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INJURY RISK ASSESSMENT OF MICROTOME MANIPULATION USING KINEMATIC ANALYSIS

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Summary. To study human tissue for the diagnosis of diseases or to evaluate the effectiveness of a treatment, a very thin sample of tissue must be obtained using a microtome. The movement associated to the manipulation of most microtomes is cyclical, and leads to a continuous repetition of the movement during the workday. This repeated motion, associated with inadequate postures, increases the risk of musculoskeletal injuries. Te use of kinematics is proposed to assess this risk, by obtaining the acceleration and velocity profiles of the movement. This characterization of the movement is very important to define the different phases and positions, gaining information on critical points of the movement that might be related to the potential of injury. In this work, the movement performed by a laboratory technician using a microtome was captured during a regular workday session. The kinematics of the movement was obtained and its characterization was attained. High accelerations in the elbow and wrist, associated with the high frequency of the motion, suggest a potential of injury at these locations. Moreover, the inclination of the neck is inside the range of risk of injury.

1 INTRODUCTION

Microtomy is a technique used in histology studies of human tissue for diagnostic and therapeutic purposes that allows a morphological study of tissues and organs, which may include a biopsy (taking the tissue sample) or an evaluation of the material obtained during surgery. It is an important method to detect cancer, as well as to determine the effectiveness of treatments [1]. The microtome is used for cutting paraffin blocks containing fragments of organs, with a thickness varying from 5 to 15 μm [2]. These very thin samples become optically transparent under the microscope, making it possible to study the sample.

There are several types of microtomes on the market, from manually operated microtomes, electronic microtomes or even ultra-thin computer microtomes, capable of slicing thinner samples (in the order of 10 nm) [2]. The operation of manual microtomes mostly requires a cyclic motion as the movement performed by the laboratory technician is either a rotary or an alternating movement of the arm. In most microtomes, the slicing of the block is performed by bringing the holder with the block with the material to the steel knife (which is fixed). This action may be performed either vertically or horizontally and the thickness of the sample is selected before the operation. To perform the slicing of the block, the laboratory technician must move the drive arm or wheel, in a repetitive motion, until the necessary sample is obtained.

This continuous repetitive motion due to the frequent use of a microtome, associated with postures, may cause musculoskeletal injuries, in the long term [3]. The study of work-related injuries is generally done by inquiries [4, 5]. New works tried to incorporate visual observations [3] or surface electromyography in the research of ergonomic related injuries [6].

Musculoskeletal disorders (MSDs) are considered by the National Institute for Occupational Safety and Health (NIOSH) to be the second most common cause of work-related illness and complications, based on their importance and in terms of prevalence and severity. Biomechanical risk factors that cause or aggravate MSDs include repetitive movements, poor postures, frequent carrying of heavy loads, excessive use of force, among others [7]. Musculoskeletal disorders in the occupational context constitute a very considerable part of all reported musculoskeletal disorders, with their most common cause being repetitive muscle activity and repeated mechanical pressure [8]. The main risk factors for MSDs are excessive physical activity or poor physical condition and repetitive movements, and in all cases the duration of contact with the harmful activity and the magnitude of the factors mentioned are considerably significant.

Histotechnologist carry a higher risk of developing MSDs' symptoms due to the fact that they are constantly in contact with the risk factors mentioned such as prolonged work in a static position and repetitive movements. The prevalence of MSDs' symptoms in at least one body segment in laboratory technicians was reported to be between 72.5% and 92.3%. Previous studies reveal that the most common complaints were neck pain, followed by shoulder and elbow pain [7]. Among laboratory technicians, those who work directly with microtomy have been studied to a certain extent, where it was possible to conclude that 80% had problems such as headaches, neck pain, and visual tension, and 75% had back pain or shoulder stiffness. A high incidence of repetitive strain injuries or carpal tunnel syndrome was reported in a national survey of histologists. Also, in a sample of 100 histologists, 71.7% of women complained of symptoms of MSDs, while in the case of men the percentage was 50%. In women, about 57% had up to 4 symptoms (compared to 37.5% for men) and 15% had 5 or more symptoms (compared to 12.5% for men). Thus, it is understood that there is a direct relationship between the routine functions of the work performed by histologists and MSDs [9]. Regarding neck pain, it is associated to bad postures of the head. An indication of the posture of the head is the forward head angle, defined as the angle between C7 and the ear relative to horizontal in the sagittal plane [10]. Angle values below 50°) are considered to increase the occurrence of forward head posture [11], with angles below 30°) considered as severe and indicating very high probability of injury [12].

The use of video allows for an analysis of the posture of the subject that may latter compared with the RULA ergonomic assessment to evaluate the potential for injuries [13]. The characterization of movement using kinematics is most useful to understand the motion and its important phases or positions. It is used in different areas to support decision making and injury potential [14–16].

The fundamental objective of this work is to identify potential correlations to injury risk of the motion performed when using a microtome. To complete the objective, the kinematics of the movement associated with the manipulation of a hybrid microtome is obtained in a laboratory setting. The identification of key moments of the motion, such as high horizontal velocities and accelerations obtained at the elbow and wrist, is important to assess possible injury risks associated with the manipulation of this type of equipment by using the available published information.

2 METHODS

In order to attain the objective of this work, it is necessary to outline the methodology used as well as the analysis performed to characterize the movement in study.

2.1 Motion capture

To be able to identify possible characteristics of the movement necessary to manipulate a microtome, a Logitech C922 Pro Stream camera was used to capture the movement of the arm of a laboratory technician at a frame rate of 60fps. The camera captured the movement in the sagital plane as this was considered to be the principal plane of the movement.

A laboratory technician performed the usual routine using a sliding microtome from Microm, model HM200 ERGOSTAR. The total time recorded was 20 minutes and several paraffin blocks were used to obtain samples. Markers were used in the anatomical points relevant to the study: shoulder, elbow, and wrist bones (Radius and Ulna ends). The laboratory technician participated in this study voluntarily, and signed a written informed consent before the study. An image from the video captured is presented in Figure 1.

2.2 Kinematic analysis

To perform the kinematic analysis, the Kinovea tool [17] to track the movement of the arm manipulating the microtome, and perform the kinematic analysis for each paraffin block. This tool uses the second-order Butterworth filter in two passes (one forward, one backward), tested at various cutoff frequencies between 0.5Hz and the Nyquist frequency. The velocity and acceleration profiles of the movement were obtained. The position of the head was also studied along the manipulation of the microtome by tracking the angle between C7 vertebrae and the ear relative to horizontal.

Figure 1: Image of the video captured during the manipulation of the microtome.

3 RESULTS AND DISCUSSION

After capturing the movement of the arm of the laboratory technician manipulating the microtome, twelve trials were digitized using the Kinovea tool [17]. Each trial corresponds to preparing a sample from a paraffin block. The average trial duration is 11.7s and the average number of frames per trial is 700 frames. Four anatomical points were digitized per frame: shoulder, elbow, and wrist bones (Radius and Ulna ends).

3.1 Kinematics

3.1.1 Trajectories

After every trial digitization, a trajectory was obtained for each anatomical point. Figure 2 presents the trajectory for the anatomical points digitized on Trial 2 (the second paraffin block used), where the repetition of the motion can be observed. As expected, the shoulder presents a smaller range of motion, and the point on the elbow has a similar motion as both points on the wrist.

If several trials are compared, it can be observed that similar trajectories are obtained, as shown in Figure 3, where the trajectories for the point on the elbow are presented for several trials.

3.1.2 Velocity

The velocity profile was obtained for the anatomical points in study. As for the trajectories, Trial 2 is used to show the typical velocity profile, presented in Figure 4. It can be observed that the shoulder point has very low speed, as its position does not change much. The velocity profile of the points on the wrist and elbow are very similar, however, there are slightly higher speeds on the elbow. For this trial, the highest velocity registered was in the order of 0.6m/s on the elbow.

Figure 2: Trajectory of the anatomical points from Trial 2.

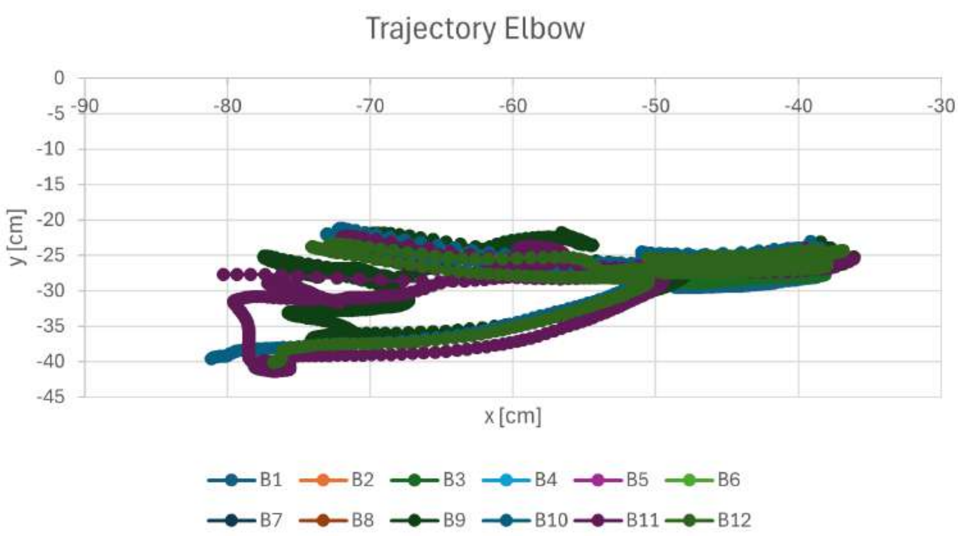

Figure 3: Trajectory of the elbow point in different trials.

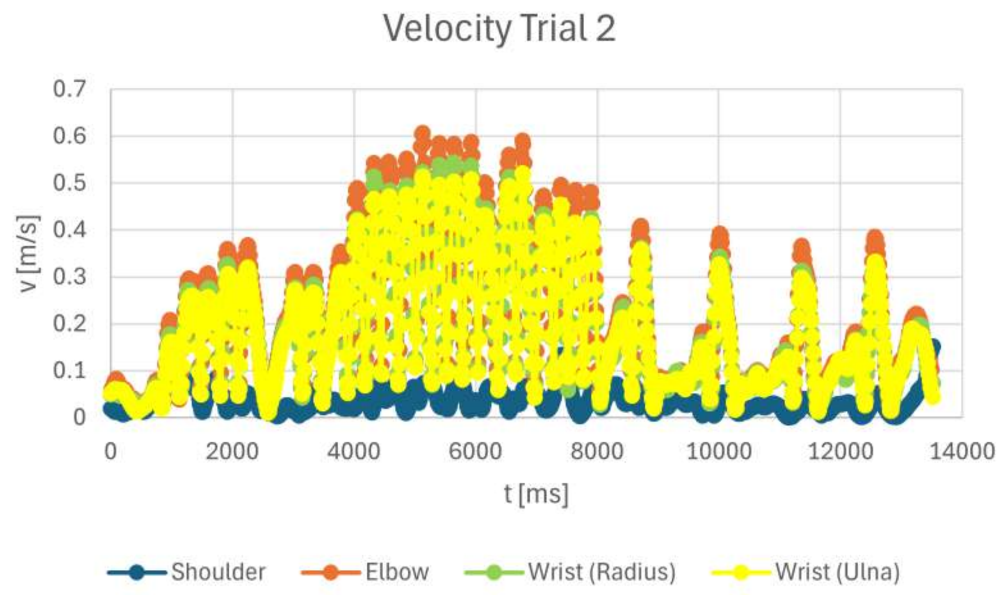

Figure 4: Velocity of the anatomical points for Trial 2.

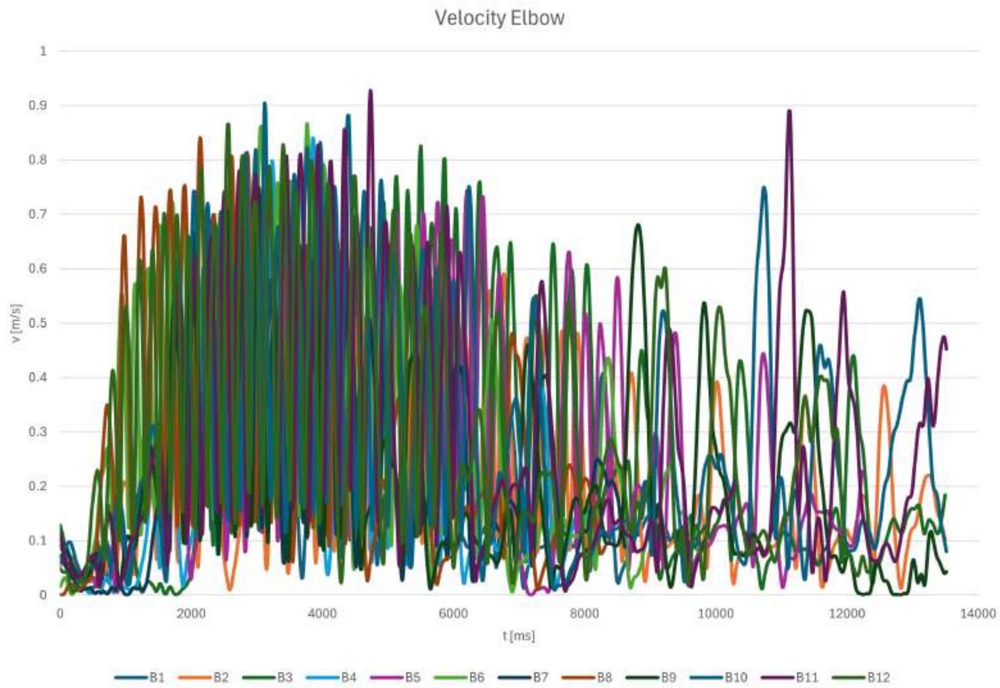

Figure 5: Velocity of the elbow point for all trials.

Taking in consideration the different trials, the profile of the velocity is similar to the one observed in trial 2. Figure 5 shows these profiles regarding the elbow point. Some trials present slight deviations but all have a similar behavior. In terms of mean velocity values of all trials, Table 1 presents these values for all anatomical points. The mean velocity on the elbow is 0.26m/s and its mean maximum velocity is 0.8m/s. The behavior of the points on the wrist in terms of velocities is identical, and similar to the elbow. Only the shoulder point presents a different behavior due to its type of motion. From the data obtained, it is clear that the elbow and wrist are most at risk due to the higher velocities found.

Table 1: Mean velocities for all trials

Velocity	Shoulder	Elbow	Wrist (Radius)	Wrist (Ulna)
Mean	0.044106427	0.256071636	0.22843382	0.229672815
Mean Maximum	0.144578964	0.802243768	0.71305574	0.704966817

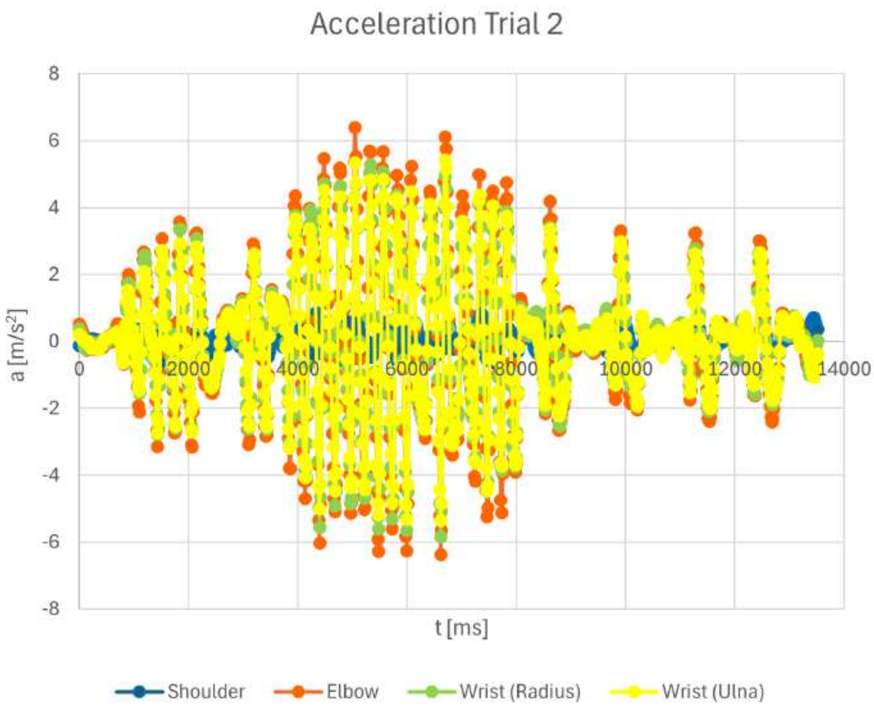

Figure 6: Acceleration of the anatomical points for Trial 2.

3.1.3 Acceleration

Similarly to the velocities, the acceleration profiles were obtained and Figure 6 presents the result for the second trial as an example. Once again, the elbow shows higher values but has a similar behavior as the wrist points. The shoulder presents smaller values of acceleration. To

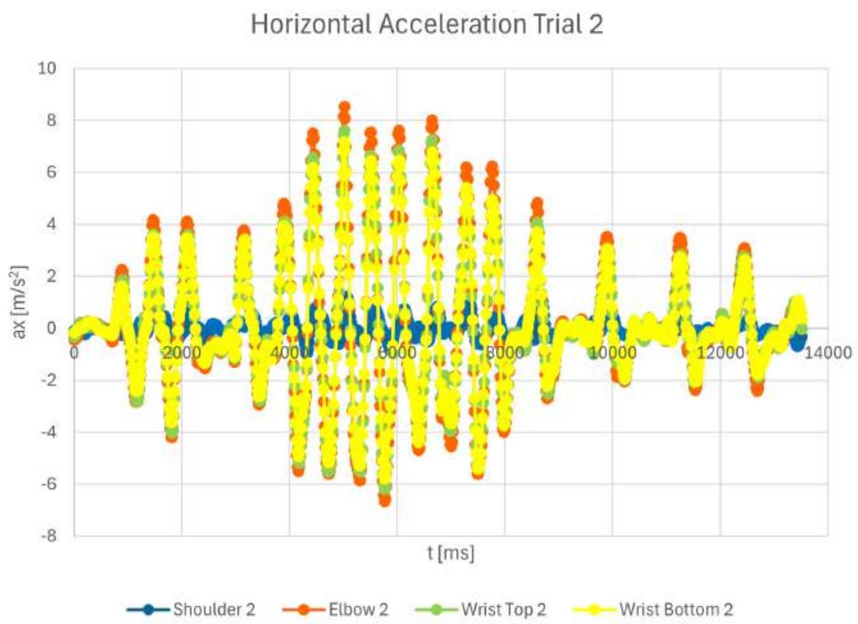

Figure 7: Acceleration on the x-axis of the anatomical points for Trial 2.

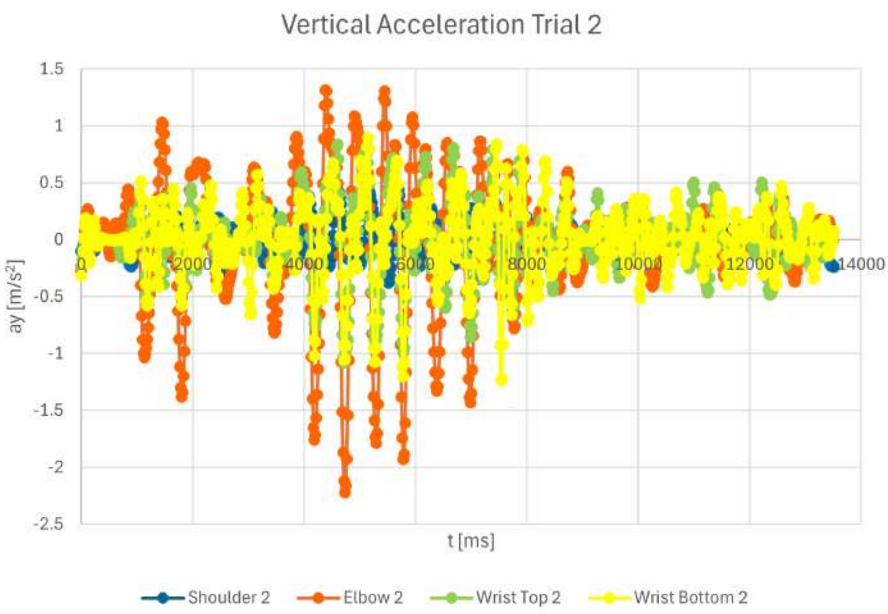

Figure 8: Acceleration on the y-axis of the anatomical points for Trial 2.

better understand the acceleration behavior, its components are shown in Figures 7 and 8. It can be observed that the component along the x-axis has a greater contribution to the acceleration profile. As the motion is mostly on this axis, this behavior is expected.

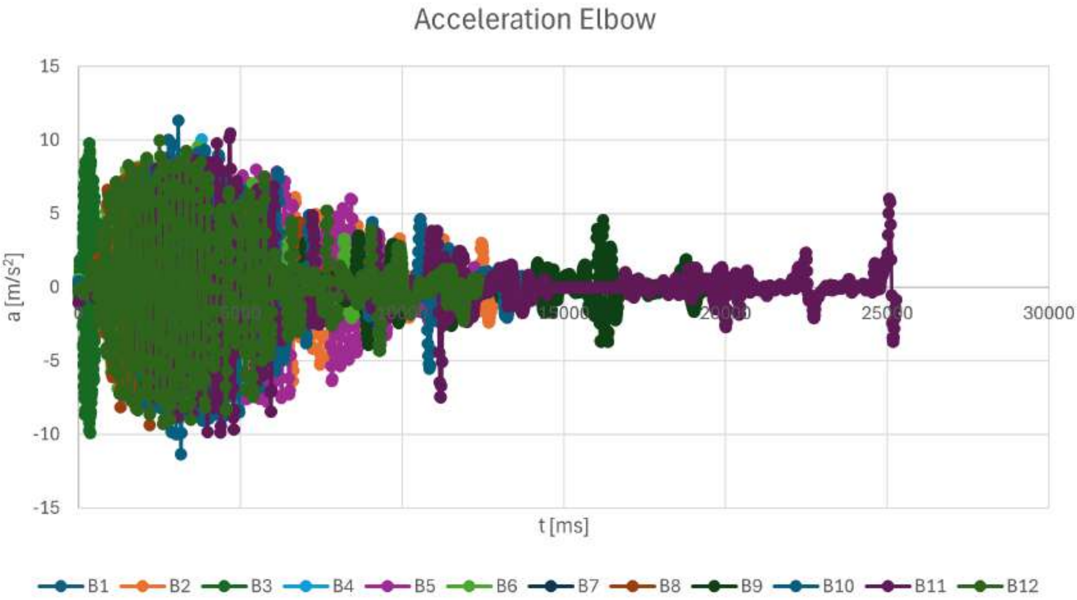

Figure 9: Acceleration of the elbow point for all trials.

Considering the acceleration of the elbow for all trials, shown in Figure 9, the behavior is similar, with a higher frequencies in the beginning. To better understand the development of the movement, the different parts of the movement are presented in Figure 10. In the first part of the motion, the paraffin block is prepared, after which starts the trimming of the paraffin block before getting to the material to be studied. In this part of the movement, there are high accelerations at high frequencies. When the material to be studied is seen, the motion slows and the sample is obtained. The acceleration diminishes and the frequency of the movement decreases.

During the thinning of the paraffin block, the range of acceleration of the trials is between -9.92 and 9.77 m/s^2, and the frequency of the movement ranges between 3.333 and 5.455 Hz, with a mean frequency of 4.641Hz. These combination of high frequencies with high accelerations are an indicator of potential of injury.

3.1.4 Head angle

The posture of the user of the microtome is also important to the comfort of that user. The head angle was measured for the different trials, during the operation of the microtome. Figure 11 shows an example of a measurement. Considering all trials, the head angle ranged between 39.7° and 58.2°). These angles are in the range of forward head posture (head angle smaller than 50°), which is considered to be an indicator of a posture that leads to injuries over time, especially in the case of a seating position at a desk.

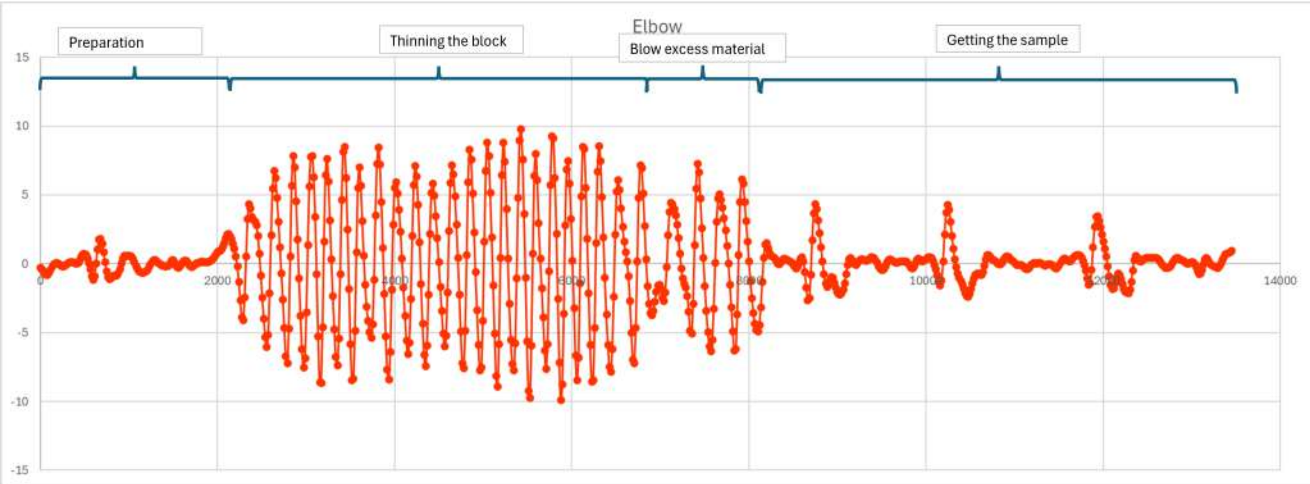

Figure 10: Movement division using the acceleration in the y-axis graph of the elbow point for Trial 2.

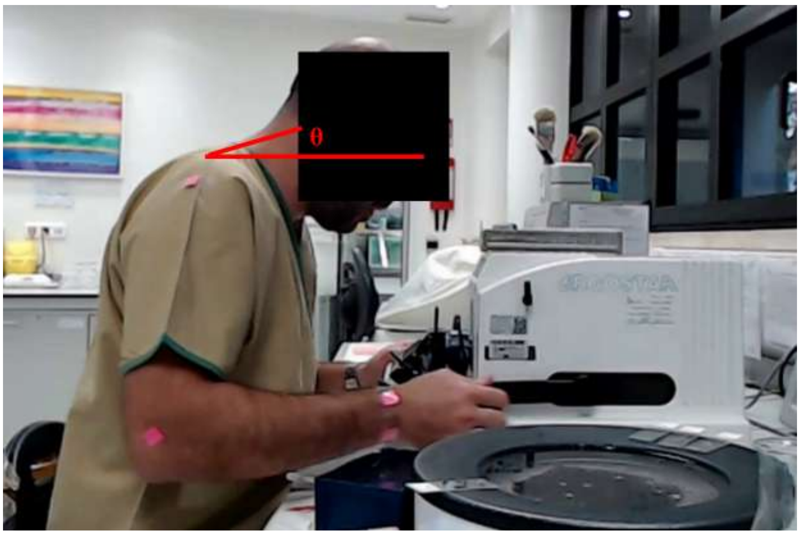

Figure 11: Head angle measurement.

4 CONCLUSIONS

The movement due to the manipulation of a microtome is the focus of this work. Due to prolonged hours using the microtome, bad postures associated with a repetitive motion are known to promote work related injuries. A laboratory technician was asked to perform his job while being recorded at a high frame rate. Three anatomical points were marked on the arm manipulating the microtome to help with the posterior analysis. A kinematic analysis was performed using the Kinovea tool and the velocity and acceleration profiles were obtained for all paraffin blocks handled by the laboratory technician. Also, the head angle was measured during operation. This study has found that:

- There are similar velocity and acceleration profiles for the different trials.
- The repetitive motion introduces high accelerations to elbow and wrist.
- High frequency and elevated accelerations are indicators of injury risk.
- The head angle in range of forward head posture ($\leq 50°$)

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