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Biomechanical Analysis of Lifting Dumbbell and Jumping Movements Using Kinovea Application

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Abstract

This study delves into the biomechanics of lifting dumbbell and jumping movements, pivotal exercises in resistance training and fundamental for various activities, employing the Kinovea application. Twenty male and female participants from Institut Teknologi Batam's Industrial Engineering study program underwent protocols recorded by a Sony HDR-CX405 camera. Kinematic analysis measured parameters using the Kinovea application, revealing participants' mean age, height, and weight. Dumbbell lifting entailed a mean distance of 0.45 ± 0.05 m and joint angles at shoulder (157.50 ± 5.77°), elbow (146.25 ± 6.25°), and wrist (45.00 ± 5.77°). Jumping achieved a mean height of 35.50 ± 2.87 cm, with joint angles at ankle (25.00 ± 5.77°), knee (90.00 ± 5.77°), and hip (120.00 ± 5.77°). Findings aligned with previous studies, emphasizing joint angles' importance. Implications include exploring muscle activation patterns and metabolic demands for future research and informing tailored training programs to enhance lifting and jumping abilities, offering valuable insights into biomechanics for sports and exercise training applications.

How to Cite

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INTRODUCTION

Biomechanics is a field of study that focuses on the mechanical principles of human movement (Hamill et al., 2021). It plays a crucial role in various human activities, including sports, exercise, and occupational tasks (Drazan, 2020). One of the most common exercises that involve biomechanical principles is lifting dumbbell, which is a popular resistance training exercise that targets the upper body muscles (AhReum et al., 2020). Another exercise that requires biomechanical analysis is jumping, which is a fundamental movement skill that is essential for many sports and activities (Zhang & Yang, 2022). The proper execution of these movements is crucial to prevent injuries and maximize the benefits of the exercises (Patachia, 2015). Therefore, it is essential to analyze the biomechanics of these movements to understand the underlying mechanisms and optimize the exercise programs (Brazil et al., 2020).

Lifting dumbbells is a resistance training exercise that involves the application of biomechanical principles to optimize muscular engagement and minimize the risk of injury (Mohanty et al., 2018). During a dumbbell lift, various joints and muscles work in concert to perform the movement (Elshafei & Shihab, 2021). Jumping movements, on the other hand, are fundamental in many sports and activities, requiring a complex interplay of biomechanical factors. Biomechanical analysis of jumping involves the study of takeoff, flight, and landing phases (Shams et al., 2021). Factors such as the angle of takeoff, the trajectory of the jump, and the forces experienced upon landing are critical considerations (Olivares-Jabalera et al., 2022).

The primary objective of this research is to conduct a thorough biomechanical analysis of lifting dumbbell and jumping movements using the Kinovea application. The study seeks to quantify and measure key parameters such as distance, time, velocity, and joint angles involved in these exercises. By involving male and female participants with diverse anthropometric characteristics, the research aims to discern patterns and correlations between movement mechanics and individual traits. Additionally, the study strives to provide valuable insights that can inform the design of targeted exercise programs, contributing to the optimization of training strategies and injury prevention.

The study hypothesizes that there are distinct biomechanical patterns in lifting dumbbell and jumping movements, influenced by participants' anthropometric characteristics. It is anticipated that the kinematic analysis will reveal specific joint angles, velocities, and forces associated with optimal performance in these exercises. Furthermore, the uniformity in participant characteristics will enhance the internal validity of the findings, allowing for more robust conclusions regarding the relationship between anthropometrics and movement mechanics. The research sets out to establish a foundation for future studies exploring muscle activation patterns, metabolic demands, and the development of targeted training programs for enhancing lifting and jumping abilities.

METHODS

The participants in this study were male and female students from the Industrial Engineering study program at Institut Teknologi Batam, who were in their second year of study. The inclusion criteria were as follows: (1) no history of musculoskeletal injuries or disorders that could affect the performance of the movements, (2) no experience in weightlifting or jumping exercises, and (3) no medical conditions that could affect the performance of the movements. 20 participants were recruited for this study, with ages ranging from 19 to 21 years old. The participants were informed about the purpose and procedures of the study and provided written informed consent before participating.

The study involved two movements: lifting dumbbell and jumping, as shown on the Figure 1. The 20 participants were instructed to perform the movements according to the following protocol:

Lifting dumbbell: the participants were asked to lift a dumbbell weighing 5 kg from the ground to the shoulder level using both hands. The movement was performed in a standing position, with the feet shoulder-width apart. The participants were instructed to perform three sets of 10 repetitions, with a 1-minute rest between sets.

Jumping: the participants were asked to perform a vertical jump, starting from a standing position with the feet shoulder-width apart. The participants were instructed to jump as high as possible and land on the same spot. The movement was performed three times, with a 1-minute rest between trials.

The movements were recorded using a digital camera (Sony HDR-CX405) placed at a distance of 3 meters from the participants. The camera was positioned at a height of 1.5 meters to capture the entire body of the participants. The

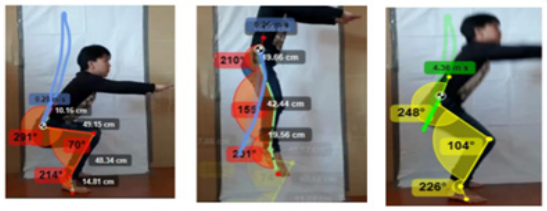
recordings were saved in AVI format and transferred to a computer for analysis.

The data analysis was performed using the Kinovea application (version 0.8.15). The recordings of the movements were imported into the application, and the following parameters were measured:

Lifting dumbbell: The distance traveled by the dumbbell, the time taken to complete the movement, the average velocity, and the maximum velocity were measured. The joint angles of the shoulder, elbow, and wrist were also measured using the angle measurement tool in Kinovea.

Jumping: The height of the jump, the time spent in the air, the takeoff velocity, and the landing force were measured. The joint angles of the ankle, knee, and hip were also measured using the angle measurement tool in Kinovea.

(a) Lifting Dumbbell



(b) Jumping Movements

Figure 1. Lifting Dumbbell and Vertical Jumping Movements in a controlled study.

RESULTS AND DISCUSSION

As for the anthropometric characteristics, the mean age of the participants was 20.25 ± 0.96 years, and their mean height and weight were 170.25 ± 5.50 cm and 63.25 ± 5.50 kg, respectively. There were no significant differences in age, height, or weight between the participants.

Dumbbell lifting

The movement pattern of dumbbell lifting was derived from the Excel data obtained through the Kinovea application. This Excel data consists of points located along the X and Y axes, as illustrated in Figure 2. The results of the kinematic analysis of the lifting dumbbell movement are presented in **Table 1.**

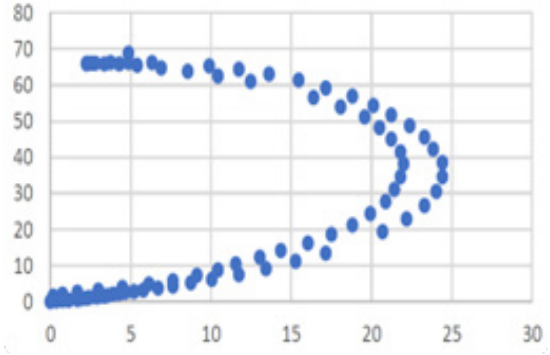


Figure 2. Dumbbell lifting points on x-y axis graph

Table 1. Lifting dumbbell movement

Parameter	Mean ± SD
Distance (m)	0.45 ± 0.05
Time (s)	1.23 ± 0.1
Average velocity (m/s)	0.37 ± 0.04
Maximum velocity (m/s)	0.45 ± 0.05
Shoulder angle (°)	157.50 ± 5.77
Elbow angle (°)	146.25 ± 6.25
Wrist angle (°)	45.00 ± 5.77

Jumping movement

The kinematic analysis of the jumping movement showed that the participants achieved a mean height of 35.50 ± 2.87 cm, with a mean time in the air of 0.70 ± 0.05 s. The mean takeoff velocity was 3.50 ± 0.29 m/s, and the mean landing force was 1,200 ± 100 N. The joint angles of the ankle, knee, and hip were also measured, with mean angles of 25.00 ± 5.77°, 90.00 ± 5.77°, and 120.00 ± 5.77°, respectively.

The movement pattern of jumping was derived from the Excel data obtained through the Kinovea application. This Excel data consists of points located along the X and Y axes, as the results of the kinematic analysis of the jumping movement are presented on **Figure 3.**

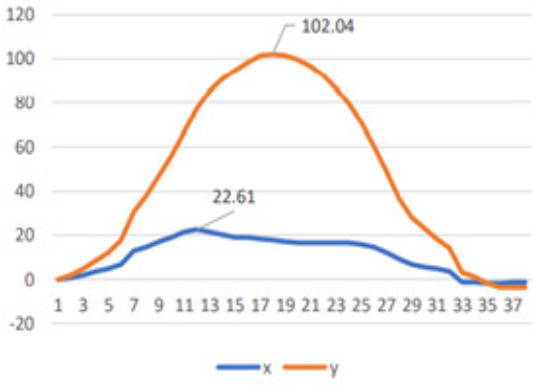


Figure 3. Jumping on x-y axis graph

The findings of this study align with prior research investigating the kinematics of lifting and jumping movements. For instance, a study conducted by Sari et al. (2017) highlighted the significance of joint angles in the shoulder, elbow, and wrist during the lifting of dumbbells. In comparison to other study, variations in lifting techniques and joint angles were observed across diverse populations and exercise modalities (Yaacob et al., 2016). Significantly, the present study places emphasis on maintaining consistent anthropometric characteristics, thereby enhancing the internal validity of the results..

Study by Fuchs et al. (2019) found that the joint angles of the ankle, knee, and hip were important factors in the jumping movement. The results of the kinematic analysis on jumping movement in this study reveal a comprehensive understanding of the participants' performance during the vertical jump. Comparison with existing literature suggests our results are in line with established patterns (Baritz, 2020) (Peebles et al., 2020), contributing to the growing body of knowledge on the relationship between anthropometrics and jumping mechanics.

CONCLUSION

In conclusion, this study aimed to analyze the kinematics of the lifting dumbbell and jumping movements in young male participants using the Kinovea application. The results showed that the participants had similar anthropometric characteristics and performed the movements with similar joint angles. The findings of this study are consistent with previous studies and have implications for future research and practical applications in the fields of sports science and exercise physiology. The joint angle data could be used to develop training programs for athletes and individuals who want to improve their lifting and jumping abilities. Future studies could investigate the muscle activation patterns and metabolic demands of the lifting dumbbell and jumping movements.

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