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Short Communication

Effects of stretching exercises on muscle tension, fatigue, strength, and lactic acid accumulation: A pre-experimental study among fish transport workers

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Abstract

Fish transport workers in Indonesia lift loads more than the specified limits, both in weight and frequency. This could cause lactic acid accumulation, fatigue and reduced physical performance. The aim of this study was to assess the effect of stretching intervention on muscle tension, fatigue, strength, and lactic acid level in fish transport workers in Indonesia. A pre-experimental study design with one group (pre- and post-test) design was conducted among male fish transport workers at the Tawang fish auction, Weleri, Central Java, Indonesia, in June 2022 for two weeks. We created a 1.5-minute stretching exercise video based on the University of New Castle's Manual Handling guideline, involving hand, feet, and shoulder movements. Participants performed these exercises independently before and during work every two hours, guided by the video. Data on lactic acid, muscle tension, fatigue, and strength were collected before and after the 2-week intervention. Data analysis was performed using Wilcoxon and paired Student t-tests to compare the outcome between post- and pre-intervention. A total of 18 fish transport workers were included in the study. The results showed a statistically significant increase in lactic acid levels following the intervention (p=0.016). However, the increase in muscle tension was not statistically significant (p=0.292). There was a significant increase in fatigue levels after the intervention (p=0.000). This could suggest that the stretching intervention may have had an unintended effect of increasing fatigue among the participants. On the other hand, there was a statistically significant decrease in muscle strength after the intervention (p=0.003). In conclusion, this study suggests that while stretching exercises can affect lactic acid accumulation, fatigue, and muscle strength, they do not influence muscle tension. Therefore, it is advised for workers to incorporate stretching exercises into their daily routine to mitigate potential injury risks.

Keywords: Muscle tension, fatigue, muscle strength, stretching, lactic acid

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Introduction

The Social Health Insurance Administration Body of Indonesia reported that the number of work accidents in 2020 reached 221,740 cases and increased to 265,334 cases in 2022 [1]. Occupational lifting is the most common cause of lower back pain, responsible for 80% of cases [1]. A Swedish study revealed that 4.5 million workers experienced a combined loss of 110 workdays due to illness. Of the reported pain, 60% was linked to low back pain, affecting

Received: December 14, 2023 - Accepted: February 26, 2024 - Published online: February 28, 2024

predominantly individuals aged 30 to 59, considered as the productive age group [2]. Another weightlifting occupation is transport workers. In Indonesia, a transport worker at a fish auction place moves fish from the port to the fish auction place manually with their own body. In this respect, the fish auction place serves as a driving force for improving both business and the well-being of fishers by marketing fish catches [2]. Lifting or manual material handling is associated with 27% of all workplace back injuries. Numerous back injuries develop over time due to the repetitive releasing of the discs triggered by improper lifting techniques or additional exertion. These injuries are typically sustained after months or even years of performing the same task. Often, injuries that appear severe are the consequence of long-term effects [3,4].

The workplace is exposed to an ergonomic hazard when workers carry loads beyond the established limits, including considerations of both weight and frequency. The National Institute for Occupational Safety and Health (NIOSH) recommended a maximum limit of 50 pounds for manual lifting tasks [5]. Generally, these workers use their bodies as a means of transportation, such as carrying goods [2]. As a result, these hazards can cause work-related diseases, such as back pain, affecting workers' productivity [6]. In addition, work accidents due to moving goods with excessive weight and continuous high-intensity activities by transport workers will reduce energy reserves and cause lactic acid accumulation in the muscles so that the muscles' ability to contract will decrease and lead to muscle fatigue [7]. This is because the body's capacity to neutralize lactic acid is not proportional to the rate at which it is produced due to the activity intensity. The amount of lactic acid in the blood is comparable to that in the muscles [8,9].

Excessive muscle work can also shorten the muscles, such as the hamstring muscles, among transport workers. The shortening of muscles will impact the emergence of other disorders, including the change in posture that can lead to lower back pain [10]. Stretching exercises constitute one of the preventive measures that can be implemented to overcome tension muscle strength and increase soft tissue elongation [11]. A study has shown that stretching can increase the range of motion, reduce soft tissue injuries, and address muscle imbalances leading to low back pain. In addition, stretching is positioned to offer additional benefits, such as improved posture alignment, which can reduce the long-term effects of poor ergonomic practices [3]. Several laboratory studies have shown that stretching can help lengthen muscle tendons, reduce maximum strength, increase the rate of pressure production, and reduce tension in muscle tendons [3,12,13].

Furthermore, a peer-reviewed study of seven stretching interventions with non-migrant workers, such as computer and factory workers, revealed that stretching effectively avoided work-related musculoskeletal discomfort and pain and musculoskeletal pain or injury [14]. It has been found that short and frequent stretching sessions can provide significant relief from the discomfort associated with repetitive movements. This not only impacts the physical health of workers but also their productivity and overall workplace well-being [15,16]. Therefore, this study aimed to determine the effect of stretching on muscle tension, fatigue, strength, and lactic acid accumulation in fish transport workers at the fish auction place.

Methods

Study design and participants

A pre-experimental (pre- and post-test of a single group) study design was conducted among fish transport workers at Tawang fish auction place, Weleri, Central Java, Indonesia, in June 2022, for two weeks. A purposive sampling method was used. This study included male fish transport workers involving the manual load of fishes by lifting the baskets exceeding the recommended limits (>50 pounds) [5] from the ship to the fish auction place and reported experiences of fatigue and muscle pain.

Intervention

A simple stretching exercise video was developed as an intervention tool with a duration of 1.5 minutes based on the Manual Handling for Stretching Exercises suggested by the University of New Castle, Australia, involving movements of the hand, feet and shoulders [17]. On the first day, the participants were introduced to the videos and received instructions on how to perform the

stretching exercises. For the following two weeks, the participants had to perform the stretching exercises independently before work and between work every two hours for 1.5 minutes as guided by the video (participant's working hours ranged from 4–5 hours/day). Data on the measurement of lactic acid, muscle tension, muscle fatigue, and muscle strength were collected before and one day after the two weeks of the intervention.

Outcomes

This study measured four outcomes: lactic acid, muscle tension, fatigue, strength, and lactic acid accumulation. The concentration of lactic acid accumulation in the blood was measured using a lactate analyzer. Blood was drawn out from the middle finger using a lancing device by a laboratory analyst officer, then applied to the strip of the lactate analyzer. Lactate levels were considered normal if <2 mmol/L and abnormal if >2 mmol/L. For further analysis, the lactate levels were presented in raw value in mmol/L.

A portable surface electromyography (EMG) was used to measure muscle contractions and demonstrate muscle activity [18]. Surface EMG is recognized as an efficient and useful instrument for determining the adequacy of intervention, as it provides reliable and unique information on biomechanical and musculoskeletal dysfunction. The EMG sensor is fixed to the respondent's leg and left in place until the measurement results are recorded. Muscle tension was then classified as relaxed (3 microvolts) and not relaxed (>3 microvolts) [18]. In the present study, muscle tension was presented in raw value in microvolt for analysis.

The reaction timer test was employed to measure fatigue among the participants. Reaction time is the interval between the presentation of a stimulus and the awareness or execution of a corresponding movement or activity. The reaction timer test involves using a stimulus, such as a lamp, to which participants respond, facilitating the calculation of the time it takes for them to react. A prolonged reaction time indicated a slowdown in nerve and muscle function. The measurement results with the reaction timer would then be compared with the fatigue measurement standards [19]. A participant was declared not to experience fatigue (normal) if the reaction time measurement results <200 milliseconds, mild fatigue 240–410 milliseconds, moderate fatigue 410–580 milliseconds, and severe fatigue >580 milliseconds [20]. In the present study, the reaction time was presented in raw value in millisecond for analysis.

Muscle strength was measured with a leg dynamometer. Participants stood upright with a straight back and bent their legs to a 30-degree angle. Holding the lever of the leg dynamometer tool, the chain length was adjusted to match their hand's length. Then participants pulled the lever upward until the needle moved, which indicated their leg strength. The chain strap on the tool was adjusted to a half-squat position with the back straight. Both knees were bent, and the chain was placed between the legs and hands, holding the tool straight down. The tool was then pulled using leg muscle strength without the help of hand and back muscles [21]. Muscle strength was categorized into five groups based on the total muscle strength [22,23]. In the present study, muscle strength was presented in raw value in kg for analysis.

Statistical analysis

The data were analyzed using paired Student t-test or Wilcoxon test to compare the outcome between pre-and post-tests as appropriated. Statistical significance was considered at $p<0.05$. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM SPPS, New York, USA).

Results

Characteristics of participants

A total of 18 fish transport workers were included in this study, as presented in **Table 1**. Half were below 40 years old, and 13 participants had over ten years of experience. The majority of participants had a normal nutritional status; however, one-third of them were overweight.

Table 1. Characteristics of fish transport workers (n=18)

Characteristics	Frequency (%)
Age (years)	
40	9 (50.0%)
≥40	9 (50.0%)
Years of service (years)	
<10	5 (27.8%)
≥10	13 (72.2%)
Nutritional status/body mass index (kg/m²)	
Underweight (17.1–18.4)	0 (0.0%)
Normal (18.5–25.0)	9 (50.0%)
Obese (25.1–27.0)	3 (16.7%)
Overweight (>27.0)	6 (33.3%)

Effects of stretching exercises on muscle tension, fatigue, strength, and lactic acid accumulation

Lactic acid levels before the intervention showed an average value of 2.37 mmol/L, with a range of 1.2–3.8 mmol/L; these values were above the normal. After the intervention, there was a slight increase in mean lactic acid levels to 2.97 mmol/L. However, the range was expanded to 2.2–5.1 mmol/L. The Wilcoxon test showed statistical significance (p=0.016), suggesting that the stretching exercise intervention significantly increased lactic acid levels (**Table 2**).

Muscle tension increased by 0.61, with mean scores of 5.67 to 6.28 before and after the intervention, suggesting that the muscle tension was not relaxed. No significance (p>0.05) was observed in muscle tension. Therefore, the intervention may not have a recognizable effect on muscle tension (**Table 2**).

The mean fatigue score before the intervention was high at 238.54, with a wide range of 159.93–571.67. Following the intervention, a significant improvement was seen in the average fatigue score to 654.83, which indicated that most experienced severe fatigue. A significant increase (p<0.001) in post-intervention fatigue levels was observed. This finding demonstrated that the stretching exercise intervention had undesirable effects on improving fatigue perception among participants (**Table 2**).

The average muscle strength was recorded at 302.78 before the intervention. Two weeks after, along with the stretching exercise intervention, the average muscle strength decreased to 268.89, demonstrating that the muscle strength was less. A significant decrease (p=0.003) in muscle strength after the intervention was reported. This proposes that although stretching might increase lactic acid levels and fatigue, it might negatively impact muscle strength, contrary to common expectations (**Table 2**).

Table 2. Effects of stretching exercises on muscle tension, fatigue, strength, and lactic acid accumulation

Variables	Mean	Increase	Median	SD	Score		p-value
					Min	Max	
Lactic acid (mmol/L)							
Before	2.37	0.6	2.20	0.74	1.2	3.8	0.016[a]
After	2.97		2.90	0.72	2.2	5.1	
Muscle tension (microvolt)							
Before	5.67	0.61	4.00	5.30	3	25	0.292[a]
After	6.28		6.00	4.47	2	20	
Fatigue (millisecond)							
Before	238.54	416.29	219.31	99.34	159.93	571.67	<0.001[a]
After	654.83		652.70	70.20	509.72	784.36	
Muscle strength (kg)							
Before	302.78	33.89	280.00	87.83	150	530	0.003[b]
After	268.89		275.00	84.14	140	470	

[a] Analyzed using the Wilcoxon test
[b] Analyzed using paired Student t-test

Discussion

The musculoskeletal system is one of the body's primary organ systems, consisting of nerves, muscles, tendons, cartilage, ligaments, and connective tissue. About 40% of an individual's body

weight is composed of muscle mass. Muscles are crucial as they contribute to anatomical integrity, support equilibrium and posture, encourage daily physical activities, and aid in carrying out daily responsibilities [24,25]. Due to physical exertion, the body's ability to counterbalance the accumulation of lactic acid is not proportional to the rate at which it is produced. In the case of fatigue after work, workers should take a break so lactic acid from the body can be cleaned or eliminated. Simple activities also help blood circulation, which can accelerate the transfer of lactic acid from the muscles by stretching. Stretching can distribute oxygen throughout the body to prevent the buildup of metabolic waste/lactic acid [26].

Lactic acid is one of the biomarkers for metabolic changes in the case of muscle fatigue (MF). MF is the gradual decline in a muscle's ability to perform a task under a constant burden due to intense and prolonged muscle contractions. MF is typically transient and reversible and manifests as a sensation of fatigue or lack of energy. Common causes of short-term fatigue include overtraining, undertraining, physical injury, and deconditioning [24]. Stretching exercises are often recommended to eliminate this buildup of lactic acid, as they could improve blood circulation and facilitate the removal of lactic acid from muscle tissues [27]. However, the effectiveness of stretching in reducing lactic acid levels is not universally agreed upon. For instance, a study mentioned that lactic acid levels increased after stretching, which contradicts previous findings and suggests that stretching exercises may not be maximally effective in reducing lactic acid levels [28]. In another study, a decline of 1,787 mmol in lactic acid levels was observed post-stretching, indicating the effect of stretching on blood lactic acid concentrations [29]. Thus, it can be concluded that stretching in this study has not been maximal in reducing lactic acid.

Muscles can be stressed when doing work for two minutes. In addition, muscle tension can arise because of posture errors, such as the head bowing forward, the stomach protruding forward, and the shoulders arching forward [30]. However, our study results in muscle tension experienced after the stretching intervention. These results are supported by studies that reported an effect on muscle tension after the intervention was given [30,31]. The intervention with stretching exercises has not reduced muscle tension after work in this study.

Fatigue is the body's defense mechanism that prevents further muscle injury [20,32]. Fatigue is also a temporary inability to respond to a given stimulus due to previous overactivity. In addition, work fatigue can be influenced by physical and environmental factors, and work capacity [33]. Physical factors in the work environment trigger an increase in sympathetic nervous system activation and secretion of catecholamines, stimulating stress levels [33]. The present study, in line with previous studies, results that fatigue was caused by physical environmental factors in the workplace, among others, caused by hot work climate and noise [33,34].

Leg muscles are important muscles that support the work of fish transport workers. Their leg muscles support them when standing, lifting fish catches, and walking to the fish auction place. Incorrect posture and prolonged standing can lead to decreased blood circulation, causing muscle contractions that compress blood vessels and hinder oxygen delivery, resulting in muscle fatigue [29,35]. Based on the muscle strength variable, there was a decrease in the mean score, indicating that stretching exercises did not improve muscle strength. In this case, the job of a transport worker does not have a fixed work time, including the load transported every day, because it depends on how much or how little the catch is. The work portion, therefore, changes every day. There was more lifting and hauling work when measuring post-work since the catch was more than during the pre-test. Hence, measurements at the post-test tended to be high.

A limitation of the study is that the relatively small size restricts the ability to generalize the findings to a larger population. The study used a pre-experimental design with one pretest-posttest group without a control group, making it difficult to determine whether the observed changes were due to stretching exercise interventions or other factors, such as natural variability in lactic acid levels or muscle strength over time. The stretching exercise intervention was performed over two weeks, which may not be sufficient to assess long-term changes or ongoing effects of stretching on the variables measured. Without a control group or blind application in the study, the placebo effect cannot be eliminated. Participants who knew they were receiving an intervention may report improvements because of their expectations or belief in the effectiveness

of the intervention rather than because of the physiological effects of stretching itself. Pretest and posttest measurement times may be affected by confounding variables such as time of day, activity prior to measurement, and state of nutrition or hydration.

Conclusion

The results indicate that stretching has not been maximal in reducing lactic acid levels, fatigue, muscle tension, and increasing muscle strength scores for fish transport workers at the fish auction place. Therefore, other interventions are required. The results of this study present a nuanced view of the impact of stretching interventions on physiological outcomes and performance in physical occupational settings. Although elevated lactic acid levels could be interpreted as indicative of increased metabolic activity post-stretching, a significant increase in fatigue and a concomitant decrease in muscle strength are noteworthy. The absence of significant changes in muscle tension also invites further investigation. These findings emphasize the need for careful consideration of the type and timing of stretching exercises, suggesting that they may have complex effects on the body that do not always align with anticipated benefits. Future research should explore stretching contexts and modalities that optimize the balance between activity readiness and fatigue management.

Ethics approval

In addition, the Research Ethics Committee of the Faculty of Public Health at Diponegoro University has approved the protocol for this investigation (approval number 105/EA/KEPK-FKM/2022). Additionally, written informed consent was obtained from each respondent.

Acknowledgments

The author thanks the Public Health Faculty of Diponegoro University for funding “Penelitian Kolektif dan Individu Dosen Fakultas Kesehatan Masyarakat, Universitas Diponegoro, with decree number 019/UN7.5.9.2/HK/2022.

Competing interests

All the authors declare that there are no conflicts of interest.

Funding

This study received funding from the Faculty of Public Health at Diponegoro University.

Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

How to cite

Kurniawan B, Rahfiludin MZ, Setyaningsih Y, *et al.* Effects of stretching exercises on muscle tension, fatigue, strength, and lactic acid accumulation: A pre-experimental study among fish transport workers. Narra J 2024; 4 (1): e627 - http://doi.org/10.52225/narra.v4i1.627.

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