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USE OF INTEGRATED INSTRUMENTATION FOR THE ASSESSMENT OF THE PHYSICAL CONDITION OF AQUACULTURISTS

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ABSTRACT

In aquaculture, studies about the integrated use of quantitative assessment tools not often reflect the physical condition of workers in their activities. The present study aims to apply integrated instrumentation to assess muscle overload and inadequate postures in seafood plant workers. Infrared thermography, manual dynamometry, and motion capture with inertialsensors were used to perform audiovisual records and on-site observations through an already established data collection protocol. Results indicate that the integration of technologiesduring data collection provides important information about the occurrence of musculoskeletal disorders in aquaculture workers. The lack of studies highlights the need for further research on the quantitative tools of ergonomic assessment. Work in aquaculture could be designed considering workers and technical characteristics, interference factors, activities, time spent at work in order to reduce the risk of musculoskeletal injuries.

KEYWORDS: aquaculture; thermography; muscle strength dynamometer; motion capture.

1. INTRODUCTION

Marine mollusks contribute 22.8% of the world's fishery production from aquaculture, of which 31.8% is represented by oysters and 12.4% by cultured mussels, totaling 13.9 million tons (FAO, 2016). Brazil is the second-largest producer of bivalve mollusks in Latin America, second only to Chile in production volume. However, the volume produced in the country represents only 0.9% of global production (SANTOS and COSTA, 2016). Oyster and mussel farming represent the largest share of Brazilian mariculture production, with the main producing states being São Paulo, Rio de Janeiro, Espírito Santo, and Santa Catarina.

In Brazil, mollusk farming began in the 1990s as an alternative for job creation and income generation for artisanal fishermen and fishing communities (BORGHETTI and SILVA, 2007). Currently, more than 2,000 people are directly and indirectly involved in aquaculture (EPAGRI, 2018). The southern region is responsible for 97.9% of national production, with the state of Santa Catarina being the largest producer. The most recent data, from 2016, demonstrate that mollusk farming is carried out by 604 mariculturists in 12 municipalities along the Santa Catarina coast. Most marine farms are located in the southern and northern bays of Santa Catarina Island: in Florianópolis, the largest national oyster producer, and in Palhoça, the largest mussel producer (or "mariscos" as they are called in the region). Scallops, mainly cultivated in Penha on the northern coast, have a much smaller production (27 tons in 2016) compared to oysters and mussels (2,280 tons and 12,534 tons respectively during the same period) (IBGE, 2018).

However, despite the significant increase in aquaculture production, the activity still lacks improvements in production systems to minimize the risks associated with it (TEIXEIRA et al., 2011). The study of the relationship between humans and work is necessary for a better understanding of the variables present in various work activities (FALZON, 2012). Work in mollusk farming entails inappropriate postures, excessive muscular force, and repetitive movements, often performed under unfavorable environmental conditions (IIDA and BUARQUE, 2016).

Ergonomics, as a discipline, includes the subfield of Occupational Biomechanics, a science that helps understand and attempt to eliminate or at least reduce biomechanical risk factors, which are considered the main causes of musculoskeletal disorders. Among the instruments used to assess physical condition in the field of Biomechanics are dynamometry, motion capture by inertial sensors, and infrared thermography. Thus, for example, it is possible to identify biomechanical alterations during work activities that may affect the normal function of multiple joints (POWERS, 2010). Due to the importance of this activity for the development of the State of Santa Catarina and the involvement of workers in this sector, the objective of this study was to evaluate the physical condition of workers involved in mollusk farming through integrated instrumentation using motion capture by inertial sensors, manual grip strength, and infrared thermography.

2. MATERIALS AND METHODS

The study design was approved by the Research Ethics Committee of Maternidade Carmela Dutra under approval number 2,413,985 dated December 4, 2017, meeting its ethical and scientific requirements. A Free and Informed Consent Form was used to ensure that participants were aware of the study's objectives and procedures before participation.

2.1 Study Location and Sample

This research was conducted at a marine mollusk farming facility located in Ribeirão da Ilha, Florianópolis-SC (-27º48'57.03"S; -48º33'54.23"W). Six mariculturists participated in this study. Research subjects were selected based on the following inclusion criteria: they had been engaged in the activity for a minimum of six months and were over 18 years of age.

2.2 Protocolo experimental Experimental Protocol

A data collection protocol was developed by the research group, encompassing the use of integrated instrumentation, in line with the studies by Speck et al. (2016) and Merino et al. (2018a) and Merino et al. (2018b). This study did not focus on describing the physiological mechanisms involved in the activities performed. Initially, filming cameras were positioned to record the activities carried out. Following this procedure, the process of integrated instrumentation began, utilizing dynamometry equipment, infrared thermography, and motion capture using inertial sensors (X-sens). The methodological procedures for each instrument used will be described below.

2.3 Dynamometry

For muscle strength assessment, the portable digital dynamometer model DM-90 from Instrutherm was used (measurement capacity of 1 to 90 kg; resolution 0.05 kg; accuracy ±0.5%). The device was within the calibration conditions specified by the manufacturer, which recommends annual calibration. To ensure maintenance of the position of the hips and knees at 90°, with feet supported on the ground, a backless bench was used. A data collection form specifically designed for recording the collected data was utilized.

During the examination, research participants were instructed to sit on the bench in a manner that kept their hips and knees at 90°, with their feet flat on the ground. Regarding the positioning of the upper limb, the shoulder remained adducted close to the trunk, the elbow at 90° with the forearm in a neutral position (between pronation and supination), and the wrist in a neutral position without deviation, as recommended by the American Society of Hand Therapists (FIGUEIREDO et al., 2007).

Participants were instructed to perform the gripping movement for each attempt after verbal command from the examiner, which consisted of pronouncing the following phrase: "one, two, three, go". Four measurements were taken for each limb, with the first used for adaptation and equipment familiarization, and therefore discarded. The arithmetic mean was calculated from the remaining measurements. The interval between attempts was one minute to prevent muscle fatigue during the test. Force was applied for 5 seconds for each measurement. The information collected during each attempt was recorded on the data collection form in kilograms-force, according to the specifications displayed on the dynamometer's dial. Dynamometry was performed before and after the morning activity, considering that some participants engage in another paid activity in the afternoon.

2.4 Infrared Thermography (TI)

For thermal imaging capture, workers remained in place for 15 minutes to allow for thermal equilibrium before the image acquisition process began. The following materials were used: an infrared thermography camera (FLIR Systems Inc. model E40); a computer (with specific software for image acquisition and processing of thermographic images, Therma Cam TM Researcher Pro 2.9); and a digital thermohygrometer (Akrom® model KR825) to monitor the temperature and humidity of the environment.

The infrared thermography camera used has an integrated real resolution of 320 x 240 pixels, with sensors that allow for temperature measurements ranging from -20°C to +650°C. This camera has sensitivity to detect temperature differences smaller than 0.08ºC and an accuracy of ± 0.5ºC of absolute temperature, according to the manufacturer's specifications.

The camera was positioned horizontally at a distance of 1m and vertically adjusted to the midline of the lumbar region to be evaluated. An emissivity of 0.98 was considered for the human body. Records were taken before and after the activities of removing oyster lanterns. In addition to the lumbar region, the wrists and hands of these workers were also recorded by infrared thermography at a distance of 0.5m, under a dark E.V.A. sheet.

A thermal sensitivity of 0.1°C per color tone was used, using the rainbow color scale, where colors vary from hottest to coldest: white, pink, red, orange, yellow, light green, dark green, light blue, dark blue, purple, and black, according to specific FLIR Tools software. The colors indirectly indicate the degree of distribution of local cutaneous blood perfusion (BRIOSCHI et al., 2002). The analysis of the results was comparative - before and after the activities - analyzing changes in intensity, size, shape, distribution, and margin, as well as the thermal difference between points and the presence of thermal asymmetry according to the criteria of Brioschi et al. (2002).

2.5 Motion Capture by Inertial Sensors

Motion capture by inertial sensors was employed to analyze the frequency and range of movements and real-time task execution management during the removal of oyster lanterns. The device consisted of 17 inertial sensors fixed to different parts of the body (Xsens MVN BiomechTM), tracking segments, orientation, position, movements, and center of mass. The system operated in real-time, capturing data at a frequency of 120 Hz. The data were transmitted wirelessly to a computer with software allowing for observation, recording, and analysis of movements through graphs of joint angles and movement duration (ROETENBERG, LUINGE, & SLYCKE, 2013). Each sensor contained three orthogonal linear accelerometers and three orthogonal gyroscopes (SHIPPEN & MAY, 2016). This system is reliable and easy to use for data collection inside or outside a laboratory (ZHANG et al., 2013).

The capture sensors were installed on the workers and calibrated according to the manufacturer's instructions (Xsens MVN Biomech TM). Subsequently, the workers performed the task of removing lanterns for a period of 15 minutes. The data obtained were then analyzed using Xsens MVN Studio Pro software and exported to Microsoft Office Excel 2010 for data tabulation and obtaining averages and standard deviations of joint range of motion and task execution time to identify the risks of musculoskeletal injuries tasks.

3. RESULTS AND DISCUSSION

The sample consisted exclusively of male workers, with an average age of 33 ± 5.2 years. Although there are women working in mariculture, the predominance of males is supported by the characteristic of the analyzed activity, which requires greater strength. It can be observed that women are responsible for the processing stages of production due to lower physical wear, although these tasks can also cause health problems, as they involve highly repetitive movement activities.

At various stages of the mollusk farming production process, intense physical effort occurs throughout the workday, mainly concerning the upper limbs, shoulder region, neck, spine, wrists, and hands (GUERTLER et al., 2016). Thus, the work performed can cause a series of complications already diagnosed in fishermen, such as lower back pain, disc herniation, degenerative conditions of the vertebral discs, among others (ROSA and MATTOS, 2010).

The handgrip strength was 29.91kgf ± 6.58 for the right hand (dominant hand) and 28.67kgf ± 5.79 in the left hand. Handgrip strength is one of the essential parameters used to indicate a person's nutritional status (KAUR, 2009) and physical performance and muscle function (SAMSON et al., 2000). The dominant hand showed higher values of handgrip strength than the non-dominant hand, corroborating with Luna-Heredia et al. (2005). Godoy et al. (2004) in a review article affirm that the right hand is significantly stronger (on average 10%) than the left in right-handed individuals. Handgrip strength values reach maximum levels in adulthood, around 25 to 35 years old (ESTEVES et al., 2005).

The total average of thermographic changes found in the shoulders, back, and lumbar region was 1.8°C ± 1.0 (ranging from 0.41°C to 3.56°C). Regarding the wrists and hands, an average of 0.7°C ± 1.0 was found. Infrared thermography analysis showed consistency between workers' complaints of pain and discomfort and the results of infrared thermography. Fernandes et al. (2012) state that temperature tends to vary depending on the initial implementation of the activity, and its magnitude depends on the duration and intensity of the proposed activity. According to Brioschi et al. (2005), thermography is safe, non-invasive, and does not involve ionizing radiation; it is useful in documenting peripheral nerve injuries and soft tissues, such as muscle strains and ligaments, inflammation, muscle spasms, and myositis. The same author concludes that the use of infrared imaging is of great value for the study of pain.

The average range of motion during oyster collection was 23.51° ± 8.95 (ranging from 0.00° to 45.78°) for the cervical spine. According to Mayer, Gatchel, and Polatin (2000), there is epidemiological evidence of increased risk for disc herniation due to cervical extension, which can cause overload and musculoskeletal disorders in this region, as it is associated with changes in postural configuration and excessive force use. Cervical flexion above 20° increases the risk of pain and disorders in this region due to increased compressive load on the musculoskeletal structures of the cervical spine (MCNEE, KIESER, and ANTOUN, 2013; NING et al., 2015).

During the task of removing oyster lanterns, inadequate postures were identified, which can lead to musculoskeletal disorders in the lumbar spine since the average angle of hip flexion of the right hip was 63.17° ± 26.87 (ranging from 1.00° to 109.53°) and that of the left hip was 64.93° ± 25.51 (ranging from 0.98° to 108.32°). Additionally, according to sector information, the final lanterns at the end of cultivation weigh on average 50kg and are manually transported onto the boat. Manual transport of heavy objects has been associated with the incidence of musculoskeletal injury in the lumbar spine (COENEN et al., 2014; PRAIRIE et al., 2016).

Regarding the shoulders, mean ranges of motion of 65.33° ± 61.37 (ranging from 0.00° to 180.00°) of adduction and 60.81° ± 55.27 of abduction (ranging from 0.97 to 180.00°) were found. Some studies have associated shoulders in flexion and/or abduction greater than 30° with the risk of musculoskeletal disorders. This is due to the reduction in blood flow and the impact of shoulder musculature on osteoligamentary structures during flexion/abduction above 60° (POPE et al., 2001; STENLUND, LINDBECK, and KARLSSON, 2002; LECLERC et al., 2004).

Wrist postures with the greatest range of motion during the task of removing oyster lanterns were: radial deviation in the right wrist (10.00° ± 11.34; ranging from 0.00° to 61.37°) and extension of the right and left wrists (19.60° ± 18.56; from 0.00° to 87.64° and 18.61° ± 13.58, ranging from 0.00° to 68.46°, respectively). Several studies have associated wrist posture with musculoskeletal disorders, as radial deviation leads to a 20% reduction in grip strength (MCGORRY, 2001) while wrist extension increases pressure.

One factor that may exacerbate the biomechanical risks observed in the task of removing lanterns from the sea is the movement of the boat due to wind and waves, which makes the foot support surface unstable. McGuinness et al. (2013) highlight the danger of working at sea, where tasks must be performed in a slippery, unstable, and moving environment, increasing the risk of accidents. The movement of the boat hinders material handling and maintaining proper posture, increasing the likelihood of musculoskeletal injuries to the upper and lower limbs (FULMER and BUCHHOLZ, 2002). This is because, on unstable surfaces, muscles of all limbs are contracted to maintain balance (SHUMWAY-COOK and WOOLLACOTT, 2000), increasing the likelihood of muscle fatigue, consistent with the study by Teixeira et al. (2011).

4. CONCLUSION

Currently, with all the technological advancements, it's becoming increasingly possible to quantify human performance. Any assessment of sports technique, performance, functional capacity, among others, should be preceded by measurement, description, and analysis. Based on the data obtained from the instruments' collection, the relevance of their use in understanding the muscular state of workers involved in mollusk farming can be confirmed.

The physical effort exerted by workers in their daily routine on a mollusk farming site can cause musculoskeletal disorders, as it involves inadequate postures and excessive static and dynamic loads. Organizational changes such as the use of personal and collective protective equipment, reduction of manual labor, courses, and training, are some options that can promote health and safety in aquaculture. These results can support future research in the prevention and control of musculoskeletal injuries and be used as a basis for designing safer and more ergonomic machinery and equipment, thus improving work procedures.

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