispebjerg Hospital: Institute for Sports Medicine and Dept of
Occupational and Environmental Medicine, Copenhagen
• Department of Rehabilitation Medicine, Linköping Health
University, Sweden

Financial support from the
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• Danish Rheumatism Association 233-1149-02.02.04
• Ministry of Culture Committee on Sports Research N200310016
• the National Board of Health under the Ministry of the Interior and Health

• Local Ethical Committee (KF 01-138/04)
• International Standard Randomised Controlled Trial Number Register, no: ISRCTN87055459.