

Review

Exercise is more than medicine: The working age population's well-being and productivity

Gisela Sjøgaard*, Jeanette Reffstrup Christensen, Just Bendix Justesen, Mike Murray, Tina Dalager, Gitte Hansen Fredslund, Karen Søgaard

Department of Sports Science and Clinical Biomechanics, Research Unit of Physical Activity and Health in Work Life, University of Southern Denmark, Odense M DK 5230, Denmark

Received 13 January 2016; revised 26 February 2016; accepted 29 February 2016

Available online 7 April 2016

Abstract

Background: Physical activity (PA) includes muscle activity during exercise, manual work, and leisure time activities including sport. Conflicting results exist regarding health effects of PA that may deteriorate with manual work and elite sports, but improve when performed in moderation in accordance with international guidelines and may additionally enhance well-being and productivity.

Methods: In Denmark 15 randomized controlled trials have been conducted, introducing exercise at the workplace enrolling >3500 workers. The interventions lasted from 10 to 52 weeks and offered ~1 h weekly supervised exercise during working hours according to the concept of intelligent physical exercise training (IPET) that is based on evidenced sports sciences training principles and tailored to work exposure, employee health status, and physical capacity. Questionnaire surveys and health checks including blood and muscle sampling were performed at baseline and follow-up. The job groups included: office and computer workers, dentists, industrial technicians, cleaning personnel, health care workers, construction workers, and fighter/helicopter pilots.

Results: In all job groups significant improvements were documented regarding health outcomes. These were job group specific: neck pain was reduced among office and computer workers, dentists, industrial laboratory technicians, health care workers as well as fighter pilots. Cardio-respiratory fitness—a health risk indicator for cardio-metabolic diseases—was improved among office and computer workers, health care workers, and construction workers. Additionally, other improvements were evidenced such as increased muscle strength and balance control. Importantly, productivity increased with improved muscle strength and decreased body mass index.

Conclusion: IPET does enhance health if an exercise program with evidenced efficacy is implemented by expert trainees with support of the employer. Accordingly, in every study group outcomes of improved health were documented and the effect sizes were of clinical relevance. Cost effectiveness estimates indicate acceptable cost relative to savings on health expenses and lost productivity.

© 2016 Production and hosting by Elsevier B.V. on behalf of Shanghai University of Sport. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Keywords: Physical activity; Physical exercise training; Workplace health promotion

1. Introduction

Exercise is a specific subset of physical activity (PA) which for decades has been considered to provide health benefits irrespective of the site where PA is performed.^{1,2} However, taxonomy has changed during the past decades with definitions becoming more consistent: PA encompasses any muscle activity while physical exercise is bodily activity that develops and maintains physical fitness and overall health and wellness.

Thus, PA also includes, beside exercise, daily life activity at leisure as well as occupational activity (Fig. 1).³ These activities may be well performed in a manner that is health enhancing like physical exercise, if relevant muscle groups are involved, the intensity is sufficient, and recovery appropriate. However, in this context it is important to recognize that actually not all PA does correlate with good health. At the labor market a relevant proxy for poor health is sickness absenteeism and analysis on the Danish National Working Cohort during this decennium showed that sickness absenteeism decreased with increased leisure time PA but increased with increased occupational PA (Fig. 2).⁴ The present paper will focus on the working age population that accounts for the major fraction of adult humans.

Peer review under responsibility of Shanghai University of Sport.

* Corresponding author.

E-mail address: gsjogaard@health.sdu.dk (G. Sjøgaard).

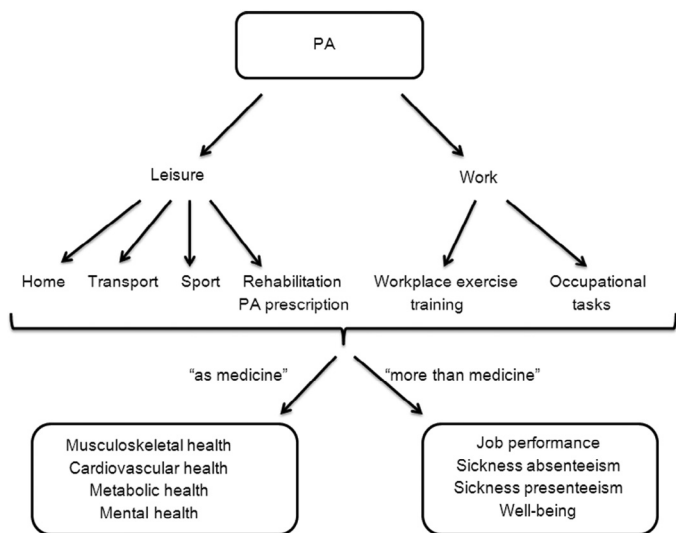


Fig. 1. Exercise is a specific subset of physical activity (PA) which for decades has been considered to provide health benefits irrespective of the site where it is performed.³

1.1. Exercise recommendations for health

In a recent review evidence was presented that “Exercise is Medicine” for 26 different chronic diseases.⁵ So in a clinical perspective the answer is a clear YES to the question: is exercise medicine? A large range of diseases—ranging from psychiatric diseases as depression to cancer, cardiovascular, metabolic, pulmonary, and musculoskeletal diseases—can be treated or relived by exercise. Interestingly, many different modes of exercise have been studied including, e.g., Tai Chi, which may be beneficial for improving osteoporosis.⁵ However, in general effectiveness of exercise was in particular related to exercise intensity during strength, as well as aerobic training in line with the recommendations by the World Health Organization (WHO):⁶ adults aged 18–64 should throughout the week do at least (1) 150 min of

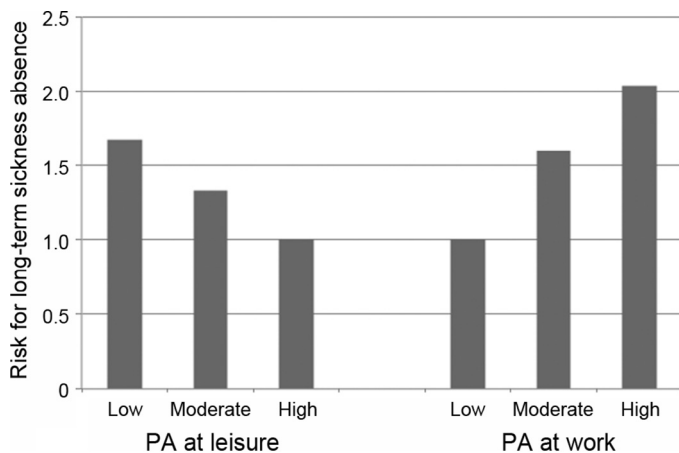


Fig. 2. The contrasting effect of the muscle activation pattern was demonstrated by analysis of physical activity (PA) levels in the Danish National Work Environment Cohort. Drawn based on recalculated data from Ref. 4.

moderate intensity aerobic PA or 75 min of vigorous intensity aerobic PA or an equivalent combination of moderate and vigorous intensity PA, (2) aerobic PA should be performed in bouts of at least 10 min duration, (3) for additional health benefits do more—up to twice, and (4) muscle-strengthening activities should be done on 2 or more days a week involving major muscle groups. These recommendations are in line with the position statement of the American College of Sports Medicine recommending to achieve a total energy expenditure of $\geq 500\text{--}1000$ MET·min per week and to perform strength and neuro-motor exercise involving balance, agility, and coordination.⁷

1.2. The workplace as arena for health enhancing exercise

The workplace has been suggested as a specially prioritized arena for health promotion; and commitment for workplace health promotion (WHP) has been implied as an almost ethical obligation, e.g., by WHO. PA may be an integral part of WHP, and WHP was shown to increase the health-related prognosis of work ability.⁸ Further, a comprehensive review reported that in an occupational context lack of exercise was a potential risk factor for sickness presenteeism, a relatively new variable attempting to assess the on-the-job-performance.⁹ Employees with the highest job strain have the highest risk of leisure time inactivity according to a meta-analysis,¹⁰ which is an argument for employers to introduce physical exercise training during working hours to maintain the work force at good health. In this context vigorous intensity is advised in order to perform as much as possible of the recommended training volume during working hours—time is money. Therefore, in an occupational setting the relevant question to pose would be: is exercise more than medicine? A positive answer is in particular important as an argument for the employer to allow exercise training during working hours. In such case evidence is important for the possible financial benefits from workplace exercise balancing the expenses in terms of the time allowances for such exercises and possibly salary for exercise instructors.

WHP may have the potential to reduce health risks that are precursors to chronic diseases,¹¹ and physical exercise training at the workplace may thus prevent lifestyle diseases such as cardiovascular, metabolic, and musculoskeletal disorders. However, conflicting results have been presented regarding the effectiveness of workplace physical exercise training on health promotion as well as for measures of on-the-job-performance, both within jobs with low as well as high occupational physical demands.⁹ Mode of exercise training seems crucial for attaining positive effects in specific job categories and knowledge on muscular adaptations with workplace training is therefore essential for optimal training planning.

1.3. Aim of the paper

The aim of the present review is to present an overview of results from our workplace physical exercise training interventions regarding: (1) effects on lifestyle diseases (considered the “medicine” effect) and (2) effects beyond the health benefits (considered the “more than medicine” effect).

2. Materials and methods

2.1. Study design

In Denmark 15 randomized controlled trails (RCTs) have been conducted introducing physical exercise training at the workplace. The RCT design was chosen to ensure a high level of evidence as requested within biomedical research. In total the studies enrolled >3500 workers. The interventions lasted from 10 weeks to 2 years and offered ~1 h weekly exercise training during working hours according to the concept of intelligent physical exercise training (IPET).¹² Most often the training was supervised at least initially, but also self-training was frequent.^{13,14} IPET is based on evidenced sports sciences training principles and tailored to work exposure, employee health status, and physical capacity.¹² The individual tailoring was performed according to the physiological measures seen in Fig. 3. This resulted in aerobic training, strength training, and/or functional training. The strength training could be further specified into neck/shoulder training or large muscle group training, and functional training could be specified into core stability training or balance training.

2.2. Job groups and procedure

The job groups included were: office and computer workers,^{12–17} dentists,¹⁸ industrial technicians,^{19,20} cleaning personnel,^{21,22} health care workers,^{23,24} construction workers,²⁵ and fighter/helicopter pilots.^{14,26} These job groups were selected to include a variety of job exposures ranging from sitting monotonous repetitive work, to more forceful repetitive work, to standing/walking dynamic work, and finally to work with very high physical exertions. In combination these workers comprised large job sectors representatively included according

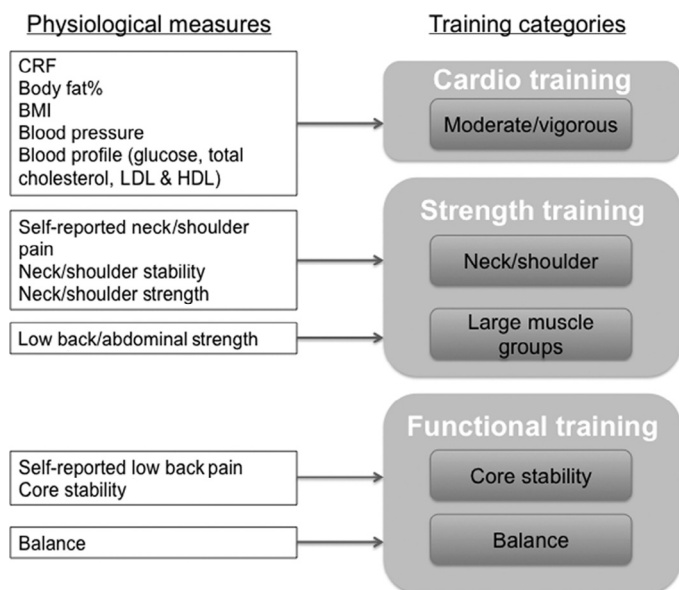


Fig. 3. Physiological measures for which cut-points were set for tailoring the individual physical exercise training categories that should be accomplished according to the programs. CRF = cardiorespiratory fitness; BMI = body mass index; LDL = low density lipoprotein; HDL = high density lipoprotein.

to the Danish Work Environment Cohort.⁴ Outcome measures were based on questionnaire surveys and health checks at both baseline and follow-up. Questionnaires addressed self-assessed health such as musculoskeletal disorders as well as on-the-job-performance such as workability and sickness presenteeism. The health checks included measures of maximal aerobic capacity, muscle strength, and a number of health risk indicators such as body mass index (BMI), blood pressure, and blood profile. In particular office workers were studied thoroughly including muscle tissue sampling together with biomechanical muscle function measurements to monitor muscle adaptations.

2.3. Tailoring physical exercise training, IPET

Each of the 5 training modes mentioned in 2.1 could be performed alone or combined with 1 or more of the others, giving a total of 32 possible training programs. According to the most comprehensive development for an individually tailored program¹² were: cardio training was added to the individual training program if surpassing any of the included physiological measures in Fig. 3 taken as health risk indicators, e.g., too high BMI, blood pressure, poor blood profile, or not meeting the recommendation for age and gender specified cardiorespiratory fitness (CRF). Strength training was specified into neck/shoulder exercises or exercises for large muscle groups. Self-reported pain in the neck/shoulder, poor neck/shoulder stability or strength—i.e., lower than 80% of mean strength for the respective age and gender groups—would add specific exercises for the neck and shoulders to the individual training program. Exercises for the large muscle groups were added if the level of strength in back/abdominal or hip/knee was lower than 80% of mean strength for the respective age and gender groups. For functional training, self-reported lower back pain or lack of core stability would add exercises for core stability, as well as a failed balance test would add balance training to the training program. Often several physiological measures for an individual qualified for recommending the same training category, but the allocation of the 5 different training categories was independent of the number of tests surpassing a cut-point.

Examples of common strength training exercises are presented in Fig. 4. All strength exercises should be performed with 2–3 sets of 15–20 repetitions maximum (RM) in the beginning, and then lowering repetitions throughout training period to 8–15 RM, i.e., increasing the load, for obtaining progression. Several exercises could well be used in different training categories, e.g., diagonal lift does improve strength but also balance.

The aerobic training was to be performed as dynamic training with large muscle groups (e.g., running/cycling) as (1) continuous intensity corresponding to moderate (64%–75% of the maximum heart rate) or (2) intermittent interval training with a vigorous or near maximal intensity (77%–95% of maximum heart rate reserve) followed by relaxation, e.g., 30 s activity, 1 min break. Intensity may be assessed by heart rate or by rating of perceived exertion (RPE) which should then on the scale of 6–20 be (1) 12–13 or (2) 14–17.


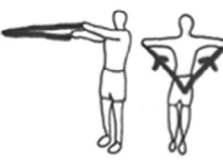
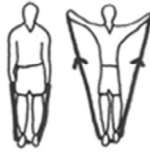



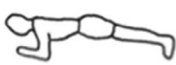


Neck/shoulder muscles	<p style="text-align: center;">Shrugs</p> 	<p style="text-align: center;">Reverse flies</p> 	<p style="text-align: center;">Lateral raise</p> 
Large muscle groups	<p style="text-align: center;">Lunges</p> 	<p style="text-align: center;">Squat</p> 	<p style="text-align: center;">Pelvic lift</p> 
Low back/core stability	<p style="text-align: center;">Plank</p> 	<p style="text-align: center;">Back extension</p> 	<p style="text-align: center;">Diagonal raise</p> 

Fig. 4. The most common physical training exercises for the strength and functional training categories. The neck/shoulder exercises could be performed using elastic bands (shown in the figure—arrows showing direction of the force performed) or by using dumbbells. Likewise for the other exercises, resistance could be increased by using elastic bands or dumbbells additional to working against gravity on body weight segments. For the reverse flies the elastic band in the figure is attached to a door handle or the like approx. 40 cm from the hands.

2.4. Statistical analyses

For each of the 15 RCT studies power analyses were performed to identify the minimal number of participants needed to evidence a clinically relevant effect at a level of significance with $p < 0.05$ and a power of 0.8. All studies were analyzed according to best practice for RCT studies, i.e., by intention to treat analyses. This implies that the below results summary of the studies presented significant findings of an effect of the training intervention only if the change in the training group was significantly larger than that of the control group.

3. Results

3.1. Exercise is medicine

In all job groups significant improvements were documented in the training versus the control group regarding health outcomes and/or health risk indicators. These outcomes were job group specific and may be clustered in 2 categories:

3.1.1. Musculoskeletal disorders

Neck pain was reduced among office/computer workers,^{13,15–17} dentist,¹⁸ industrial laboratory technicians,^{19,20} cleaners²¹ as well as fighter pilots,²⁶ forearm pain was reduced among laboratory technicians,²⁰ and low back pain was reduced among office and health care workers.^{24,27} In mixed populations including pain and no-pain cases the magnitude of changes in pain intensity were from overall mean values of little below 3 (on a 10-point numeric box scale) to a little above 2. However, analyzing the effects among workers with pain levels above 3 (pain cases) the effects were much more pronounced decreasing the overall mean pain values to almost half, i.e., from around 5 to

below 3. This reduction was particularly large among those with high adherence, as pain reduction related to training volume in a dose–response relationship with the highest pain reduction being up to 80% over a 12-week period.¹⁵

In office workers the painful muscles showed adverse functional, morphological, hormonal, as well as metabolic characteristics.^{28–32} Metabolic muscular capacity increased³³ as demonstrated even at the gene level,³⁴ and muscle morphological recovery was documented using advanced immunohistochemical stainings for satellite cells³⁵ and neuronal nitric oxide synthase.²⁸

3.1.2. Cardio-metabolic disorders

BMI, body fat%, and blood cholesterol—markers for metabolic disorders—were improved in several job groups: office/computer workers,³⁶ health care workers,³⁷ and construction workers.²⁵ Further, as a health risk indicator for cardio-vascular diseases, blood pressure decreased for office workers³⁶ and health care workers,³⁷ although in 1 study of cleaners it increased²² but mostly remained unchanged. Additionally, increases in CRF were seen that have been shown to be closely associated with decreased risks of cardio-metabolic diseases and all-cause mortality (Table 1). The improvement in CRF can at the same time be considered as an effect being “more than medicine”, since increased aerobic capacity implies an increased work capacity during heavy physical work or a relatively lower load when performing the same absolute work intensity.

3.2. Exercise is more than medicine

Physiological improvements beyond health improvements were evidenced. These have been combined into the below 2 categories:

Table 1
Improvements in physiological capacities with workplace exercise training in terms of intelligible physical exercise training.

Physiological capacities	Improvement (%)	Job	Reference
Strength			
Neck/shoulder	8	Office	Dalager et al. ¹³
Neck/shoulder	40	Office	Andersen et al. ²⁹
Neck/shoulder	10	Office	Pedersen et al. ³⁶
Core/abdomen	22	Cleaning	Jorgensen et al. ²¹
CRF			
Absolute	10	Office	Pedersen et al. ³⁶
Absolute	13	Construction	Gram et al. ²⁵
Relative	5	Office	Pedersen et al. ³⁶
Relative	9	Cleaning	Korshoj et al. ²²
Relative	8	Health care	Christensen et al. ³⁷
Relative	14	Construction	Gram et al. ²⁵

Notes: All improvements were significant in the training versus the control group in intention-to-treat analyses. Strength was measured as static neck flexion/extension, shoulder elevation/abduction, or low-back extension/abdominal flexion. Cardiorespiratory fitness (CRF) was assessed either in absolute terms of oxygen uptake in mL/L or in relative terms of mL/min/kg body weight.

3.2.1. Physical function

Increases were seen in CRF—in absolute and/or relative terms—among office/computer workers,³⁶ health care workers,³⁷ cleaners,²² and construction workers²⁵ as mentioned in 3.1.2 and summarized in Table 1. This allowed for a relatively lower workload in particular during the latter 3 occupations with physically demanding work. Strength training of the painful muscles recovered maximal muscle activation and strength.²⁹ Importantly, with strength training the improved functional capacity allowed for decreased relative muscle load during occupational repetitive work tasks,³³ for details see Table 1. Interestingly, not only muscle strength increased but also strength-endurance,^{13,29} which may have particular importance for performing the occupational repeated work tasks. Of note is that the increase in core/abdominal strength among cleaners may underlie the increased balance control reported in this job group.²¹

3.2.2. Occupational performance

Poor health among employees implies substantial costs for the companies. The costs relate to increased sickness presenteeism (decreased on-the-job-performance while being at the workplace) as well as absenteeism (habitual absence from work) leading to loss of work productivity.³⁷ Sickness presenteeism was assessed as self-reported on-the-job-performance, using questions in regard to productivity, work ability, and quantity and quality of work. Importantly, in spite of spending 1 h a week performing physical exercise training during work time, in none of our studies we found a decrease in the variables underlying on-the-job-performance. However, we did, in an intention-to-treat analysis, find a significant 8% increase in productivity of the intervention among health care workers after 3 months but not after 1 year of intervention.³⁸ Likewise among dentists we found improved self-reported quality of work.¹⁸ Interestingly, some exploratory analysis of our

RCTs actually revealed some relevant findings: productivity increased with decreased neck/shoulder pain, and with improved muscle strength—in particular trunk flexion and extension—as well as decreased BMI among health care workers.³⁷ Further, workers with sedentary monotonous tasks (office/computer)—who were physically active at leisure compared with those being inactive—perceived less stress and more energy. These perceived differences were underlined by corresponding differences in physiological measures of the stress-hormone cortisol.³⁹ Regarding sickness absenteeism analysis on our RCTs so far has not identified significant changes with the interventions.

4. Discussion

It is remarkable that in every study group outcomes of improved health were documented and the effect sizes were of clinical relevance. Additionally, functional improvements were reported that potentially had positive effects on work performance and a recent systematic review found some effect on productivity.⁹ In several of the studies the exercises were offered to all employees irrespective of their health status, as it was launched as a preventive as well as rehabilitative activity. Importantly, the possible risk of exercises inducing injuries was addressed carefully. First of all, the instructors gave detailed supervision and the exercises were kept simple. Further, whenever an employee reported any beginning complaint, recommendations were given by the instructor to change or omit the exercise for a period. Such events were rare and no serious side-effects were reported throughout the years of the interventions.

In general the magnitude of changes was related to training adherence and compliance in a dose–response relationship. This was evidenced for reductions in musculoskeletal symptoms by subsequent secondary analysis of data from 2 of the studies^{7,38} and by general linear modeling with physical training as the independent variable.¹⁹ This is in contrast to a number of other studies summarized in reviews and meta-analysis, e.g., by the Cochrane Collaboration. However, of note is that intensive muscle strength training did rehabilitate painful muscles, which has been proven in several RCTs. Correspondingly, vigorous aerobic training did improve CRF in several RCTs.

Three essential factors characterized these interventions which made them distinct from a number of unsuccessful interventions: (1) sports exercise training specialists were involved in designing the specific exercise training programs that were evidence based and of general high intensity, (2) training sessions were regularly supervised by expert trainees in the field or very careful initial instructions were given only using simple self-administered exercises adherence being monitored, and (3) physical exercise training was performed during working hours 1 h per week, usually divided into 2–3 training sessions, which requested involvement of the employer to allow such activities and thus signaling support of WHP for employees. Future improvements of the IPET concept may consider taking advantage of information and communication technologies-supported devices assisting trainee and workers for instructions, adherence monitoring, and motivational purposes. It is concluded that workplace exercise training does enhance health if a

program with evidenced efficacy is implemented by expert trainees and supported by the employer. Cost effectiveness estimates indicate acceptable cost relative to societal savings on health expenses. These novel findings can be envisaged to impact tremendously on future treatment, prevention, and health enhancement at the workplace.

5. Conclusion

Physical exercise training at work as IPET benefits the worker in terms of decreasing health risk indicators, improving physical capacity and functions as well as perceived health. Also, the employer may benefit from allowing the employees work time for such training through decreased sickness absenteeism and presenteeism in terms of improved or maintained productivity and work ability. Finally, on the societal level exercise can be “more than medicine” since exercise in a specific manner can maintain the individual’s ordinary daily physical functions and ability to move (walk, run). This is becoming more and more important among the aging workers and in a public health perspective.

Authors’ contributions

All authors were involved in the development of this review article and contributed with one or more of the RCTs included in this review. GS wrote the first draft. JRC and JBJ added particular information regarding motivation and presenteeism. MM, TD, and GHF added special information regarding training schedules and implementation. KS was responsible for the discussion and conclusion of the overall paper. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

None of the authors declare competing financial interests.

References

- Paffenbarger Jr RS, Blair SN, Lee IM. A history of physical activity, cardiovascular health and longevity: the scientific contributions of Jeremy N Morris, DSc, DPH, FRCP. *Int J Epidemiol* 2001;**30**:1184–92.
- Hu G, Tuomilehto J, Borodulin K, Jousilahti P. The joint associations of occupational, commuting, and leisure-time physical activity, and the Framingham risk score on the 10-year risk of coronary heart disease. *Eur Heart J* 2007;**28**:492–8.
- Sjøgaard K, Søgaard G. Physiological bases of work assessment. In: Wilson J, Sharples S, editors. *Evaluation of human work*. New York, NY: Taylor & Francis, CRC Press; 2015.p.419–45.
- Holtermann A, Hansen JV, Burr H, Søgaard K, Sjøgaard G. The health paradox of occupational and leisure-time physical activity. *Br J Sports Med* 2012;**46**:291–5.
- Pedersen BK, Saltin B. Exercise as medicine—evidence for prescribing exercise as therapy in 26 different chronic diseases. *Scand J Med Sci Sports* 2015;**25**(Suppl. 3):S1–72.
- World Health Organization. *Global recommendations on physical activity for health*. Geneva. Available at: http://apps.who.int/iris/bitstream/10665/44399/1/9789241599979_eng.pdf; 2010. [accessed 10.01.2016].
- Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc* 2011;**43**:1334–59.
- Nurminen E, Malmivaara A, Ilmarinen J, Ylöstalo P, Mutanen P, Ahonen G, et al. Effectiveness of a worksite exercise program with respect to perceived work ability and sick leaves among women with physical work. *Scand J Work Environ Health* 2002;**28**:85–93.
- Cancelliere C, Cassidy JD, Ammendolia C, Côté P. Are workplace health promotion programs effective at improving presenteeism in workers? A systematic review and best evidence synthesis of the literature. *BMC Public Health* 2011;**11**:395. doi:10.1186/1471-2458-11-395
- Fransson EI, Heikkilä K, Nyberg ST, Zins M, Westerlund H, Westerholm P, et al. Job strain as a risk factor for leisure-time physical inactivity: an individual-participant meta-analysis of up to 170,000 men and women: the IPD-Work Consortium. *Am J Epidemiol* 2012;**176**:1078–89.
- Goetzel RZ, Roemer EC, Short ME, Pei X, Tabrizi MJ, Liss-Levinson RC, et al. Health improvement from a worksite health promotion private-public partnership. *J Occup Environ Med* 2009;**51**:296–304.
- Sjøgaard G, Justesen JB, Murray M, Dalager T, Søgaard K. A conceptual model for worksite intelligent physical exercise training—IPET—intervention for decreasing life style health risk indicators among employees: a randomized controlled trial. *BMC Public Health* 2014;**14**:652–63.
- Dalager T, Bredahl TG, Pedersen MT, Boyle E, Andersen LL, Sjøgaard G. Does training frequency and supervision affect compliance, performance and muscular health? A cluster randomized controlled trial. *Man Ther* 2015;**20**:657–65.
- Murray M, Lange B, Nornberg BR, Søgaard K, Sjøgaard G. Specific exercise training for reducing neck and shoulder pain among military helicopter pilots and crew members: a randomized controlled trial protocol. *BMC Musculoskelet Disord* 2015;**16**:198. doi:10.1186/s12891-015-0655-6
- Andersen LL, Kjaer M, Søgaard K, Hansen L, Kryger A, Sjøgaard G. Effect of two contrasting types of physical exercises on chronic neck muscle pain. *Arthritis Rheum* 2008;**59**:84–91.
- Blangsted AK, Søgaard K, Hansen EA, Hannerz H, Sjøgaard G. One-year randomized controlled trial with different physical-activity programs to reduce musculoskeletal symptoms in the neck and shoulders among office workers. *Scand J Work Environ Health* 2008;**34**:55–65.
- Andersen CH, Andersen LL, Zebis MK, Sjøgaard G. Effect of scapular function training on chronic pain in the neck/shoulder region: a randomized controlled trial. *J Occup Rehabil* 2014;**24**:316–24.
- Fredslund GH, Sjøgaard G. Specific neck and shoulder training for dentists, dental assistants and dental hygienists. *Tandlægebladet* 2014;**118**:988–95. [in Danish].
- Jay K, Brandt M, Sundstrup E, Schraefel M, Jakobsen MD, Sjøgaard G, et al. Effect of Individually tailored biopsychosocial workplace interventions on chronic musculoskeletal pain and stress among laboratory technicians: randomized controlled trial. *Pain Physician* 2015;**18**:459–71.
- Zebis MK, Andersen LL, Pedersen MT, Mortensen P, Andersen CH, Pedersen MM, et al. Implementation of neck/shoulder exercises for pain relief among industrial workers: a randomized controlled trial. *BMC Musculoskelet Disord* 2011;**12**:205. doi:10.1186/1471-2474-12-205
- Jorgensen MB, Ektor-Andersen J, Sjøgaard G, Holtermann A, Søgaard K. A randomised controlled trial among cleaners—effects on strength, balance and kinesiophobia. *BMC Public Health* 2011;**11**:776. doi:10.1186/1471-2458-11-776
- Korshoj M, Lidgaard M, Skotte JH, Krstrup P, Krause N, Søgaard K, et al. Does aerobic exercise improve or impair cardiorespiratory fitness and health among cleaners? A cluster randomized controlled trial. *Scand J Work Environ Health* 2015;**41**:140–52.
- Christensen JR, Faber A, Ekner D, Overgaard K, Holtermann A, Søgaard K. Diet, physical exercise and cognitive behavioral training as a combined workplace based intervention to reduce body weight and increase physical capacity in health care workers—a randomized controlled trial. *BMC Public Health* 2011;**11**:671. doi:10.1186/1471-2458-11-671
- Rasmussen CD, Holtermann A, Bay H, Søgaard K, Birk JM. A multifaceted workplace intervention for low back pain in nurses’ aides: a pragmatic stepped wedge cluster randomised controlled trial. *Pain* 2015;**156**:1786–94.

25. Gram B, Holtermann A, Søgaard K, Sjøgaard G. Effect of individualized worksite exercise training on aerobic capacity and muscle strength among construction workers—a randomized controlled intervention study. *Scand J Work Environ Health* 2012;**38**:467–75.
26. Lange B, Toft P, Myburgh C, Sjøgaard G. Effect of targeted strength, endurance, and coordination exercise on neck and shoulder pain among fighter pilots: a randomized-controlled trial. *Clin J Pain* 2013;**29**:50–9.
27. Andersen LL, Christensen KB, Holtermann A, Poulsen OM, Sjøgaard G, Pedersen MT, et al. Effect of physical exercise interventions on musculoskeletal pain in all body regions among office workers: a one-year randomized controlled trial. *Man Ther* 2010;**15**:100–4.
28. Jensen L, Andersen LL, Schroder HD, Frandsen U, Sjøgaard G. Neuronal nitric oxide synthase is dislocated in type I fibers of myalgic muscle but can recover with physical exercise training. *Biomed Res Int* 2015;**2015**:265278. doi:10.1155/2015/265278
29. Andersen LL, Andersen CH, Skotte JH, Suetta C, Søgaard K, Saltin B, et al. High-intensity strength training improves function of chronically painful muscles: case-control and RCT studies. *Biomed Res Int* 2014; **2014**:187324. doi:10.1155/2014/187324
30. Sjøgaard G, Rosendal L, Kristiansen J, Blangsted AK, Skotte J, Larsson B, et al. Muscle oxygenation and glycolysis in females with trapezius myalgia during stress and repetitive work using microdialysis and NIRS. *Eur J Appl Physiol* 2010;**108**:657–69.
31. Mackey AL, Andersen LL, Frandsen U, Suetta C, Sjøgaard G. Distribution of myogenic progenitor cells and myonuclei is altered in women with vs. those without chronically painful trapezius muscle. *J Appl Physiol* 2010;**109**:1920–9.
32. Gerdle B, Kristiansen J, Larsson B, Saltin B, Søgaard K, Sjøgaard G. Algogenic substances and metabolic status in work-related Trapezius Myalgia: a multivariate explorative study. *BMC Musculoskelet Disord* 2014;**15**:357. doi:10.1186/1471-2474-15-357
33. Søgaard K, Blangsted AK, Nielsen PK, Hansen L, Andersen LL, Vedsted P, et al. Changed activation, oxygenation, and pain response of chronically painful muscles to repetitive work after training interventions: a randomized controlled trial. *Eur J Appl Physiol* 2012;**112**:173–81.
34. Sjøgaard G, Zebis MK, Kiilirich K, Saltin B, Pilegaard H. Exercise training and work task induced metabolic and stress-related mRNA and protein responses in myalgic muscles. *Biomed Res Int* 2013;**2013**:984523. doi:10.1155/2013/984523
35. Mackey AL, Andersen LL, Frandsen U, Sjøgaard G. Strength training increases the size of the satellite cell pool in type I and II fibres of chronically painful trapezius muscle in females. *J Physiol* 2011;**589**: 5503–15.
36. Pedersen MT, Blangsted AK, Andersen LL, Jørgensen MB, Hansen EA, Sjøgaard G. The effect of worksite physical activity intervention on physical capacity, health, and productivity: a 1-year randomized controlled trial. *J Occup Environ Med* 2009;**51**:759–70.
37. Christensen JR, Kongstad MB, Sjøgaard G, Søgaard K. Sickness presenteeism among health care workers and the effect of BMI, cardiorespiratory fitness, and muscle strength. *J Occup Environ Med* 2015;**57**:e146–52.
38. Christensen JR, Overgaard K, Hansen K, Søgaard K, Holtermann A. Effects on presenteeism and absenteeism from a 1-year workplace randomized controlled trial among health care workers. *J Occup Environ Med* 2013;**55**:1186–90.
39. Hansen AM, Blangsted AK, Hansen EA, Søgaard K, Sjøgaard G. Physical activity, job demand-control, perceived stress-energy, and salivary cortisol in white-collar workers. *Int Arch Occup Environ Health* 2010;**83**:143–53.