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Morning warming-up exercise—effects on musculoskeletal fitness in construction workers

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Abstract

The aim of the present study was to evaluate the effects on muscle stretchability, joint flexibility, muscle strength and endurance in construction workers of a 3-month period of a 10-min morning warming-up exercise (MWU), performed at the building site every working day. Thirty construction workers participated in the program. Seventeen construction workers at other building sites served as controls. Muscle stretchability, joint flexibility, muscle strength and endurance were measured before and after the program. Significant increase of thoracic and lower back mobility, increase of hamstring and thigh muscle stretchability were seen in the MWU group. A significant difference in back muscle endurance was found due to decreased endurance in the controls. Muscular strength was not influenced by the MWU. The results indicate that a short dose of morning warming-up exercise could be beneficial for increasing or maintaining joint and muscle flexibility and muscle endurance for workers exposed to manual material handling and strenuous working positions.
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1. Introduction

The prevalence of musculoskeletal disorders and the relative risk of disability pension due to musculoskeletal disorders is high in construction workers in Sweden (Holmstrom and Engholm, 2003; Vingard et al., 1992). Construction workers are exposed to physical as well as psychosocial demands (Holmstrom et al., 1992).

Musculoskeletal symptoms can be reduced by organizational and ergonomic improvements as well as "modifier interventions" (Westgaard and Winkel, 1997). Moreover, it would be valuable to establish novel strategies for individuals to withstand overexertion, especially for individuals exposed to heavy physical workloads.

Prospective studies have provided evidence for lower back muscular endurance being a predictor of first time occurrence of low back pain (LBP) in men (Biering-Sorensen, 1983). A moderate inverse relationship between physical activities in leisure time and LBP in men was found in a prospective study by Leino (1993). However, frequent physical exercise was reported as a borderline significant predictor of sciatic pain in construction and office workers (Riihimaki et al., 1994).

Forward bending is a combination of lumbar flexion and pelvic tilting (Nordin and Frankel, 2001). Tight hamstring muscles may restrict pelvic tilting due to their attachment to the ischial tuberosity on pelvis (Gajdosik et al., 1994). Restricted hip flexion may result in excessive lumbar motion with increased tensile loads on the spine (Nordin and Frankel, 2001) with a possible increased risk for low back pain (Esola et al., 1996; Porter and Wilkinson, 1997). Hultman et al. (1992) reported significantly greater lumbar flexibility and

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hamstring stretchability in men with healthy lower backs than in men with LBP. Battie et al. (1990) also reported relationship between tight hamstring muscles and LBP.

Among coachers and athletes it is generally believed that active warming-up exercises are a necessary prerequisite to strenous performances which, to some extent, is supported in the scientific literature (Ingjer and Stromme, 1979; Safran et al., 1988; Gray and Nimmo, 2001).

It is, thus, reasonable to hypothesize that warming-up exercises could be of benefit for individuals with physically strenous jobs, like construction workers. In the late 1990s a Swedish construction company, where the present study was performed, had 5 team leaders who, at different building sites, were conducting morning warming-up (MWU) exercise programs.

To the best of our knowledge, there are no previous systematic studies on effects of warming-up exercises conducted on individuals with physically strenuous jobs.

The aim of this study was to evaluate the effects on muscle stretchability, joint flexibility, muscle strength and endurance in construction workers after a period of a MWU program of 3 months.

2. Material and methods

2.1. Subjects

2.1.1. Experimental group (MWU)

The MWU group consisted of 37 male construction workers from the same building site. They were informed about the study and accepted to participate. Prerequisites for participation were the following: (i) employment as construction worker at that specific building site during the last 12 months, (ii) being without diseases or symptoms jeopardizing the examinations and the performance of the MWU.

Five workers were transposed to other building sites during the study period and two were excluded because they participated in the MWU program less than three times a week. Baseline characteristics for the MWU program group ($n = 30$) and for the drop-outs are presented in Table 1.

2.1.2. Control group

The control group consisted of 20 male construction workers, matched to the MWU group for age and construction profession. The prerequisites for participation were the same as for the MWU group. The workers in the control group came from two different building sites.

Three subjects in the control group were not available for the second examination due to sick leave or change of building site. The reported control group therefore consisted of 17 subjects. Baseline characteristics for the control group and for the drop-outs are presented in Table 1.

2.1.3. Power calculation

The calculations of power showed a need for 21 subjects in each group in order to achieve a statistical power of 80% and an alpha of 5%. The intention was to reveal differences of minimum 8° at straight leg raising test and 30 s at back extensor endurance test.

2.2. Methods

2.2.1. Intervention program

For a period of 3 months a 10-min exercise period was performed every morning, starting at 6.50 AM, during paid working time at the building site. The program was composed by physiotherapists and conducted by a trained worker at the site. The exercises were performed in regular working-clothes and consisted of heart-rate-increasing and limbering-up activities, ending with stretching exercises. The exercises were performed with music.

Examples of performed exercises were: different arm-swings combined with knee-bendings, shoulder lifts, leg-kicks, spinal movements, transfer of body weight from side to side and jogging mark time. Each MWU session was ended with stretching, particularly of the hamstring, quadriceps, and calf muscles.

The subjects were told not to change their habitual leisure time physical activities during the study period.

2.2.2. Outcome variables

The outcome measurements were focused on mobility of the spine and extremities, on muscle tightness and on the muscle strength and endurance of the trunk and extremities. The measurements were performed before and after a 3-month period of a 10-min MWU exercise or after a corresponding 3-month period (controls). Individual characteristics, physical activities at leisure and at work, prevalence of musculoskeletal symptoms and diseases were recorded. All measurements were performed at the building sites in a shed or in an office room.

The back pain monitor (BPM) package system (personal communication, Souvanen and Tohka, Helsinki, 1995; http://www.e-healthbase.com accessed 4 March 2004) was used to measure body function including mobility and performance tests.

A questionnaire, included in the BPM-package system, concerning experienced workload, leisure time activity, pain and dysfunction was answered by the workers. Workload had six response options, leisure time activity had three response options. Pain was rated on four category scales with a sum index from 0 to 36. Dysfunction due to pain was rated on seven category scales with a sum index from 0 to 63.

Table 1
Baseline characteristics of the subjects in the experimental (MWU) and subjects in the control group and in the excluded/dropout groups at entry

	MWU ($n = 30$)	MWU excluded/ dropouts ($n = 7$)	Controls ($n = 17$)	Controls dropouts ($n = 3$)
Age (yr) mean (SD)	39.7 (11.8)	34 (14.8)	39.8 (15.4)	35.7 (10.0)
Height (cm) mean (SD)	180.5 (5.9)	177 (2.9)	179.2 (6.1)	178 (7.9)
Weight (kg) mean (SD)	84.1 (10.4)	82 (12.4)	82.2 (6.1)	82 (8.7)
Occupation			1 missing data	2 missing data
Concrete worker	11	3	8	1
Carpenter	17	4	6	0
Other	2	0	2	0
Workload (1–6), median (min–max)	5 (1–6)	6 (4–6)	5 (1–6)	5 (5–5)
Leisure activity				
Low	10	3	6	0
Moderate	12	3	6	1
High ($\geqslant 2/w$ with perspiration)	8	1	5	2
Pain (0–36), median (min-max)	3.0 (0–16)	2.0 (0–17)	0 (0–19)	0 (0–2)
Dysfunction (0–63), median (min–max)	3.5 (0–37)	5.0 (0–19)	3.0 (0–36)	0 (0–2)

The mobility of the neck was measured by using a "cervical-range-of-motion" (CROM) device (Youdas et al., 1992). A liquid goniometer (MIE Medical Research Ltd.) was used to measure the stretchability of the hamstring muscles (muscles from the back of the thigh) and the mobility of the spine and shoulder joints (Hyytiainen et al., 1991). The total mobility in the shoulder joints was registered as number of degrees missing up to 180° with the subject in a supine position. The stretchability of the hip flexors (the iliopsoas and rectus femoris muscles) was registered by means of a goniometer in supine position with one leg outside the edge of the examination bed (Ekstrand et al., 1982). This stretchability was registered as degrees in relation to the horizontal plane. Minus values indicate good stretchability, which means the thigh is hanging under the horizontal plane.

The static performance of the trunk extensors was measured in prone position with 240 s as the predetermined limit of termination (Biering-Sorensen, 1984; Latimer et al., 1999). The static performance of arm muscles was measured at 90° of abduction with similar technique as reported by Horneij et al. (2002). The dynamic performance of trunk flexors was measured with curl-ups in a standardized supine position with the hips and knees in 90° of flexion (Hyytiainen et al., 1991).

The dynamic performance of the upper limbs was measured as maximum arm elevations with 10 kg in each hand (Shipp et al., 2000). The dynamic performance of the lower limbs was measured as maximum number of rising up from half-kneeling position to standing up position (Alaranta et al., 1994). The predetermined rate of speed for all dynamic performance tests was controlled by a metronome and the predetermined limit of termination was set to 50 repetitions.

The mobility of the cervico–thoracic part of the spine was assessed by a technique for measuring relative segmental flexion mobility in the motion segments C7–T5. The technique is referred to as the cervico–thoracic ratio (CTR) (Norlander et al., 1995).

The two examiners, physiotherapists, were not blinded. They were both trained in the different measuring techniques. Before the start of the project the concordance between the two examiners was trained. They both performed half of the examinations in the MWU group as well as in the control group. The measurements were performed strictly according to manuals. In cases where divergencies were registered, stricter definitions were added to the manuals.

2.2.3. Data presentation and statistical methods

Data are presented as means with standard deviations (SD) except for pain and dysfunction which is expressed as median and range. To test for differences between variables based on normally distributed continuous variables the Student's *t*-test was used for paired or unpaired data. To test for differences between variables based on categorial data the Wilcoxon signed ranks test for paired and unpaired data was used. The chi-square test was used to determine differences in the distribution of symptoms between groups. p-Values <0.05 were considered significant and all tests were two-tailed.

3. Results

3.1. Compliance/feasibility

Twenty-eight of the 30 construction workers performed the MWU at least three times a week during the 3-month period. Nineteen participated every working day. Everyone in the MWU and control groups assured that they had not changed their habitual physical exercise activities during the time of the project.

3.2. Pain, dysfunction, leisure and workload

There were no significant differences concerning pain, dysfunction, degree of leisure activity nor workload between the MWU and control group neither before nor after the 3-month period. In the MWU group the median (range) score for pain was 3.0 (16.0) before the intervention and 2.0 (17.0) after the intervention. The corresponding figures for dysfunction were 3.5 (37) and 2.5 (31), respectively. In the control group the median (range) score for pain was 0.0 (19.0) at baseline and 1.0 (17.0) after the 3-month period. The corresponding figures for dysfunction were 3.0 (36) and 3.0 (21), respectively.

3.3. Mobility

Thoracic and trunk flexion increased significantly in the MWU group after the intervention and decreased in the control group (Table 2) and the difference was significant. The range of motion in the neck, spine and shoulder joints is presented in Table 2. Neither did the range of motion in arm elevation change in any of the groups. The mean values at the first registrations for both groups were practically identical (Table 2).

The assessment of relative segmental flexion mobility in the cervico–thoracic spine showed no significant changes at any level in the MWU group after the intervention. In the control group a significant increase of relative flexion mobility was seen in one segment, T1–T2, at the second registration.

3.4. Stretchability

The stretchability of the left and right hamstring muscles increased significantly in the MWU group but not in the control group. The groups differed significantly after the 3-month period of morning warming-up exercise (Table 3).

The stretchability of left and right hip flexors increased significantly in the MWU group but not in the control group.The difference between the MWU and control groups after the 3-month period only reached significance for the left side (Table 3).

3.5. Muscular strength and endurance

Left side leg muscle dynamic endurance increased significantly in the MWU group after the MWU program but did not differ from the control group. In the MWU group the back muscle isometric endurance time was the same, mean 153 s, before and after the intervention. However, the back muscle isometric endurance time decreased significantly in the control group from mean 171(62)–140(68) s. The difference between the groups after the 3-month period was significant. No other tests of muscular strength and endurance demonstrated any significant changes in neither MWU group nor control group (Table 4).

4. Discussion

The aim of this study was to evaluate effects of a MWU program on musculoskeletal function in construction workers. At baseline the median value of pain was 3, on a scale with a sum index from 0 to 36, in the MWU group and 0 in the control group.The difference did not reach significance. No significant differences between the groups concerning baseline characteristics were found, which should make comparisons between the groups possible.

4.1. Methods

Shortcomings of the current study are the non-randomized design. When carrying out an intervention like MWU in real working life it is difficult to obtain

Table 2
Mobility of the neck, spine and shoulder Joints in the subjects in the MWU and control group before and after a 3 months' period of MWU program. The values are means (SD)

	MWU ($n = 30$)		Controls ($n = 17$)		MWU versus controls (Significant differences)
	Baseline	After	Baseline	After	After
Neck flex (deg)	58 (12)	59 (11)	60 (7)	58 (10)	—
Neck ext (deg)	70 (13)	74 (12)	69 (12)	67 (12)	—
Neck rot d*x* (deg)	69 (9)	68 (17)	69 (6)	69 (5)	—
Neck rot sin (deg)	71 (10)	71 (17)	69 (5)	66 (6)*	—
Thoracic flex (deg)	86 (18)	90 (18) *	89 (17)	84 (17)*	***
Trunk flex (deg)	63 (14)	66 (12) *	66 (15)	63 (14)*	***
Arm elev d*x* (deg remaining to 180°)	8 (7)	8 (7)	8 (12)	8 (12)	—
Arm elev sin (deg remaining to 180°)	10 (10)	7 (7)	11 (14)	10 (15)	—

***$p<0.001$, **$p<0.01$, *$p<0.05$.

Table 3
Stretchability of the hamstring muscles and hip flexors in subjects in the MWU and control group before and after a 3 months' period of MWU program. The values are means (SD)

	MWU ($n = 30$)		Controls ($n = 17$)		MWU versus controls (Significant differences)
	Baseline	After	Baseline	After	After
Hamstring muscles, d.x (deg from horizontal plane in supine position.)	54 (6)	66 (7)***	57 (6)	58 (6)	***
Hamstring muscles, sin (deg from horizontal plane in supine position.)	53 (8)	64 (8)***	59 (7)	59 (7)	***
Hip flexors, d.x (deg from horizontal plane in supine position. Minus signs indicate below horizontal plane.)	−10 (10)	−17 (13)**	−8 (10)	−9 (11)	
Hip flexors, sin (deg from horizontal plane in supine position. Minus signs indicate below horizontal plane.)	−10 (10)	−16 (12)**	−11 (11)	−9 (13)	**

*** $p<0.001$, **$p<0.01$, *$p<0.05$.

Table 4
Muscle strength and endurance in the subjects in the MWU and control group before and after a three months' period of a MWU program. The values are means (SD)

	MWU ($n = 30$)		Controls ($n = 17$)		MWU versus controls (Significant differences)
	Baseline	After	Baseline	After	After
Back muscle, isometric endurance (s)	153 (56)	153 (71)	171 (62) Missing = 2	140 (68) ** Missing = 2	**
Abdominal muscles, dynamic endurance (no)	23 (16)	23 (17)	21 (16) Missing = 1	17 (17)	—
Arm muscles, dynamic endurance, d.x (no)	30 (8)	29 (10)	26 (14)	23 (11)	—
Arm muscles, dynamic endurance, sin (no)	27 (9)	27 (11)	23 (10)	23 (11)	—
Leg muscles, dynamic endurance, d.x (no)	38 (13)	39 (13)	35 (15)	35 (15)	—
Leg muscles, dynamic endurance, sin (no)	38 (11)	40 (11) *	33 (13)	36 (15)	—
Arm muscle, isometric endurance (s)	44 (15)	46 (14)	49 (19)	44 (17)	—

** $p<0.01$, * $p<0.05$.

study groups big enough when selecting at random at one building site. When using different building sites for selecting workers one has to deal with confounding factors such as different type of working tasks and different management.

The two examiners were not blinded. This fact may have influenced the results. However, the examiners did not know the results from the first examination when the second was performed. To minimize inter-reliability errors the examiners measured the same workers at the first and the second examination.

Due to sick leave and change of work-tasks, the control group consisted of only 17 subjects, resulting in diminished power. We succeeded in finding controls similar to the intervention group and with working tasks of the same kind.

The CROM and liquid-filled goniometers (Youdas et al., 1992) as well as the CTR method (Norlander et al., 1995), used for measuring neck, back and joint mobility (Ekstrand et al., 1982) have shown good to high intrarater reliability. The reliability of the trunk muscle endurance test has also been reported as good (Hyytiainen et al., 1991).

4.2. Results

The improvement of stretchability of the hamstring muscles was more than 10° in the MWU group. An improvement of that magnitude could be considered an improvement of clinical relevance. Our results concerning increased hamstring stretchability after the MWU are in accordance with Li et al. (1996), who found increased SLR test and increased pelvic tilting during forward bending after a 3 week intervention with a daily hamstring muscle stretching.

The stretchability of hamstring muscles was significantly better in the control group compared to the MWU group before the MWU program. After the program the MWU group had improved and showed a higher value of stretchability than the control group. The control group did not improve between the two measurements. The increase of stretchability could be a result of the MWU. The dose of stretching in the MWU program was about the same as reported as effective by Roberts and Wilson (1999). Our results are in accordance with results found by Wiktorsson-Möller et al. (1983) showing effects on range of motion in the lower extremity of combined warming-up and stretching. Williford et al. (1986), however, did not find support for warming up prior to stretching as to improve joint flexibility.

Small changes of absolute or relative mobility in single items like neck and segmental cervico–thoracic mobility are of uncertain clinical relevance. The significantly increased relative mobility of one cervico–thoracic segment in the control group could be interpret as a normal biological variation of segmental flexion mobility (Norlander et al., 1996).

The isometric back muscle endurance test showed a significant difference between MWU and control group after the MWU program. The difference was due to a decrease of endurance time in the control group. The endurance time did not change in the MWU group. Since all types of performance tests, particularly muscle endurance tests, depend to a large extent on the motivation of the individual, this finding may simply reflect differences in motivation between the two groups. Maybe the control group was not as motivated as the MWU group to perform the utmost. Speaking against this interpretation is the fact that other muscle tests performed by the control group did not demonstrate any significant decreases between the first and second measurements.

The results of dynamic and static muscle endurance tests did not improve after the MWU, except for a small increase of left leg dynamic endurance in the MWU group. However, the MWU group did maintain their muscle strength and endurance capacity. Another type of training with weights and certain amounts of repetitions are needed for improvements of muscular strength and endurance.

The MWU group had a high degree of attendance during the months the project was in progress. It is therefore reasonable to believe that the MWU intervention had some influence on the registered improvements of mobility and stretchability. Lack of improvements in the control group corroborates that certain effects were achieved by regularly performed warming-up activities.

The construction company, where our study was performed, had in 2003 trained around 40 team leaders for MWU. In Stockholm practically all building sites of the company have regular MWU exercise during paid working time.

5. Conclusions

After a period of morning warming-up (MWU) exercises hamstring and thigh muscle stretchability as well as thoracic and lower back flexion mobility increased significantly in the MWU group and differed significantly to the controls. A significant difference in back muscle endurance was found due to decreased endurance in the controls. Muscular strength was not effected. The results indicate that a short dose of MWU exercise could be beneficial for increasing or maintaining joint and muscle flexibility and back muscle endurance for workers exposed to manual material handling and strenous working positions.

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