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ORIGINAL PAPER

THE IMPACT OF INERTIAL EXERCISES PERFORMED IN THE WORKPLACE ON SHOULDER MUSCLES' STRENGTH AND MUSCLES' FATIGUE RESISTANCE IN WOMEN WITH DISABILITIES

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Abstract

Background: Workers who do monotonous and repetitive work in a static position often complain about fatigue and decreased work efficiency. Some studies indicate that to improve muscle fatigue, resistance strength training can be used. **Material and Methods:** To investigate the effect of 4-week inertial training on shoulder muscles' strength and muscles' fatigue resistance 44 female workers with disabilities were examined. The participants were randomized into the training group (T) (N = 32) and the control group (C) (N = 12). Before the training and after that shoulder muscles' strength were tested at the start and at the end of the workday (Monday and Friday). The participants were asked to complete questionnaire concerning their fatigue at work (T and C), inertial training and work efficiency (T). **Results:** The work performed during the last day of the workweek, i.e., Friday (before training) resulted in a significant decrease in shoulder muscles' strength in T and C. Muscle strength achieved at the end of the workweek (Friday afternoon) was significantly lower than achieved at the start of the workweek (Monday morning) in both tested groups (before training). Moreover, inertial training resulted in a significant increase in shoulder muscles' strength in T; 34–74% for different muscles. No changes in muscles' strength were noted in C. Increased muscle strength in T following inertial training effectively prevented muscle fatigue. After training the differences in shoulder muscles' strength noted in T during different times of the workday and workweek were insignificant. Moreover, 4-week inertial training increased significantly the work efficiency of women from T by 4%; no changes were noted in C. Inertial training was well tolerated by the participants. **Conclusions:** Using inertial training in women with disabilities to prevent shoulder muscles' fatigue during the workday and workweek is recommended. Med Pr Work Health Saf. 2024;75(2):113–122

Key words: fatigue, work, inertial training, disability, workday, workweek

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INTRODUCTION

Subjects who do monotonous and repetitive work in a static position often complain of fatigue, discomfort, and soreness in the neck and shoulder regions. Muscle fatigue is defined as a decrease in maximal force or power production in response to contractile activity [1]. Fatigue is also described as a sense of tiredness and feeling of exhaustion, fatigue leads to a difficulty in performing voluntary tasks [2]. There are some factors influenced by the level of fatigue in assembly-plant employees. Those are: workers' position during work, muscle restriction blood flow, loads lifted during work, type of muscle contraction. Important factors that result in the fatigue of rotator cuff muscles during work are body postures and arm elevation angle [3].

Wiker et al. [4] stated that their findings should encourage ergonomists to eliminate overhead work even in light-weight manual assembly environments. It is noteworthy that even a low-intensity, prolonged, assembly task leads to significant muscle fatigue [5,6]. Halim et al. [7] concluded that prolonged standing contributed to psychological and muscle fatigue among the production workers. Moreover, the level of muscle strength developed during work influences fatigue resistance. There are positive relationships between shoulder abduction, adduction and internal rotation strength and upper extremity fatigue resistance. Also, hand grip strength was associated with upper extremity dysfunction and fatigue resistance [8]. Therefore, greater muscle strength results in greater fatigue resistance. Moreover, in workers performing highly repetitive and forceful exertion and awkward postures, the risk of both an impaired work ability and musculoskeletal disorders increase significantly [9–11]. Long-term fatigue often leads to work disability, musculoskeletal disorders and long-term sick leaves [12,13]. Additionally, fatigue and insufficient muscle strength result in diseases and production losses [14]. Considering the above, it is possible that long-term standing work performed with the upper limbs by people with disabilities may cause fatigue and a decrease in work efficiency. It is possible that both a single workday and a workweek may reduce the strength of the shoulder muscles, increasing the feeling of work hardness. However, strength intervention programs at the workplace can be a good strategy to minimalize the above mentioned consequences of fatigue. Increasing muscle strength following resistance training may results in significant and clinically important reductions in fatigue [14,15] and can lead to reducing pain of the hand/wrist in manual workers with chronic upper limb pain [15]. Moreover, greater muscle strength improves the quality of life and the ability to perform daily tasks [16]. One of highly effective strength training methods is inertial training. This relatively unknown type of training turned out to be more effective than traditional resistance exercise [17]. A significant increase in muscle strength as a result of inertial training becomes evident in a relatively short time in subjects with limited functional abilities [18,19].

Therefore, the aim of this study was to examine the influence of the workday and the workweek on shoulder muscle strength in female workers with disabilities. It is possible that following muscle fatigue (in muscles engaged during a workday), muscle strength can be reduced during the workday/workweek. Moreover, the aim of this study was to investigate the effect of 4-week inertial training on skeletal muscle strength and muscle fatigue resistance.

MATERIAL AND METHODS

Seventy-five middle-aged females with a disability certificate, employees of sheltered workshops attended the initial recruitment meeting, and 52 agreed to participate in the study. Only volunteers who met the following inclusion criteria could take part in the study: no regular training in the prior 24 months, generally good health, working at least 12 months in the current workplace, permanent employment. The exclusion criteria were: tendon or ligament injury in the previous 2 months and fractures in the previous 3 months, a disability precluding participation in the research due to health reasons. After applying these criteria, the study ultimately included 44 women (age M±SD 40.6±9.13 years; body mass 67.6±11.1 kg; height 161±4.92 cm). The participants were physically inactive, they had various mild disabilities (amblyopia, hearing loss, musculoskeletal disability). While working, the employees performed manual activities at a special production board (the production of electrical harnesses) in a standing position. During work, the arms were flexed and abducted at the shoulder joint most of the time. The participants were randomly allocated into 2 groups: the training group (T) (N = 32) and the control group (C) (N = 12) using the chit method, which is a simple way of generating random sequences. The T group participated in 4 weeks of inertial training while the C group refrained from training. All the participants were asked to maintain their standard diet and physical activity levels throughout the duration of the study. However, their lifestyle was not controlled. All subjects submitted their written informed consent to participate in the study. All procedures were approved by the local ethics committee (1744/03), with approval based on the Declaration of Helsinki, and all research methods were applied in accordance with relevant guidelines and regulations.

Training

Inertial training was performed 3 times a week (every Monday, Wednesday, and Friday) at the workplace, in a production hall specially adapted for this purpose for a period of 4 weeks. For exercises Inertial Training Measurement System (ITMS) was used, as described by Naczk et al. [20]. Each training session included 3 sets of exercises involving the shoulder muscles. Each set consisted of:

- adduction and abduction of the right upper limb (20 s) and then (with no break) – the left upper limb (20 s). The exercise was performed in a sitting

position (laterally to the ITMS). In the starting position the arm was abducted from the trunk at approx. 90° and the range of motion was about 80°, and with no break;
- flexion and extension of the right (20 s) and – with no break – of the left upper limb (20 s) at the shoulder with the participant in the sitting position in front of the device. In the starting position, the arm was extended from the trunk at approx. 90° and range of motion was about 80°. All the participants exercised with a constant load equal to the mass of the flywheel, i.e., 19.4 kg. The participants were asked to exercise at maximal intensity (the speed of movement). A 2-minute break occurred between the consecutive sets. Each training session was preceded by a standard 5 min of warm-up, involving 2 sets of 10 double-arm rotations, opposite arm swings, and lateral arm swings with trunk rotation. After that, each participant performed 2 sets of 10 slow cycles with the ITMS. A single training session lasted about 20 min, employees were called from the production hall to training room.

Measurements

To test the influence of the workday and workweek on the strength level, 8 tests of the strength of the adductor and flexor muscles of the shoulder joint were performed by each participant. Therefore, shoulder strength was measured 4 times in the measurement week before training and 4 times in the measurement week after training. There was no training during the measurement weeks.

Measurement sequence:
1) Monday morning (before work) before training,
2) Monday afternoon (after work) before training,
3) Friday morning before training,
4) Friday afternoon before training,
5) Monday morning after training,
6) Monday afternoon after training,
7) Friday morning after training,
8) Friday afternoon after training.

Therefore, the maximal force using ITMS were measured before and after the training period, under the training conditions. After warm-up, each participant performed a 10-second maximal test of the adductor and flexor muscles in the shoulder joint, right and left arms separately, with a 2-minute break between the measurements. The data from the tensometer and encoder were sent to the *data acquisition* (DAQ) module and saved on the computer equipped with MAD01 software (Inerion, Stanowice, Poland). The average values of maximal force from the left and right arms were used for further analysis. The participants' position and exercise technique were the same as during training (see above). Before the training and measurements, the participants learned exercise techniques in inertial conditions during 2 familiarization sessions. The intraclass correlation coefficient (ICC), the consistency 0.971 and the ICC agreement 0.969 indicate high reproducibility of ITMS strength measurements.

To investigate muscle fatigue different methods are used. One is the measurement of maximal force, and the calculation of the fatigue index (FI) [21–23]. The Oyewole method [23] was used and FI was calculated using formula:

$$\text{FI} = (100\% \times \text{force}) / \text{maximal force} \tag{1}$$

Body composition

Before and after training, the body composition was evaluated using bioelectrical impedance device (BIA 101 Anniversary, Akern, Italy). The participants were asked to maintain their normal lifestyle and were not allowed to exercise or eat for 12 h preceding the measurements, they could not drink prior to the measurements. The measurements were made on Friday morning (before and after training), in accordance with the manufacturer's guidelines.

Questionnaire

After the training period, the respondents were asked to complete questionnaires containing the following questions:
- how do you rate the level of fatigue at your work? Possible answers: very tiring, tiring, average, light, very light;
- how did you feel about inertial training using an ITMS device carried out at your workplace? Possible answers: very pleasant, pleasant, unpleasant, very unpleasant, I have no opinion;
- would you like to participate in systematic inertial training at your workplace? Possible answers: I would love to participate, I would be happy to exercise, I wouldn't mind, if I had to, I wouldn't like to train, I would definitely refuse to participate in the exercises;
- as a result of training, my health and well-being – possible answers: improved very much, improved, did not change, worsened, worsened very much.

Moreover, the participants were asked about work efficiency (the number of products assembled during the day) before and after training.

Statistics

The Shapiro-Wilk test was used to test, if the data were normally distributed. Descriptive statistics, including means and standard deviations, were calculated. The two-way analysis of variance (ANOVA) with repeated measures was used to determine the effect of exercises. If differences were detected, the Scheffé *post hoc* procedure was applied to determine where the differences occurred. Levels of significance were set at $p \leq 0.05$. The simple effect of training for each participant was defined as a relative increase in an analyzed variable after training compared with the value from before training.

RESULTS

None of the analysed parameters significantly differed between the T and C groups at the beginning of the experiment. The absolute values of analyzed parameters before and after training are presented in Table 1. The Monday workday (before and after training) did not impact the shoulder muscles' strength in neither of the tested groups significantly (Table 2); FI for both groups ranged 0.96–1.04. However, the abductors' and flexors' strengths tested before training

Table 1. Absolute values of strength in tested shoulder muscles before and after training in a study of females with a disability in Poland, 2019

Participants	Muscle strength [N] (M±SD)			
	adduction		flexion	
	right limb	left limb	right limb	left limb
Training group (N = 32)				
before training				
Monday morning	30.4±9.58	29.7±10.8	35.1±10.6	34.0±10.5
Monday afternoon	29.7±10.4	29.0±9.44	34.6±12.6	32.5±10.4
Friday morning	27.4±8.90	28.1±10.2	33.9±11.6	32.3±11.7
Friday afternoon	25.3±8.81	26.4±10.0	29.7±9.90	29.3±10.4
after training				
Monday morning	**42.0±14.3**	**40.7±12.4**	**49.6±14.2**	**46.1±13.1**
Monday afternoon	**42.5±14.6**	**38.9±13.0**	**48.4±15.9**	**47.5±14.5**
Friday morning	**43.0±15.7**	**40.7±14.4**	**47.7±15.6**	**46.8±15.8**
Friday afternoon	**44.0±14.8**	**42.9±13.9**	**47.9±14.7**	**47.6±14.0**
Control group (N = 12)				
before training				
Monday morning	29.0±8.82	28.2±8.32	34.1±10.5	33.1±9.81
Monday afternoon	28.8±8.77	27.5±8.27	33.5±10.1	32.8±10.4
Friday morning	28.3±8.55	28.0±8.67	33.6±11.1	32.7±9.90
Friday afternoon	27.0±8.78	26.3±8.15	31.6±9.72	30.9±9.56
after training				
Monday morning	28.6±9.34	28.3±8.72	32.9±9.27	32.7±8.98
Monday afternoon	28.6±9.04	28.6±8.71	33.9±10.8	34.0±10.6
Friday morning	28.3±8.95	28.1±8.83	33.5±11.9	32.8±11.4
Friday afternoon	26.2±8.56	25.6±8.18	30.5±9.81	30.0±9.82

Morning – measurement performed at the morning (before work); afternoon – measurement performed afternoon (after work).
Bolded are significant difference from baseline ($p \leq 0.05$).

Table 2. Changes in muscle strength at the beginning and end of the working day and on the first and last day of the working week in a study of females with a disability in Poland, 2019

Variable	Muscle strength															
	before training								after training							
	training group (N = 32)				control group (N = 12)				training group (N = 32)				control group (N = 12)			
	right limb		left limb		right limb		left limb		right limb		left limb		right limb		left limb	
	fatigue index	p	fatigue index	p	fatigue index	p	fatigue index	p	fatigue index	p	fatigue index	p	fatigue index	p	fatigue index	p
A1–A2	0.98	0.64	0.98	0.61	0.99	0.62	0.98	0.24	1.01	0.74	0.98	0.19	1.00	0.97	1.01	0.61
F1–F2	0.98	0.73	0.96	0.33	0.98	0.21	0.98	0.70	0.96	0.39	1.03	0.20	1.03	0.34	1.04	0.26
A3–A4	0.92	0.04	0.94	0.03	0.95	0.00	0.94	0.00	1.01	0.48	1.05	0.06	0.92	0.00	0.91	0.00
F3–F4	0.88	0.00	0.91	0.00	0.94	0.01	0.95	0.00	1.00	0.84	1.02	0.44	0.91	0.01	0.92	0.01
A1–A3	0.90	0.03	0.95	0.30	0.98	0.15	1.00	0.78	1.02	0.56	1.00	0.99	0.99	0.84	1.00	0.91
F1–F3	0.97	0.39	0.95	0.34	0.99	0.25	0.99	0.43	0.96	0.30	1.02	0.22	1.02	0.67	1.00	0.97
A1–A4	0.83	0.00	0.89	0.03	0.93	0.00	0.93	0.00	1.05	0.25	1.05	0.27	0.92	0.00	0.90	0.00
F1–F4	0.85	0.00	0.86	0.01	0.93	0.00	0.94	0.00	0.97	0.32	1.03	0.36	0.93	0.00	0.92	0.01

A – adduction, F – flexion.
1 – measurement completed Monday morning, 2 – measurement completed Monday afternoon, 3 – measurement completed Friday morning, 4 – measurement completed Friday afternoon

were significantly lower on Friday afternoon compared to Friday morning in T and C groups (Table 2). Also, FI indicates muscle fatigue on the following workday. Moreover, the workweek (before training) did not influence the strength level significantly (except abduction for the right limb in the T group) when strength levels noted at the Monday morning and Friday morning were compared (Table 2). However, the abductors' and flexors' strengths tested before training were significantly lower on Friday afternoon compared to Monday morning in T and C groups (Table 2). The FI also indicates the negative impact of the workweek and the workday on muscle strength in both groups: it ranged 0.83–0.94.

Inertial training caused significant abductors' and flexors' strength increase in the T group, regardless of the pair of the results (pre- or post-training) compared, e.g., Monday morning before and after training, Monday afternoon before and after training, etc. (Table 1). The strength increases in tested muscles ranged 35–74% in T. Pre- and post-training muscle strength of the tested muscles, did not change significantly in group C, changes ranged 3.53–3.90%.

The abductors' and flexors' strengths tested after training were still significantly lower on Friday afternoon compared to Friday morning in C group (Table 2), they did not, however, change significantly in T group. Moreover, the workweek (after training) did not affect the maximal strength of the tested muscles when strengths noted on Monday morning and Friday morning were compared (Table 2). The shoulder abductors' and flexors' strengths tested after training were significantly lower on Friday afternoon compared to Monday morning in C group; FI 0.90–0.93. However, the muscle strength remained unchanged in T group (Table 2); FI 0.97–1.05.

The body mass, BMI, fat-free mass, fat mass, and body water expressed in kg and % did not change significantly following the training period in both the tested groups.

The results of questionnaire are shown in Figure 1. Before and after the training period the participants were asked about work efficiency (the number of products/day – on Friday) before and after training. Before and after training the participants from T group manufactured M±SD 60.2±9.21 and 62.6±8.33 products per day, respectively. Thus, work efficiency increased by 4.00% ($p \leq 0.01$). In C group the workers manufactured a similar number of products per day before and after the training period (M±SD 60.7±8.08 and 60.7±11.7, respectively, $p > 0.05$).

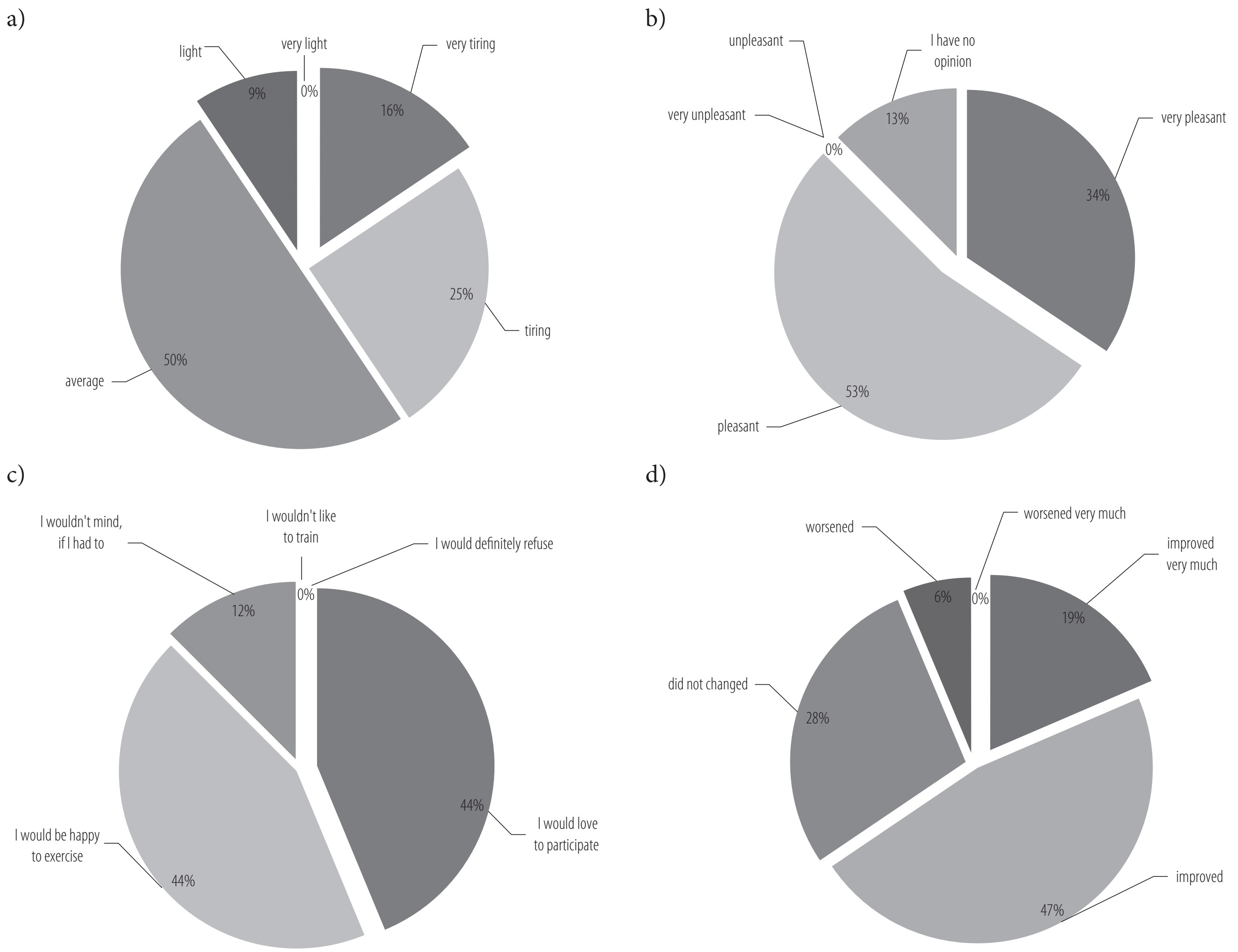

Figure 1. Results of questionnaire concerning work and inertial training in a study of females with a disability in Poland, 2019; a) the level of work fatigue of the participants, b) evaluation of the inertial training exprience, c) willingness to participate in systematic inertial training at the participants' workplace, d) result of training for the participants' health and well-being – figures contain the percentage distribution of answers (training group, N = 32) to the questions included in the questionnaire

DISCUSSION

This study indicates that the shoulder strength does not change following the workday at the start of the workweek. Moreover, the workweek (before training) did not influence the strength level significantly (except the abduction the right limb in T group) when strengths noted on Monday morning and Friday morning were compared. This indicates that a single day of work at the beginning of the week does not result in significant fatigue of the musculoskeletal system. Therefore, it can be concluded that a single day of work did not cause significant fatigue, and the workload and work ergonomics were correct. Similarly, a workweek did not cause a decrease in the strength of the tested muscles (comparing the strength noted on Monday morning and Friday morning). However, the abductors' and flexors' strengths tested before training were significantly lower on Friday afternoon compared to Friday morning in T and C groups. The results obtained in present study are consistent with the conclusions of Qin et al. [6] who note that a repetitive manual task causes muscle fatigue and increases the subjective ratings of perceived exertions. Similar findings were reported by Halim et al. [7], the authors concluded that prolonged standing work contributed to muscle fatigue among the production workers.

The strength of the adductor and flexor muscles in the shoulder joint noted on Friday afternoon comparing to Monday morning decreased significantly in both groups (before training). Also, FI was high and indicated on significant muscle fatigue. Such results suggest that the cumulative effect of fatigue caused by the working week and the last day of work (Friday) leads to a significant decrease of strength in muscles involved in the production process. Similar conclusions were made by Young et al. [24], their study demonstrated increasing fatigue of the hand/arm in plumbing over the day and persistent fatigue from Tuesday to Friday, which was the effect of cumulative fatigue. Results obtained in present study are also consistent with Pille and Tint [25] who stated that upper limb muscles' tiredness increases during the workweek in garment workers who work in static posture. Fatigue developed during the workweek is reflected not only by objective indicators (a decrease in muscle strength and FI) but also by subjective ones. In the questionnaire, 41% of the respondents indicated that their workweek was tiring or very tiring for them, 50% stated that it was moderately tiring and only 9% stated that their work was easy. The reduced level of efficiency of the muscular system in people with disability leads to excessive fatigue and reduces the ability to perform professional work [26,27]. An important role in counteracting excessive fatigue is played by preventive changes in work organization (the workplace and working position) and work ergonomics. The use of physical training, e.g., a set of simple and short-term strength exercises to improve the efficiency of the locomotor system, is not very common. In present research, inertial training was used, whose effectiveness in increasing muscle strength may be higher than traditional strength training [17].

Following 4-week inertial training the shoulder muscle strength increased significantly in T group, and remained unchanged in C. The improvement in strength (34–74% for different muscles and pairs of pre-post results) as achieved by the workers in the present study was extremely high. The efficacy of inertial training in achieved by production workers in present study was usually greater than that obtained by other authors during traditional resistance training. Sundstrup et al. [15] stated that 10-week strength training including shoulder, arm and hand muscles, performed at the workplace and caused an 11% increase in maximal voluntary contraction (MVC). However, it is noteworthy that in the cited study MVC was measured in handgrip, when the training also involved other muscles. The increases in shoulder muscle strength observed in present study were also greater than those noted by Andersen et al. [28] and Andersen et al. [29]. A very large increase in shoulder muscle strength noted in present study may be due to the effect of exercises' learning. Even though each subject participated in 2 familiarization sessions, the improvement in neuromuscular coordination in the first week of training could be significant. On the other hand, a strength increase noted in present study is similar to that obtained by the welders tested by and Krüger et al. [30] following 12-week resistance training; improvements ranged 34–61%, depending on a muscle group. Moreover, Naczk et al. [19] indicate that 6-week inertial training can result in >60% improvement in elbow and knee flexors' muscles strength, even in the elderly.

As the authors mentioned above, muscle strength significantly decreased in both groups following the workday (Friday before training). Moreover, a decrease in shoulder strength was noted when comparing its values obtained on Monday morning and Friday afternoon. However, a significant increase in shoulder muscle strength effectively decreased muscle fatigue caused by the workday and by the workweek. The shoulder muscle strength did not change following the workday (Friday after training), and did not change when values obtained on Monday morning and Friday afternoon after training were compared. At the same time, in the control group, significant muscle fatigue following the workday (Friday) and the workweek persisted. It can be assumed that increasing the shoulder muscles' strength through the inertial training carried out in working conditions can effectively prevent the fatigue development. Findings of this work are consistent with Krüger et al. [30] who stated that a specific strength training program enabled workers to perform their working tasks with a lower relative muscle load and reduced subjective exhaustion. It is also possible that the training-induced increase of shoulder muscular strength translated into an improved working ergonomics. The above statement is confirmed by a significant increase in work efficiency (by 4%) in group T following training and no changes in group C. Therefore, inertial training contributes to a better tolerance of the loads occurring during work. It is noteworthy that there is strong evidence of the effectiveness of strength training at the workplace to reduce musculoskeletal complaints in specific regions of the body [31–33]; although this is not examined in this work.

Inertial training is not a well-known strength training method. It has not yet been used as a prevention of overload of the musculoskeletal system during work. Results of this study indicate that it can also be successfully used by people with disabilities and effectively reduces muscle fatigue caused by work. It should also be noted that inertial training was very well received by the tested. The respondents stated that training was pleasant for them (87% of respondents) and they would be happy to continue it, if possible (88%). Inertial training at the workplace was possibly a change from the routine of, the often boring, workday. The phenomenon of endorphins being released following intense physical exercise is also known, which has a positive effect on well-being [34]. This mechanism could have influenced the workers' better well-being and subjective improvement in health following training (66% respondents answered that the training had improved their health). Therefore, better self-assessment of the health status of respondents from group T does not have to result from increased muscle strength, but may be the result of breaking away from the work routine and breaking work monotony. Moreover, all the participants completed the training program and there were no injuries. In this study, the authors examined the impact of inertial training on the level of shoulder muscle strength and its importance in preventing work fatigue. However, it should be mentioned that using other variables can also effectively counteract fatigue, e.g., changing body position during work, applying short active rest breaks to break the monotony of work, improving work ergonomics.

CONCLUSIONS

The work performed during the last day of the workweek (Friday) resulted in a significant reduction in shoulder muscle strength in female employees with disabilities. Muscle strength and FI achieved at the end of the workweek (Friday afternoon) were significantly lower than those recorded at the beginning of the workweek (Monday morning). Moreover, inertial training resulted in a significant increase in shoulder muscles' strength in women with disabilities. Increased muscle strength following 4 weeks of inertial training effectively prevents muscle fatigue and can increase the work efficiency of women with disabilities. Inertial training was well tolerated by women with disabilities. Finally, the use of inertial training in women with disabilities to prevent work fatigue can be strongly recommended.

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