THE EFFECTS OF LOADS AND LIFTING TECHNIQUES ON MOVEMNET KINEMATICS IN MANUAL LIFTING

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In this study, subjects lifted a box from the floor manually and their movements were recorded by video camera. The recorded images were then digitized and analyzed by the motion analysis system. The independent variables consisted of five loads (0, 8, 16, 20, and 24 kg) and four lifting techniques (2 squat and 2 straddled leg lifting techniques). Their effects on trunk inclination angles and knee joint angles were studied. The profiles of the kinematics parameters showed there was a difference between the two squat lifting techniques and the two straddled leg lifting techniques. The results of this study also suggested that the safe weight for manual lifting from the floor using any one of the four techniques studied was 8 kilograms.

KEY WORDS: manual lifting, lifting techniques, joint angles

INTRODUCTION: Manual material handling (MMH) is one of research rears in ergonomics. Literature showed that there is a correlation between back injuries and lifting activities (Kelsey, Githens and White, 1984). The improper practice in MMH is the major cause of occupational injury. The high costs of workers compensation for injury and disability also led to increasing public concerns about the workplace safety (Shelerud, 1998).

In Hong Kong, the occupational safety and health regulations on MMH were established in 1997. International guidelines e.g. International Labour Organisation Convention No. 127 and Recommendation No. 128 have been directly adopted as the result of lack of local studies. Unfortunately, the guidelines cannot be adopted in their entirety because there are differences in physical capabilities between members of the Chinese and Caucasian races (Wu, 1997; Lee, Wu, and Hsu, 1995; Wu & Hsu, 1993; Evans, 1990).

Barker and Atha (1994) proposed that the lifting technique was the fundamental determinant factor to reduce biomechanical stress. Anannontsak and Puapan (1996) also observed that a good working posture could reduce the prevalence of low back pain. Consequently, examination of the lifting technique was an important component in risk assessment and was emphasized by the occupational health and safety professionals in the training sessions on MMH. Although the dynamics and kinematics parameters and the muscle activity of the movement of the lifting activities were studied, the trainers did not have the adequate information necessary to determine the correct universal lifting technique.

Use of straight back and bent knee lifting technique (squat technique) was recommended though the efficiency and contribution of the leg muscle activities had been less studied. It was of interest to evaluate the effect of squat technique or its three derivatives on movement kinematics in order to avoid the acute and chronic low back injuries. This study will help the occupational health practitioner or the occupational therapist to organize his or her training program on MMH locally.

METHOD: 10 male undergraduates of the Chinese University of Hong Kong were recruited for this study. The subjects were in good physical condition with no apparent acute or chronic back pain. Their height, weight, and shoulder width were recorded.

A work platform that consisted of eight modules of wooden platforms and the AMTI (Advanced Mechanical Technology, Inc., Newton, MA) force platform was built to provide the floor area for the experiment. Signals of the force transducers of the force platform were collected at the rate of 500 Hz by the software (PC-Vect software package, BTS).

Video camera (JVC, GY-X2BE, Japan) for two-dimensional video filming technique was placed at the distance of 5 meters laterally to the subject. The whole process of the lift was filmed at the rate of 50 Hz and 1/250 shuttle speed by the camera. The digitization and the data analysis of the video image were performed by the motion analysis system (Bewegungs Analyse System, Germany).

Four lifting techniques were studied. In the symmetrical squat technique, the feet of subject were on the frontal plane and were separated by distance of the shoulder width. In the asymmetrical squat technique, the right foot of the subject was behind the frontal plane and the left foot was on the frontal plane. The lower position of the right knee should not touch the ground. The straddled leg with knee ground support technique was similar to the asymmetrical squat technique with the exception that the right knee was on the mid-sagittal plane of the box and supported the body. With the addition of box tilting to the straddle with knee ground support posture, the fourth lifting technique was derived. The subject had to rotate the box forwards to the lower anterior edge of the box. In this way, the box rested on the subject's right thigh.

The loads (0, 8, 18, 20, 24 kg) were put into a carton of 50cm wide x 50cm length x 55cm high. Each subject performed 20 randomized lifts, as there were combinations of four lifting techniques and five loads. Initially, the subject was asked to choose a number that represented an unknown sequence of box weight to the subject. This sequence number was then discarded and could not be repeated in the next experiment. Subject then selected a letter of the alphabet that determined the sequence of the lifting technique. The box weight and the lifting technique were given to the subject for each lift. The subject then approached the box that had been placed on the force platform and the lifting posture was prepared. The video recording was commenced before a red LED light was illuminated by the researcher to start the trial. When the subject stood upright for 1 second, the lifting was finished and the video recording was stopped. The subject was asked to unload the box onto the platform. He was given a two-minute rest prior to the next lift.

Thus, the independent variables were weights of load and lifting techniques. The dependent variables were the knee joint and the lower trunk inclination angles. Profiles of these angles were then analyzed.

RESULTS AND DISCUSSION: The lifting phase was defined from the zero force platform signal to the maximum vertical displacement of the center of gravity of the box. The finishing times that included preparation phase for trials were varied as lifting speed was not controlled. Thus, the normalized lifting time (NLT) was expressed in terms of the percentage of the total finishing time taken.

The motion analysis system calculated the trunk inclination angle that was the angle between the axis of the frontal plane of the trunk and the horizontal plane. Profiles of the inclination trunk angles were shown in the Figure 1. When the box weight of 24 kg was lifted by the symmetrical and asymmetrical squat techniques, angles decreased by 20° angle. However, a decrease of 5° to 10° angles was found in lifting 0 kg by the same techniques. The minimum angles occurred at about 40% NLT although the values varied. Beyond the 40% NLT, increases in the angles were observed. These different profiles could be explained by the effect of the box weight and the specific back lift that was employed (Boston, Rudy, Lieber, and Stacey, 1995).

Continuous increases in the trunk inclination angles were found in the straddled leg techniques without box tilting when 0 kg and 8 kg were handled. However, increases in angles were observed beyond 20% NLT when 16 kg was lifted. Similarly, when 20 kg and 24 kg were lifted, the trunk inclination angles increased beyond 40% NLT.

With technique of box tilting, the trunk inclination angles continuously increased in all cases. Contribution of back lift, that was considered being the harmful technique, was little. Thus, it would be the advantage of the combined technique.

As the back lift was not recommended in any circumstance, lifting technique and loads that led to decreases in the trunk inclination angle should be avoided. In addition, the profiles of the trunk inclination angles in the straddled leg techniques have suggested the safe limit of 8 kg in lifting from the floor.

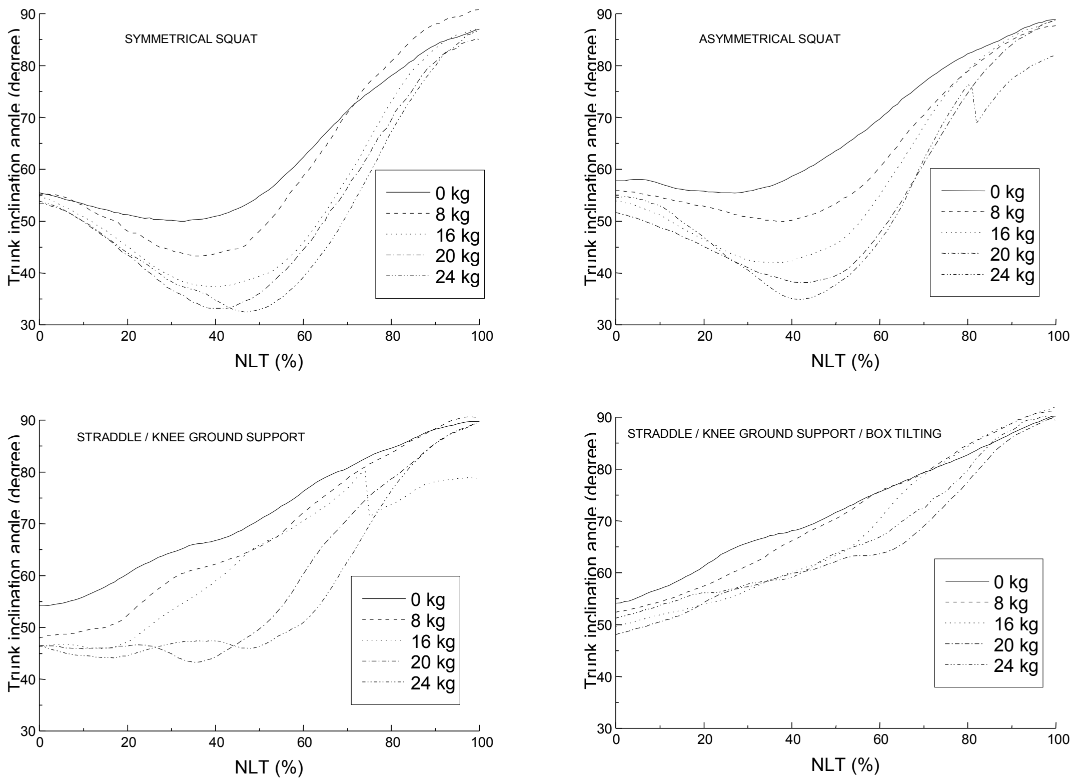

Figure 1 - Profiles of trunk inclination angle against NLT.

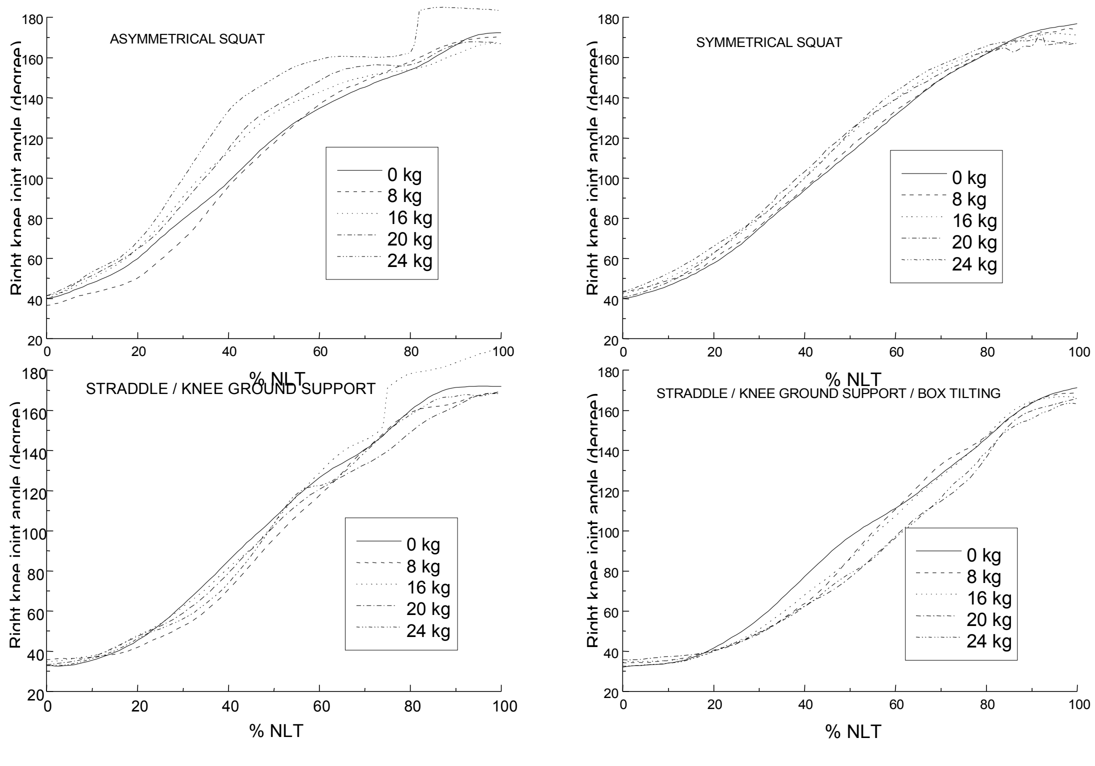

Figure 2 - Profiles of right knee joint angle against NLT.

The knee joint angle was important in order to initiate momentum for commencement of the leg lifting technique (Burgess-Limerick et. al., 1995). The weights of the box have two different effects on the two groups of the lifting techniques (Figure 2). When compared to the lifting of the zero box weight with the same technique, curves shifted upwards in the squat techniques while curves shifted downwards in the straddled leg techniques. But the curve for the lifting of 8 kilograms using the asymmetrical squat technique shifted downwards. The upwards shifting of the curves in the knee joint angles in the two squat techniques implied that there was a shifting towards the back left when the heavier load was handled. In the first half of the lifting activity, the trunk inclination angle was reduced because the knee joint angle increased without adequate coordination of the hip joint. On the other hand, the downward shifting of the curves in the two straddled leg lifting techniques were affected by the increasing loads. The increasing trunk inclination angle transfers the load to the two legs that would result in reduction of the biomechanical stress to the back.

CONCLUSION: From the data collected on trunk inclination angle and knee joint angle, there was no evidence to suggest the preference to the lifting techniques. However, based on these results, for optimal safety it is not recommended to lift the weight of more than 8 kilograms from the floor.

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