ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2018; 4(12): 246-252
www.allresearchjournal.com
Received: 04-10-2018
Accepted: 09-11-2018

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A topological model for worksite intelligent physical exercise training (IPET): Associated with life style health risk factors

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Abstract
Association and implementation of multi-dimensional Health campaigns in terms of physical activity has proven positive effects regarding optimization of relevant exercise and different training protocols. The aim of this paper sought to present a study protocol with a topological model for planning the optimal individually tailored physical exercise and training for each worker based on individual health check, existing guidelines and state of the art sports science training recommendations in the broad categories of cardio-respiratory fitness, muscle strength in specific body parts, and functional training including balance training. The hypotheses of this research based on multiple review are individually tailored worksite-based intelligent physical exercise training, IPET. A strength of this study is the rigid RCT design and the involvement of experts within occupational health as well as sports science.

Keywords: Physical activity, exercise training, sickness absence, strength training

Introduction
Physical activity during work and leisure is often associated with the greatest stress that the body encounters in the course of daily life and calls for a number of physiological regulatory processes and their interplay which are entirely dependent on the type of the physical activity performed. It has been studied from multiple reviews and found that such sort of associations of physical activities to provide health benefits irrespective of the type or the site of physical activity performed. Typically, physical activity is divided into the domains of work and leisure, but the international recommendations for health-promoting physical activity do not distinguish between occupational and leisure time physical activity. In this context there has been a lack of attention to the extensive literature documenting high intensity occupational physical activity to deteriorate health.

A paradox of physical activity at work and leisure
According to the international recommendations on physical activity for health [1] it is recommended that: “most adults engage in moderate-intensity cardio-respiratory exercise for vigorous-intensity cardio-respiratory exercise training or a combination of moderate- and vigorous-intensity exercise to achieve a total energy expenditure of ≥500-1000 MET $\cdot$min$\cdot$wk^{-1}. On 2–3 d$\cdot$wk^{-1}, adults should also perform resistance exercise for each of the major muscle groups, and neuromotor exercise involving balance, agility, and coordination”. The latter modes of training may be categorized as functional training. The target levels for physical activity in terms of duration and intensity for the cardio-respiratory exercise training can be obtained by accumulating smaller periods of physical activity, for example by splitting 30 min in 3 bouts lasting 10 minutes or more. Physical activity intensity levels have been divided into e.g. 6 categories and related to %HR max, heart rate reserve (HRR), % VO2max, metabolic equivalent task (MET), or rating of perceived exertion (RPE) for setting the framework for recommendation for exercise training to conquer life style diseases due to physical inactivity [1, 4]. Such levels of recommended physical activity may have occurred in the cohorts of longshoremen [5] and bus-conductors [6] with data obtained at the end of the 19th and beginning of the 20th century. These early studies are cornerstones in our understanding of the relationship between physical activity and cardiovascular diseases and show positive relations between physical activity at work and cardiovascular health.

However, the labor market has changed dramatically and work tasks performed with large muscle groups in terms of major dynamic physical activity are almost extinct. Accordingly, a more recent paper on the perspectives from these earlier studies stated that leisure time physical activities have to be included, “presumably because of lack of variability in intensities of physical work” [7].

The occupational physical activity in contrast to leisure time physical activity has to be thought up to 8 hours a day, 5 days a week, which in the middle of the 20th century set fundamentally different levels compared with the health enhancing levels recommended [1]. Instead of minimum levels of physical activity, levels of maximum permissible intensity were proposed. Consensus guidelines were first time presented by the International Labor Organization in 1971 [8]. The maximum level of work intensity for an 8 hrs workday was a mean value of 30% of heart rate reserve estimated as delta value from resting HR to HR-max. Somewhat higher values of 50% HRR were acceptable if the work tasks have to be endured for only one hour a day. These intensities are only marginally reaching levels that will improve cardio-respiratory fitness. To this adds that over the last century the physical activity in many job types has steadily decreased [9] and a major concern for public health in modern working life is the aspect of inactivity; in part due to the sedentary working conditions. However, in spite of technical improvements and an increased computerization of job task many sectors still demand manual work in terms of continuous walking, standing, lifting, pushing and pulling. These demands are especially common in work with personal care, heavy industry or service jobs but with great differences in the daily exposure profiles. An 8 hour work day with standing and walking such as cleaning may easily exceed the recommended guidelines but still not reach a level that could be health enhancing [10]. Similarly, jobs with awkward postures such as among health care workers or constructions workers with occasionally high peak loads may pose high demands on the low back but without the timing and intensity that could provide a training effect in general or specifically on the low back muscles. Optimal health enhancing training for the worker may depend on the occupational load - ranging from inactive or low to moderate and high mechanical and or metabolic loads- in combination with individual health and physiological capacity profiles.

Evidence of health enhancing physical activity at the work site

An extensive review/survey during the last decade an increasing number of randomized controlled trials, RCT, have been conducted introducing physical exercise training programs at the worksite often performed during working hours. Growing evidence is presented that such programs result in clinically relevant health effects and preliminary cost effectiveness estimates indicate acceptable cost relative to societal savings on health expenses [14, 15]. Work site health promotion and job exposure dependent exercise training is thus contemporarily recognized as a significant tool for health improvement in the workforce and thereby also in benefit of the company. Complementing the work exposure profile to develop a healthy exposure/training profile by integrating leisure time activity in work life is increasingly considered cost effective. In Denmark we have recently conducted nine RCT’s successfully in terms of improving health among a number of different job categories ranging from physically inactive to low, moderate, and finally, heavy physical work. The interventions enrolled ~ 2500 workers and lasted from 10 – 52 weeks. Questionnaire surveys and health checks were performed at baseline and follow-up. The job groups included were: Office or computer workers [16, 17, 18], industrial laboratory technicians [19], cleaning personnel [20], health care workers [21], construction workers [22], and fighter pilots [23]. Relative aerobic capacity –a health risk indicator for cardio-vascular diseases- was improved among office and computer workers, health care workers, and construction workers while a reduction in musculoskeletal disorders – a main cause for sickness absence – was seen in office and computer workers, industrial laboratory technicians, cleaning personnel as well as fighter pilots, and a number of other improvements in physical capacities were evidenced with effect sizes of clinical relevance.

Three essential factors characterized these interventions which made them distinct from a number of unsuccessful interventions: 1) Physical exercise training was performed during working hours 1 $hr{\cdot}wk^{-1}$, usually divided into 2–3 training sessions, which requested involvement of the employer to allow for such activities and thus signalling support of health enhancement for employees, 2) sports exercise training specialists were involved in designing the specific exercise training programs that were evidence based and of generally high intensity, 3) training sessions were regularly supervised by expert trainees in the field and adherence was monitored. It is concluded that worksite exercise training does enhance health if a program with evidenced efficacy is implemented by expert trainees with support of the employer. In these studies the training programs were similar for all participants, however, from a highest benefit perspective training should be individually tailored.

Adherence to physical exercise training

Although the RCT’s mentioned above were successful in improving health, their effect sizes could be improved by increased adherence to the training by the enrolled employees. Regular adherence was as a mean 61% but among the studies ranged from 31% to 86%, which allows for significant improvement in most studies. The implementation of the training needs more attention since this may improve adherence and thereby the effect size [24]. This is true for exercise programs offered during working hours and in particular for motivation of adequate exercise training during leisure. The latter may be particularly crucial in job categories characterized by major inactivity, since the total duration of physical activity requested in a health perspective amounts to several hours a week, which every employer may not accept as working time. Such leisure physical activities may be planned in a social context at the company and attended just before or after working hours. Thus the worksite may be considered as an ideal arena for implementation of physical activity: it is organized with information and communication systems, has contact with its workers on a daily basis, and may take social responsibilities. These features may play significant roles in scheduling physical exercise training for the worker during working hours, in relation to work time – i.e. before or after, or during leisure by announcing relevant info from around the local community on these issues.

Cost-effectiveness

Preliminary cost effectiveness estimates in worksite RCT's conducted in Denmark indicate acceptable cost relative to societal savings on health expenses. However, more subtle analyses are requested. The present study therefore will record relevant information for cost-effectiveness estimates. While focus primarily has been on the cost of sickness absence that with some uncertainties can be calculated, a number of new studies point towards the much larger but more invisible cost of employees with a health related reduced productivity and work ability but still maintaining work [25]. This so-called "presenteeism" may economically be a much more important factor to consider for the companies [13]. In the present study in addition to absenteeism measured as sickness absence, also presenters have evaluated based on self-reported productivity [26] and work ability [27].

The aim of this paper is to present a topological study with a conceptual model for planning individually tailored physical exercise training for each worker, optimized by the use of an individual health check, existing guidelines and state of the art sports science training recommendations in the broad categories of cardio-respiratory fitness, muscle strength in specific body parts, and functional training including balance training. The areas of fitness were aligned with those in a recent review in the area to consult for relevant references [28]. Special attention was given to the procedure of implementing the training in order to optimize adherence.

Health check

In our extensive review, participants had scheduled a one hour health check at baseline before the intervention and at follow up after one and two years of intervention. Measurements included were: VO_{2max}, muscle strength, body mass, body height, body fat percent, waist/hip ratio, blood pressure, blood lipid and glucose profile. Additionally a balance test was performed. All employees received individual notification shortly after the checks. Cut-points for recommending specific training modes are given in the section "Outcome measures".

Musculoskeletal check

An objective examination was performed by a chiropractor for musculoskeletal disorders at baseline before the intervention lasting approximately ½ hour. Based on the musculoskeletal check employees were excluded if considered in risk of deteriorating health by a major part of the training program or they were advised with individual recommendation to take special care in relation to specific exercises e.g. in case of minor musculoskeletal disorders. The musculoskeletal check consisted of a body position test [31, 32], movement test [33, 34, 35], stability-palpation test [36, 37]. Based on this check the chiropractor could recommend training of core stability or neck/shoulder strength.

The intervention program

A conceptual model was developed for designing individually tailored programs termed "Intelligent Physical Exercise Training", IPET. The concept of IPET at the worksite was: 1) to balance the physiological capacity of the employees relative to occupational exposure, 2) to tailor the exercise to individual capacities and disorders to improve employees' health, 3) to motivate participants by offering evidenced and enjoyable programs implemented with care.

The occupational exposure was sedentary work with intense computer use for all eligible participants in this study. This implied that inactivity had to be reduced by following the guidelines from American College of Sports Medicine [1]. To reach these targets in quantity it was negotiated with employees and top-management that 1 hr of vigorous intensity training (77 – 95%HRmax, RPE 14–17) per week would be performed during working hours and 30 min moderate intensity training (64–76%HRmax, RPE 12–13) six days a week during leisure by each participant or a minimum of 3 hrs per week. The instructors were supervising the 1 hr vigorous intensity training at facilities in the workplace or in the local area one day a week during the first year; during the second year they supervised only 1 hr a month. The health ambassadors were active in advising and motivating for the leisure time training, mainly dynamic activities using large muscle groups (64–76%HRmax).

The health check and musculoskeletal check as well as questionnaire served to tailor the activities to the individual for the high intensity training 1 hr a week at the worksite. The training was composed of the 3 major training categories: Cardio-respiratory fitness, strength training, and functional training (or neuromuscular training). The latter two were subdivided into strength training for neck/shoulder or large muscle groups, and functional training for core stability or balance, respectively, resulting in 5 different categories to allocate training specific duration. Specific cut-points were set from the health check measures for recommending a specific training category (see below). Additionally, questionnaire reply (see below) of musculoskeletal complaints for > 30 days/year in neck/shoulder or low back resulted in recommending training of neck/shoulder strength and functional core stability training, respectively. Likewise, the musculoskeletal check could result in recommended training of neck/shoulder strength and functional training of torso and/or balance. Depending on the number of recommended training categories (max 5) the time allotted to these exercises was adjusted accordingly. Several cut-points often qualified for recommending the same training category, but the time allocated to the five different training categories was independent of the number of tests surpassing a cut-point.

Instructors as well as health ambassadors were recruited to assist the participants and spur their motivation (see above). Further, each employee received a hand-out with an individual intelligent physical exercise training program. All training sessions lasted 50 min – allowing 10 min for getting to and from the site of work and the site of training within the one hour off work – and were led by instructors. Of these sessions always 20 min were in the beginning allocated to cardio-respiratory fitness training, including 10 min warm-up, due to the physical inactivity at the job. After this the instructor guided each employee to train their specific exercises and at recommended training intensities. Those employees who did not surpass any of the cut-points for recommending specific training categories were to train 25 min cardio-respiratory fitness and 25 min strength training for large muscle groups while all others had specifically composed training categories.

Exercises for cardio-respiratory training were up to the employee to choose with guidance from instructors and with the focus on training at high intensity and could be running, stepping, rowing, ball games etc. Exercises for strength training of large muscle groups were selected from 5 different exercises: 1 for shoulders, 3 for abdomen-back and 1 for the breast muscles. The intensity for strength training of large muscle groups was 60 – 80% of one repetition maximum, RM. Frequency: 3 sets of 8 repetitions. Breaks: Employees were instructed to shift between exercises, which meant maximum 10 s breaks between sets. Exercises for neck and shoulder strength were shrugs, reverse flyers, and arm abduction, i.e. evidenced previously to increase strength/endurance and reduce neck/shoulder pain [17, 38]. The intensity for neck and shoulder training was to pain limits or as heavy as possible and with proper technical execution. Frequency: 3 sets of 8 repetitions. Breaks: 1 – 2 min breaks between sets. Exercises for functional training were selected from 9 different exercises: 5 for balance training and 4 for core stability training. Functional training had no demands for intensity or frequency.

Measures of sickness absence recorded by the company and responded to the questionnaire by the employer together with their data on salary and self-reported productivity and workability will feed into models of health economics [14]. Account will be taken on the hours of training during working hours.

Outcome measures

Measures obtained during the health check were

Estimated maximal oxygen uptake (VO_{2max})

VO2 max was the primary outcome for this study and was estimated from the relation between sub-maximal workload and steady state heart rate obtained in Åstrand one-point sub-max test using the Åstrand nomogram [39] and correcting for age [40]. The tests were performed on a bicycle (Monark 874E, Monarch Exercise AB, Sweden) and with heart rate (HR) measured (Polar S610i Heart Rate Monitor and Polar FT2 Heart Rate Monitor). Test procedure: The starting load was 60 Watt for women and 90 Watt for men pedaling at 60 rpm. After 2 min of warm-up the load was adjusted based on the measured HR. If the HR was below 120 beats per min (bpm) the load was adjusted with 30 Watt every minute until a steady state HR (change of ≤ 4 bpm per 1 min) was reached between 120 – 170 bpm. The test length was maximum 10 min and employees were instructed not to talk during the test. The cut-point for recommending extra cardio-respiratory fitness training was a test value <80% of the reference value from the Danish working population [41].

Muscle strength

Maximal isometric muscle strength was measured with Bofors MODEL dynamometer (Bofors Elektronik, Karlskoga Sweden) mounted in a reproducible standardized setup for 4 tests: Shoulder elevation, arm abduction, back extension, and abdominal flexion. In every test the employees completed 3 maximal voluntary contractions (MVC) with at least a 30 s break between tests (if the 3rd MVC was 5% higher than the first and second test the employee was instructed to perform another test with the maximum of 5 tests). The highest value was recorded and moment arm for all test was registered. The cut-point for recommending strength training was a test value for a particular body region <80% of the reference value from the Danish working population.

Balance test

A unilateral stance test was performed with eyes open and participants were instructed to look directly ahead at a black spot placed approximately 2 meters in front of them at eye height. The participants stood on the dominant foot (defined as the foot used for standing while kicking a ball) with the big toe of the non-dominant foot leaning against the medial malleolus of the dominant foot. The test was performed for 30 seconds. Each participant was allowed three trials with loss of balance before the end of the test being classified as failed. The cut-point for being allocated to balance training was failure of all three trials.

BMI and body fat

Body height, weight, and fat were measured using a bio impedance device (Tanita TBF 300). Employees were normally hydrated and were measured without shoes and socks and with light clothing. Waist/hip ratio was measured with a ruler. The cut-points for recommending cardio-respiratory training were: BMI ≥ 25 or fat% >24 to >44% depending on age and sex.

Blood pressure

Blood pressure was measured in seated position after 5 – 10 minutes of rest. Blood pressure was measured on the right arm with an electronic blood pressure device (OMRON M7). Blood pressure was measured 3 times with one minute rest between tests and the mean of the 2 lowest values was calculated. The cut-point for recommending cardio-respiratory training was diastolic pressure> 90 mmHg or systolic pressure > 140 mmHg.

Blood profile

On the health check day overnight fasting blood samples (>7 hrs) were taken between 07:00 – 09:00 am. Blood samples were handled by technical personal from The University of Southern Denmark. The cut-points for recommending cardio-respiratory training were: Blood sugar ≤ 4 or ≥7 mmol/l, blood triglycerides ≤ 2 mmol/l, total cholesterol≥6 mmol/l, LDL ≤ 3 mmol/l, and HDL ≥ 1 mmol/l.

Self-reported measures

Questionnaire

All employees completed a questionnaire three times: at baseline as well as after one and two years of intervention. Questions addressed: demographics, education, job, income before tax, productivity [26], workability [27], psychosocial aspects, pain/kinesiophobia, self-rated health, sick leave, smoking, alcohol, physical activity at leisure, and sports activities specified as: ball games, Nordic walking, jogging, cycling, aerobics, spinning, dancing, swimming, kayaking/rowing. Questions regarding musculoskeletal disorders were assessed by a modified version of the Nordic questionnaire of musculoskeletal disorders. Cut points for recommending strength training for neck/shoulder or functional training for core stability were > 30 days complaints during the last year in the neck/shoulder area and low back area, respectively. At follow-up after one and two years, respectively, questions regarding adherence as well as the impact of the health ambassadors were included. Their impact was rated from 1 for no impact to 10 for major impact.

Diary

Employees in the training group reported every week to the health ambassador regarding their physical activity at leisure. The reports were categorized into: Running, organized fitness training, strength training, home & gardening, climbing stairs. The total time for activity as well as time with moderate and high intensity, respectively was inquired.

Report by instructor

The instructors filled in a training diary with attendances and intensity of training in terms of RPE for employees in the training group for each 1 hr weekly scheduled training sessions.

Statistical study

All results are reported as mean (SD) and $p < 0.05$ is considered statistically significant. Primary and secondary outcomes will be analyzed within (paired t-test) and between the intervention group and the control group after intervention (ANCOVA). Categorical variables will be tested using chi-square and McNemar tests. Analyses will be performed using SPSS statistical software, version 21. Intention to treat analyses will be performed and values carried forward and backwards for missing values in both baseline and follow up measurements. If measurements have missing values in both baseline and follow up they will be replaced by means of all existing data in each group, respectively. Per-protocol analysis will be carried out with employees from the training group who meet the criteria of at least 70% adherence in the training period. Sample size calculation is based on a 5% improvement in VO_{2max} on a group level with a SD of 20%, type 1 error of 5% and a power of 80% which showed a requirement of 128 employees in each group. With an estimated dropout of 30% the research project has to recruit around 400 employees.

Discussion

In RCT studies it is a common strategy to give all participants in the intervention group the same treatment in absolute terms. In studies on physical activity for health promotion the exercises have been cardio-respiratory fitness training at given percentages of VO2max, strength training at a given percentage of maximum voluntary contraction [17] or fixed combinations. The novelty of this study is that the exercise programs were individually tailored. This may enhance the individuals' health promotion but at the same time impair the strength of the study in terms of significant effect on the primary outcome. A first attempt in developing IPET was among construction workers [22] where individually tailored exercise programs were developed based on a health check similar to the one in the present study. A combination of cardio-respiratory and strength training for specific body regions was developed for each individual employee and implemented for 12 weeks. A second step was to test intelligent physical exercise adjusted to the work place in terms of possible flexibility in duration, frequency, and supervision in order to fit the IPET to the work tasks [38]. Strength training was performed for 20 weeks but with highly variable training patterns. In the present study, optimizing the duration of the various exercise modes within the 1 hr training once per week during working hours was a challenge and we based our decisions on evidence based exercise training physiology. The minimum of training for each of the five categories was 5 min. Further, we considered strength training with large muscle groups also to induce an effect on cardio-respiratory fitness. Of the in total, potentially possible combinations only 9 combinations were recommended for 12 or more of the participants, i.e. ≥3% of the total number of participants in each of these combinations. Interestingly, these 9 combinations together included more that 85% of all participants. Actually, the last column also shows that around 3/4 of employees were recommended neck/shoulder strength training and a similar number cardio training. Both of these training categories were represented in 7 of the above 9 combinations. The particular need for these training activities are not surprising for this workforce, since they are sedentary 8 hrs five days a week and work in constrained neck/shoulder postures. Similarly, it is likely for other occupational groups based on health checks to identify optimal training combinations that are practically manageable at the work site.

A strength of this study is the rigid RCT design and the involvement of experts within occupational health as well as sports science. The topological model presented here is easily applicable for practical use. If proven effective, the intelligent physical exercise training scheduled as well as the information for its practical implementation can provide meaningful and scientifically based information for public health policy and health promotion strategies for employees in job groups at high risk for physical inactivity. This knowledge can be beneficial for occupational health professionals, supervisors, companies and employees in these job groups. Because the interventions are carried out during ordinary circumstances at a wide range of Danish workplaces, it is expected that the findings can be transferred and interventions implemented in other workplaces with high physical demands. In this way we tried to establish this topological model for worksite intelligent physical exercise training (IPET)

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