1.0 INTRODUCTION

Neuromuscular control is the ability to receive input from muscles, tendons, joints and process information in a meaningful way in the central nervous system. Good neuromuscular capability allows human to control the balance of the body in the right way when faced with an uncontrollable situation[7,8,10]. Training to improve neuromuscular control were as unstable mat, rocker board, wobble board, bosu ball and so on. Systematic training allows one could prevent from happening ankle injury and avoid repeated injuries and even accelerate the recovery process[11].

At present, it appears that the highest injury in sports was an ankle sprain injury. An ankle sprain injury was highest in football sport. If the ankle injuries are not treated in time or incompletely, they would lead to excessive relaxation of ankle ligament, joint instability, repeated sprains, ankle joint dysfunction or other consequences [11]. Therefore, the importance of neuromuscular control training within each individual to avoid injury and prevent repetitive injury from occurring. This exercise was also very good for a healthy ankle, re-injury ankle and injured ankle. Neuromuscular control training proprioceptive to respond to the movement generated on the surface [8].

Therefore, in most cases ankle training for prevention and rehabilitation needs the help of therapist or the utilization of dedicated tools. A number of simple ankle prevention and rehabilitation devices have been produced, each of them was used for specific prevention and rehabilitating exercises [11]. For instance, neuromuscular control and strength training exercises can be performs by using elastic bands and wobble board or bosu ball. The ankle rehabilitation training is carried out within the range of ankle movement, in which the ankle joint, surrounding muscles and tendons are regarded as a whole. However the use of conventional method still inefficient in terms of the assessment database, without using the principle of progressive exercise, overload exercise, systematic training and training planned schedule.

This paper presents the background and details of existing devices for rehabilitation of ankle sprained, and proposes a new device based on existing product mechanism. The emphasis is on those projects that represent conventional tools and innovative tools that have a commercial significance . In addition, we will discuss the key issues in the design process of Integrated Multiple Ankle Technology Device (IMATD) and apps database, and we hope that this will be helpful to the future research on this field.

1.1 Brief Introduction Neuromuscular Control

Neuromuscular control consists of three types of mechano-receptors, visual and vestibular. All play an important role for proprioceptive control. Proprioceptive was the ability nerve to receive responses movement and give a good response to the movement [8,9,10]

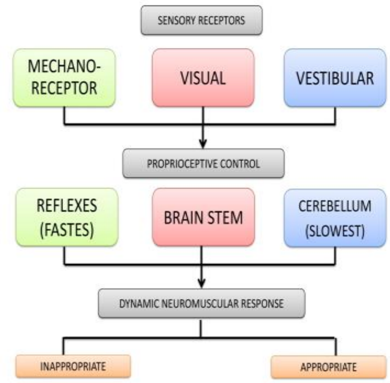


Figure 1 Neuromuscular function

Mechano-receptor function is "transducer to convert mechanical energy of a new action potential" and to provide position sense and conscious awareness by initiating reflexes to stabilize joints and avoid injury [8,9,10]. Along with mechano-receptors and vestibular function, the visual system plays an important role in the ability of an individual to control balance and maintain an upright posture [9,10]. When these three conditions are isolated and balance was tested, it has been found that vision was the most significant contributor to balance, playing a bigger role than either of the other two intrinsic mechanisms. The vestibular system send signals primarily to the neutral structures that control eye movements, and to the muscles that keep an upright posture [8]. The brain uses information from the vestibular system in the head and proprioception from throughout the body to understand the body 'dynamic and kinematic (including its position and acceleration) from moment to moment [9,10].

The proprioceptive information reaching the brain's response will be given by the central nervous system to respond neuromuscular control. This reaction was divided into three, namely reflexes (fastest), brain stem and cerebellum (slowest). To reflexes (fastest) was reaction at the spinal level was a reflex response. This represents a fast response that was protective reflexive necessary for joint stabilization. This also helps mediate movement from higher levels of the central nervous system [9]. While the brain stem was the second level of motor control was via the lower brain (basal ganglia, brainstem and cerebellum). This area acts as a way station for command from higher levels. It also was involved in the timing of motor activities, learning of planned movements and control of complex movement patterns of a sustained and repetitive nature. Finally was the cerebellum control of voluntary movement. After the processing of information occurs a motor response. This represents the slowest neural response occurs. This represents the slowest neural response because of the presence of control neuromuscular activities. The resulting device have 2 DOF, Wobble and Vibration movement, 3 Speed of slow (1Hz), medium (1.67Hz) and fast (1.43Hz) and android applications.

Figure 3 Integrated multiple ankle technology Device

3.1 2 Degree Of Freedom [DOF]

There were a various types of degree of freedom as example 1 DOF, 2 DOF or 3 DOF. 1 DOF equipment normally available on the market involving only one type of movement such as dorsi-flexion / plantar-flexion. For this study, the device produced using 2-DOF mechanism that produces only two types of movement that is focused on movements of dorsiflexion / plantar flexion and inversion / eversion. It was enough to produce a movement that for ankle rehabilitation and can restore neuromuscular control [1,2].

3.2 Wobble and Vibration Movement

In a previous study found that wobble movement good for prevention and rehabilitation of ankle. It takes a good impression on the ankle. Wobble movement help balance training program. Balance training program can reduce the risk of ankle sprain [3,4,5]. From the research study shows that balance training was an effective means of improving joint proprioception and single leg standing ability in subject with unstable and non-impaired ankles. Meanwhile vibration training was a useful tool to increase the stability in functionally unstable ankles. Whole body vibration was promising treatment method for patients with acute unstable ankle inversion sprain [6,7]. Therefore, in this study a combination of wobble and vibration movement united in one device to give a good impact on the healthy ankle, re-injury and injured ankle. The movement of this device is clock-wise.

3.3 Speed

This tool was also capable of producing 3 types of speed movement which were slow, medium and fast. The movement in terms of sports rehabilitation was intensity variable that can be manipulated to a patient or athlete for progressive exercise activities. Progressive exercise activities very good to enhance performance and recovery of athletes. The motor moves based on time delay. For slow movement, time taken for one complete cycle is 1 second. For medium speed movement is 0.7 seconds and O.6 seconds for fast movement. We can obtain the frequency of the motor using f =1/s. Where f is frequency or rate of motor cycle (Hz) and s is the time taken for one complete motor cycle(s). Therefore for slow movement, the frequency is 1Hz, while medium and fast are 1.67Hz and 1.43 Hz respectively.

3.4 Apps Android

This means that all activities are controlled by android apps, it serves to calibrate each movement and control of the tool movement and speed of the tool during exercise performed. Android apps built to store all database obtained during the exercise.

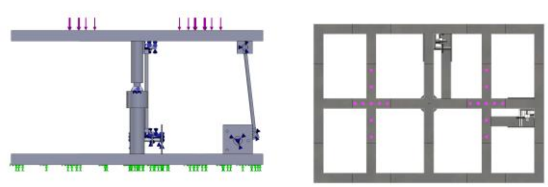
Figure 4 Apps android

4.0 RESULT

4.1 Finite Element Analysis [FEA]

In this research, finite element analysis (FEA) is used to evaluate the structural analysis of this device before continue to prototyping process. Generally, this device consists of four major parts; the base frame, platform frame, inversion-eversion mechanism and dorsi-plantar flexion mechanism. The 3D models for each part were created and simulated in SolidWorks® to determine the safety factor for this device.

4.2 Boundary Condition



(a) (b)

Figure 5 Illustration of boundary condition for the FE simulation (a) integration and constraints applied (b) load acting on the platform.

Figure 5(a) shows the overall boundary condition applied in the FE simulation. In this simulation, each part was applied with plain carbon steel material which had Young's modulus, E of 220.6 MPa. The blue arrow in Figure 5(a) indicates the interaction of surface-to-surface whereby each surface of the jointing parts was assigned with rigid body condition to prevent the penetration. Meanwhile, the green arrow represents the fixed constraint boundary condition for the base in order to prevent any uncalled movement during the simulation. In sequence to mimic the actual condition where a subject standing on the platform, the total of 2000 N of load, P_Total was applied on the platform as shown in Figure 5(b). It is assume that the maximum load allow for particular subject to standing on the platform is 2000N which equivalent to 200kg of subject weight. Referring to Figure 5(b), there are two area of the load applied on the platform, where it represents as the footstep position of the subject standing on the platform. Therefore, each load area was applied with 1000 N respectively to having total ideal load, of 2000 N.

4.3 Maximum Stress

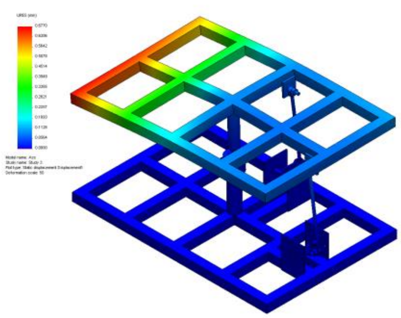


Figure 6 Stress distribution on the device

Figure 6 shows FE simulation results of stress distribution on the device. As shown in Figure 6, the centre of the platform indicated the maximum stress of 78.8 MPa. Comparing the yield strength and maximum stress obtained in this simulation, the maximum stress result is not critical where it is not exceeding the 220.6 MPa of yield strength of the material. Hence, it shows that the material selection and platform design was good enough to sustaining the total load given.

4.4 Maximum Deflection

Figure 7 shows the deformation results of the device based on FE simulation. The maximum deflection was indicated at the end of the right edge with the deflection of 0.67 mm as shown in Figure 7. Comparing the deformation occur between right and left edge, the left edge deformed less because this area has been supported with shaft from inversion-eversion mechanism. Based on the yield strength and maximum stress values, the deformation occur in this study can be categories as elastic deformation where the platform will return to its original shape when the applied load been removed.

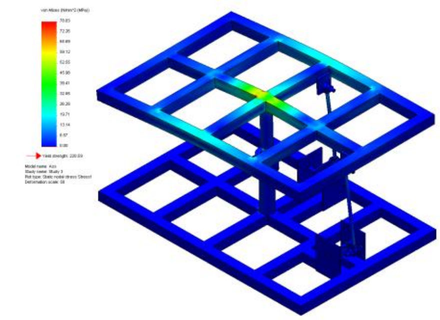


Figure 7 The FE simulation results of the deformation on the device.

4.5 Safety Factors

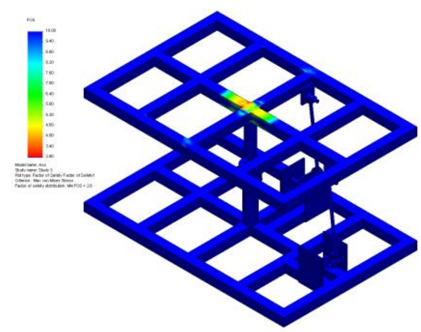


Figure 8 The safety factor results based OnVon Misses Failure theory.

The safety factor results of the device based on Von Misses failure theory is shown in Figure 8. It is obtained that, the minimum safety factor for this device was 2.8. The results shows that the device structure able to sustain the given load without failure. As a result, the material selection and structural design for this device is sufficient for the rehabilitation activities.

5.0 DISCUSSION

According to the analysis of present ankle rehabilitation device, the following are the key issues of the design of the ankle rehabilitation devices

5.1 Safety and Reliability

Not much attention has been paid to the technology of human device symbiosis to date because almost all devices have been designed and constructed on the assumption that the devices are physically separated from humans [12]. In particular, safety and reliability are the underlying evaluation criteria for mechanical design, actuation and control architectures [13]. From the previous studies involved the safety issue when ankle rehabilitation was conducted on patients. Therefore, the analysis conducted in this study to determine the safety of this equipment by maximum weight.

5.2 Designing Proper Mechanism

Mechanism is the main structure of rehabilitation device, which determines the basic character of the devices. The proposed mechanism should have sufficient degree of freedom, highly dependable of operation, and high dexterity. Rotary center of the mechanism should coincide with the ankle joint in work process. Therefore, this study focused on reconfigurable of the rehabilitation device to meet different requirement of different people.

5.3 Control Strategies

Ankle rehabilitation device should run smoothly and in reliability, has a simple structured and efficient in control, suitable to home or clinic use. Good adaptable in control is necessary to meet different people's requirements. Hence, Integrated Multiple Ankle Technology Device (IMATD) controlled by apps android with a wide range of speeds for efficient in control.

6.0 CONCLUSION

The design of integrated multiple ankle technology device (IMATD) that carried out has been completed as well successful and finished with final detailed design drawing and consist of analyzed on every critical parts at the motor system especially the critical shafts, also the selection of the materials used that depends on design criteria. For this design integrated multiple ankle technology device most of the part where use carbon steel material. The prospect of ankle rehabilitation device will be more humanized, active patterns to be set or changed to meet different people's requirement.

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