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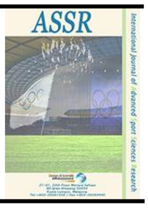

Study, Measuring and Vibration Data Analysis for Hip Replacement Patient during Daily Activities

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Abstract

The older age people are usually suffering from big medical problems due to failure in hip joint, this lead to artificial hip replacement surgery. These troubles give a big engorgement to study, measure and analyze the vibration data and heart straining muscle with patient of replaced artificial hip joint in order to reduce the effect of vibration using different damping unit. This work investigates the frequency, acceleration, and heart straining muscle which will be measured at foot, knee, and hip joint in the patient leg of artificial replacement hip with different damping units. The suggested vibration measurement system was used to measure vibration in the patient leg with artificial replacement hip as a case study. This patient is of age, weight, length and leg length of 26 years, 85 kg, 175 cm and 98 cm respectively. The results showed that the acceleration in X- direction in case without using any damping unit will be (6.07, 1.18, and 0.25) g for (foot, knee, and hip) respectively. These values manifested that there is reduction in the acceleration with 80.5%, and 95.8%, for knee, and hip) respectively in comparison with foot acceleration. Also result exhibited that the best reduction in acceleration is recorded in the case of using the athletic shoe + air ground + silicon as a damping unit with a value of 63.4%, while the best reduction in the heart straining muscle is recorded using the athletic shoe + silicon as a damping unit with 51.1%

Keywords: Hip replacement, vibration, heart straining muscle, human body.

1. Introduction

The hip joint is one of the largest joints in the human body and is what is known as a "ball and socket joint". Hip is the joint where the thigh bone (femur) meets the hip bone (pelvis) using a ball and socket interface. The ball is the head of the femur which approximately two third of a sphere. The socket is the concave acetabulum. The mating surface (ball and socket) affect each other using cartilage interface (Susan and Hall, 1995).

In a healthy hip joint, the bones are connected to each other with bands of tissue known as ligaments. These ligaments are lubricated with fluid to reduce friction. The main purpose of the hip joints is to support the upper body when a person is standing, walking and running, and to help with certain movements, such as bending and stretching. The hip is a true ball-and-socket joint surrounded by powerful and well-balanced muscles, enabling a wide range of motion in several physical planes while also exhibiting remarkable stability. As the structural link between the lower extremities and the axial skeleton, the hips not only transmit forces from the ground up but also carry forces from the trunk, head and neck, and upper extremities (Campbell et al., 2001). It will be necessary replaced the hip if one (or both) of your hip joints becomes damaged and causes you persistent pain or problems with everyday activities such as walking, driving and getting dressed.

Some common reasons why a hip joint can become damaged include:

- **osteoarthritis** – so-called "wear and tear arthritis", where the cartilage inside a hip joint becomes worn away, leading to the bones rubbing against each other
- **rheumatoid arthritis** – this is caused by the immune system (the body’s defence against infection) mistakenly attacking the lining of the joint, resulting in pain and stiffness
- **hip fracture** – if a hip joint becomes severely damaged during a fall or similar accident it may be necessary to replace it

Many of the conditions treated with a hip replacement are age-related so hip replacements are usually carried out in older adults aged between 60 and 80.

The purpose of a new hip joint is to:

- relieve pain
- improve the function of your hip
- improve your ability to move around
- improve your quality of life

In 1958 sir John Charnley introduced the bone cement for his arthroplasty to fix the metal prosthesis which appears to solve the problem anchorage and his design of low friction THP was considered gold stander even today due to its high success rate 85% (Sabry, 1986). By 1961, Charnley was performing surgery regularly with great results. McKee and Watson Farrer (1966) describing a metal on metal hip with stainless steel material (Pospula, 2004; Hughes and Carthy, 1998). Hip joint replacement consists from many parts such as pelvis, socket, stem, and femur. In general there are two types of hip prosthesis (Ugo Andreaus and Michele Colloa). The total hip prosthesis means that the damage occur in the all parts of the mating surfaces (femur and pelvis) (Marston et al., 1996). The Partial hip prosthesis means that the damage occurs in one member of the mating parts (femur or pelvis) (U.S. Food & drug administration). The importance of the normal hip in any athletic activity is emphasised by the role this joint plays in movement and weight-bearing.

An understanding of the biomechanics of the hip is vital to advancing the diagnosis and treatment of many pathologic conditions. Some areas that have benefited from advances in hip biomechanics include the evaluation of joint function, the development of therapeutic programs for treatment of joint problems, procedures for planning reconstructive surgeries and the design and development of total hip prostheses (Johnston et al., 1998). Biomechanical principles also provide a valuable perspective to our understanding of the mechanism of injury.

Colombi (2002) dedicated to the fatigue analysis of cemented total hip arthroplasty. In particular the damage evaluation scenario is simulated and a sensitivity analysis is performed. To this end, two different damage evaluation algorithms (the elastobrittle and the continuous damage one) are proposed and implemented in the finite element. Some global damage criteria are introduced to quantify the damage accumulation. The continuous damage algorithm is shown to perform better compared to the elasto-brittle damage one in the estimation of the fatigue lifetime of the cement mantle. A sensitivity analysis is then performed as a function of the cement Young's modulus, the stem-cement friction and the stem Young's moduls. Numerical moderate sensitivity to the stem Young's modulus.

Kayabasi and Ekici (2007) investigated the behavior of newly designed implants under body weight load during stumbling by parametric modeling. Two different implant materials have been selected to study appropriate material and fatigue life resistant. In the finite element analysis, physical interactions among joints are simulated by contact algorithms. The femur–bone-cement interface and the bone-cement–implant interface surface to surface. In the analysis, a viscoelastic material model is utilized for bone-cement. Numerical shape optimization is applied to the prosthesis. The results of finite element simulations are compared with Charley’s implant results and appropriate material for the implant is proposed.

Bennett and Goswami (2008) performed a finite element analysis (FEA) on six hip stem designs. The hip implant designs were then analyzed at forces ranging from 2.5 to 7 kN. These forces were selected because a typical gait cycle generates forces up to 6–7 times the body weight in the hip joint. The FEA results were compared for various stem designs assuming a rectangular cross-section. The design objective for a hip stem is to have a low stress, displacement, and wear at a very high fatigue life. Subsequently, the stems that had the highest stress and displacement models were then optimized for a lower stress and displacement combination. Fatigue and wear analyses were performed assuming that the implants were made of metal and polyethylene liner.

Fratlla et al. 2012 studied the distribution of stress within experimental models under forces similar to those that occur during chewing by using photo elasticity. The experimental models were manufactured from photo elastic material. They imitate the bridge and dental-periodontal support aggregate in a hemi mandible. The bridges had single tooth or two teeth support with vertical abutments. Based on the is chromatic bands, quality and quantity analysis of stress can be carried out, which shows and explains the behavior of the bridges with the analyzed shapes. It was concluded this optical method yields information regarding the distribution of stress that occur under the action of a known force in a photo elastic model that is similar to the biomechanical complex bridge and dental-periodontal support.

Mahmood and Said 2013 studied the effect of changing the design parameters (head diameter, neck length, neck ratio, stem length) on Charnley design where studied, and the effect of changing the design parameters (head diameter, neck length, stem length) on Stanmore design where also studied, for stumbling case as impact load where the load reach to (8.7* body weight) for impact duration of 0.005sec. Using finite element method by using ANSYS software , the experimental work consist of applied three different energy levels (0.44J, 0.88J, 1.33J) on fixed hip by using rig. This rig consists of a wood box with a smooth sliding shaft where a load of (0.453kg). The results show that the contact stress is greater than effective stress generally. And it is affected by changing the head diameter for both Charnley and Stanmore design. And also the total contact stress is greater than the effective stress and also is affected by changing the head diameter for both (Charnley and Stanmore design).

There is limited reliable information about the effects of the type of damping parts on resulting vibration parameters, gait cycle parameters, forces and moments affected on hip joint. This work studies the frequency and acceleration, and heart straining muscle which will be measured and estimated at foot, ankle, knee, hip in the human with artificial hip replacement with different damping units.

2. Methodology

2.1 Experimental Work

The idea of measuring the vibration in the human leg of patient with replaced hip joint is based namely on measuring system using treadmill with measuring sensor type a Nor axon U.S.A. Inc. • 13430 N. Scottsdale Rd., Suite 104 • Scottsdale, AZ 85254 as shown in Fig.(1). The suggested vibration measurement system was used to measure vibration in the patient leg with replaced artificial hip.

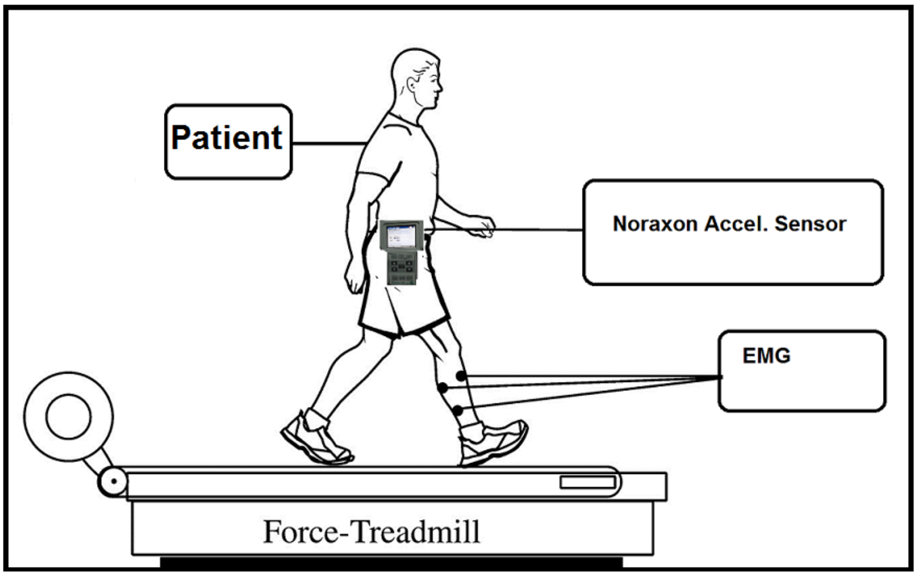


Figure. (1) The Equipment for measuring vibration data and heart straing of Patient with artificial hip replacement

2.2 Experimental Procedure

The idea of the vibration measurement system was a patient with replace artificial hip is accelerated horizontally by treadmill conveyor belt as shown in Fig. (2). The accelerometer is firmly fixed on different points on the patient leg parts fig.(3) . This patient is of age, weight, length and leg length of 26 years,85kg,175cm and 98 cm respectively .The replaced artificial hip joint is Charnley type as shown in fig.(4). The vibration data is transmitted to a computer using a Nor axon U.S.A. Inc. • 13430 N. Scottsdale Rd., Suite 104 • Scottsdale, AZ 85254. This measuring system is used to get various parameters such as (velocity, acceleration, and frequency) at each point. The general properties of this vibrating measuring system is

Up to 4 channels of SEMG or motion/force sensors

- Bluetooth or USB cable transmission
- Choice of protocols
- Audio and video tutorials
- DV Video synchronization (50/60 Hz)
- Comprehensive reports, programmable sessions
- Fully operational with all Nor axon Soft-ware Editions

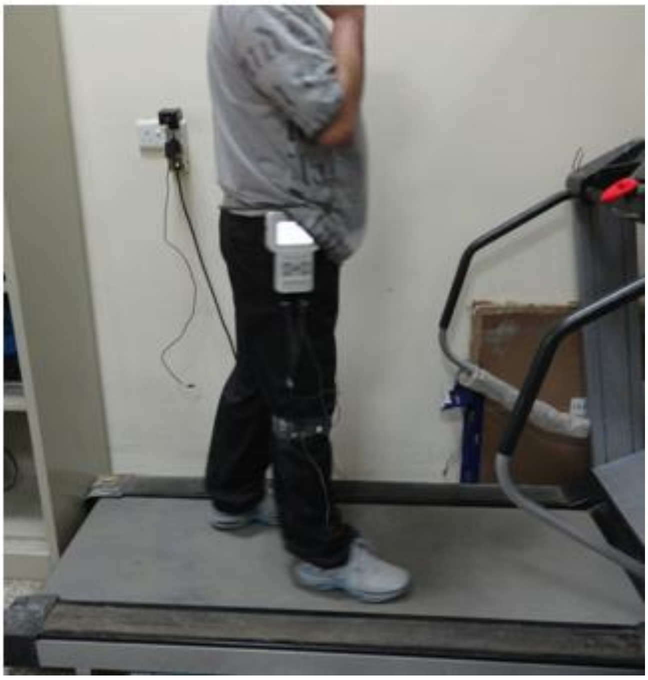


Figure. (2)The vibration measurement system using a Nor axon USA Inc. Scottsdale Rd.

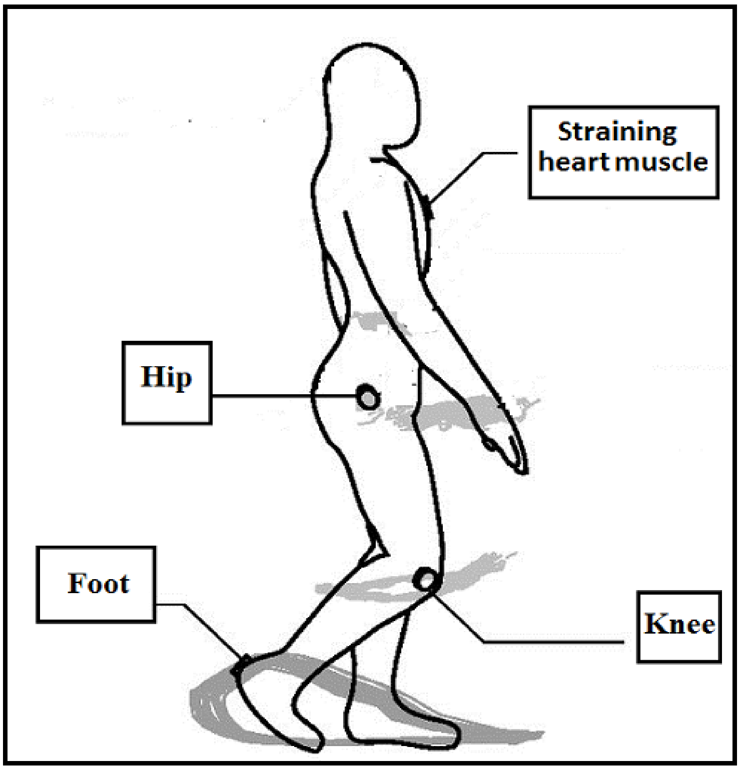


Figure. (3) Accelerometer Points positions along patient leg and heart straining

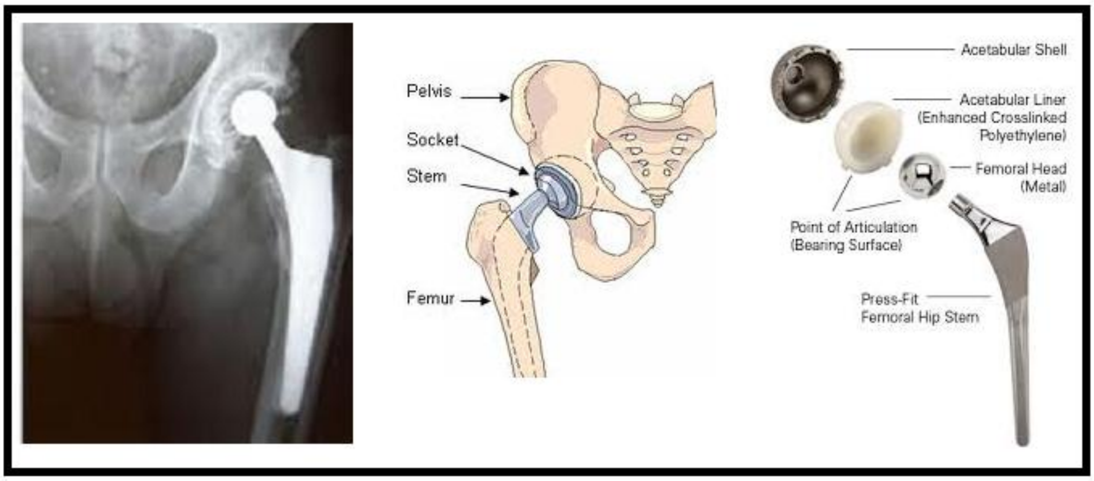


Figure. (4)The artificial hip using by the patient before and after artificial hip replacement surgery

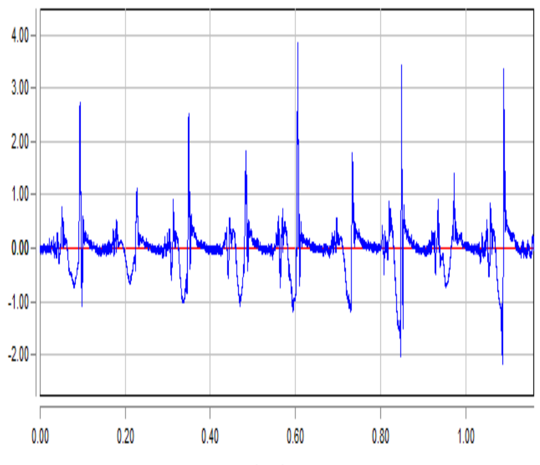
3. Results and Discussion

The vibration data which are acceleration, velocity, displacement and frequency are measured at three positions foot, knee, and hip joints for patient with artificial hip joint replacement. Each point was measured five times and the mean were taken. RMS value of acceleration ,frequency , and heart muscle straining result were recorded in table (1), Fig.(5), Fig.(6), Fig.(7), and Fig.(8) during treadmill gait cycle with different damping type shoes such as without damping, orthopedic medical shoe , orthopedic medical + silicon damping shoe, leather shoe, leather shoe + silicon damping, athletics shoe, athletic shoe + silicon damping, athletic shoe + ground air, and athletic shoe +ground air + silicon damping . These results show that as the sensor point height increased from the treadmill conveyor belt, the acceleration and frequency decreases .The reason behind this behavior is that, when the sensor position height increased, this mean the distance from the excitation source increased and then the frequency and acceleration decreased.

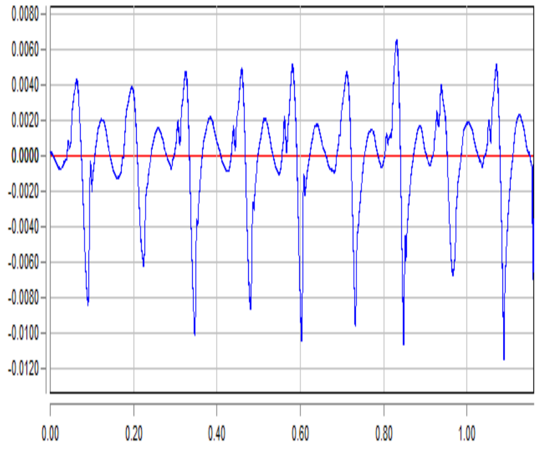
In addition to that the muscles, skin, and fat may function as a damper reducing the frequency and acceleration. The Results show that the acceleration in X- direction in case without using any damping unit will be (6.07,1.18,and 0.25)g for (foot, knee, and hip) respectively .These values shows that there are reduction in acceleration with 80.5%,and 95.8%, for knee, and hip) respectively in comparison with foot acceleration .While in y-direction the acceleration will be (1.63,0.84, and 0.7)g for (foot, knee, and hip) respectively .These values shows that there are reduction in acceleration with 48.4%,and 57.%, for (knee and hip) respectively in comparison with foot acceleration .Also in Z-direction more the acceleration will be (1.05,0.82,and 0.2)g for (foot, knee, and hip) respectively .These values shows that there are reduction in acceleration with 21.9%,and 80.9%, for (knee and hip) respectively in comparison with foot acceleration . The recorded value of heart straining muscle in the case of without damping unit will be 43 Uv

When using the orthopedic medical shoe as a damping unit, the reduction in acceleration at foot, knee ,and hip in comparison with the case of without damping were (38.6%,19.6%,and 56.2%),(20.3%,-8.3%,and 39%),and(-36%,22.8%,and -5%)for X, Y, and Z direction, while the heart straning muscle will be reduces with 32.5% .Also When using the orthopedic medical shoe + silicon as a damping unit, the reduction in acceleration at foot, knee ,and hip in comparison with the case of without damping were (56.8%,28.8%,and 40.9%), (16.1%,-7.1%,and 23.2%), and (-12%,47.1%,and -10%)for X, Y, and Z direction, while the heart straning muscle will be reduces with 30.2%. When using the leather shoe as a damping unit , the reduction in acceleration at foot, knee ,and hip in comparison with the case of without damping were (48.6%,25.7%,and 3.8%), (-5%,16.6%,and 39%), and (-46%,25.7%,and -20%)for X,Y, and Z direction, while the heart straining muscle will be reduces with 30.2%. When using the leather shoe +silicon as a damping unit , the reduction in acceleration at foot, knee ,and hip in comparison with the case of without damping were (58.9%,-12.2%,and 38%),(8.4%,-35.7%,and 28%),and(-24%,34.3%,and -30%) for X, Y, and Z direction, while the heart straning muscle will be reduces with 41.8%.

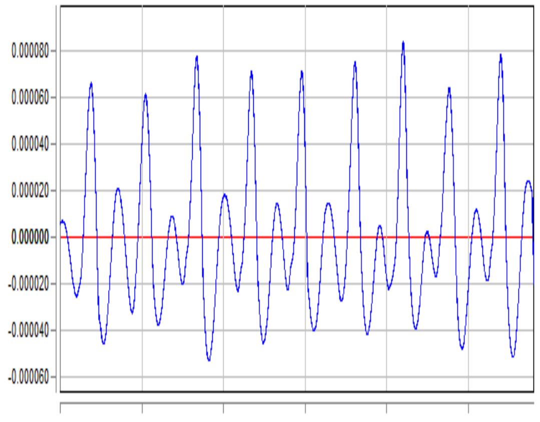
When using the athletic shoe as a damping unit , the reduction in acceleration at foot, knee, and hip in comparison with the case of without damping were (62.6%,-14%, and -76.2%),(32.2%,4.7%,and 10.9%), and (-12%,11.4%,and -15%) for X,Y, and Z direction, while the heart straining muscle will be reduces with 37.2%. When using the athletic shoe + silicon as a damping unit , the reduction in acceleration at foot, knee ,and hip in comparison with the case of without damping were (59.9%,-2.4%, and -60.9%),(13.5%,21.4%,and 43.9%),and(-20%,61.4%,and 5%)for X,Y, and Z direction, while the heart straining muscle will be reduces with 511%. Using the athletic shoe + ground air as a damping unit will lead to reduction in acceleration at foot, knee ,and hip in comparison with the case of without damping with (59.4%,25.1%, and –42.8%), (11.8%,-10.7%, and 12.2%), and (-68%,47.1%, and -5%)for X,Y, and Z direction, while the heart straining muscle will be reduces with 27.9%. When using the athletic shoe + air ground + silicon as a damping unit , the reduction in acceleration at foot, knee ,and hip in comparison with the case of without damping were (63.4%,4.3%, and 11.4%),(37.28%,10.7%, and 28%), and(-52%,44.3%,and -5%) for X, Y, and Z direction, while the heart straning muscle will be reduces with 25.6%.



Acceleration

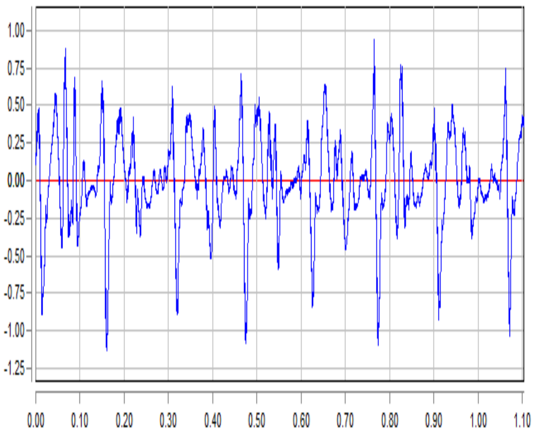


Velocity

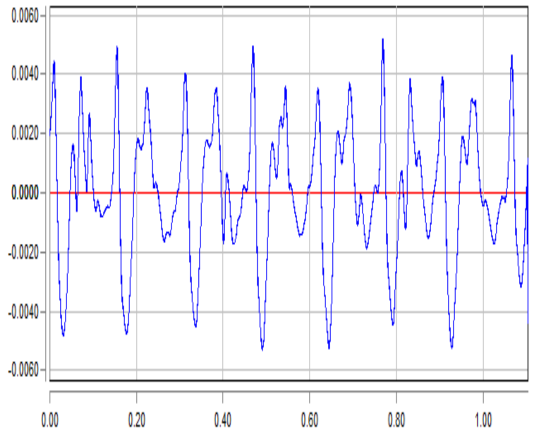


Displacement

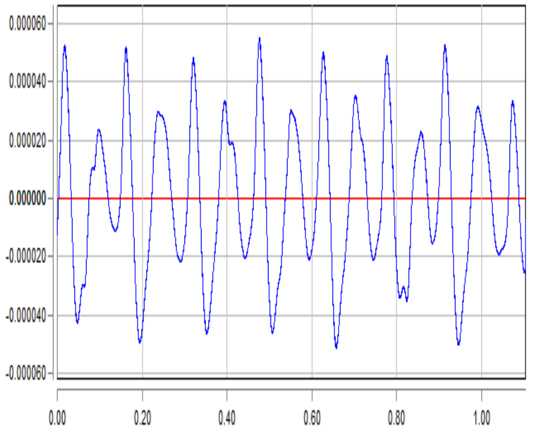
Figure. (5) Vibration data acceleration, velocity and displacement foot region with respect to time in X- direction using the Orthopedic Medical as a damping unit



Acceleration



Velocity



Displacement

Figure. (6) Vibration data acceleration, velocity and displacement at knee region with respect to time in Y- direction using the Athletic Shoe+ Silicon damping as a damping unit

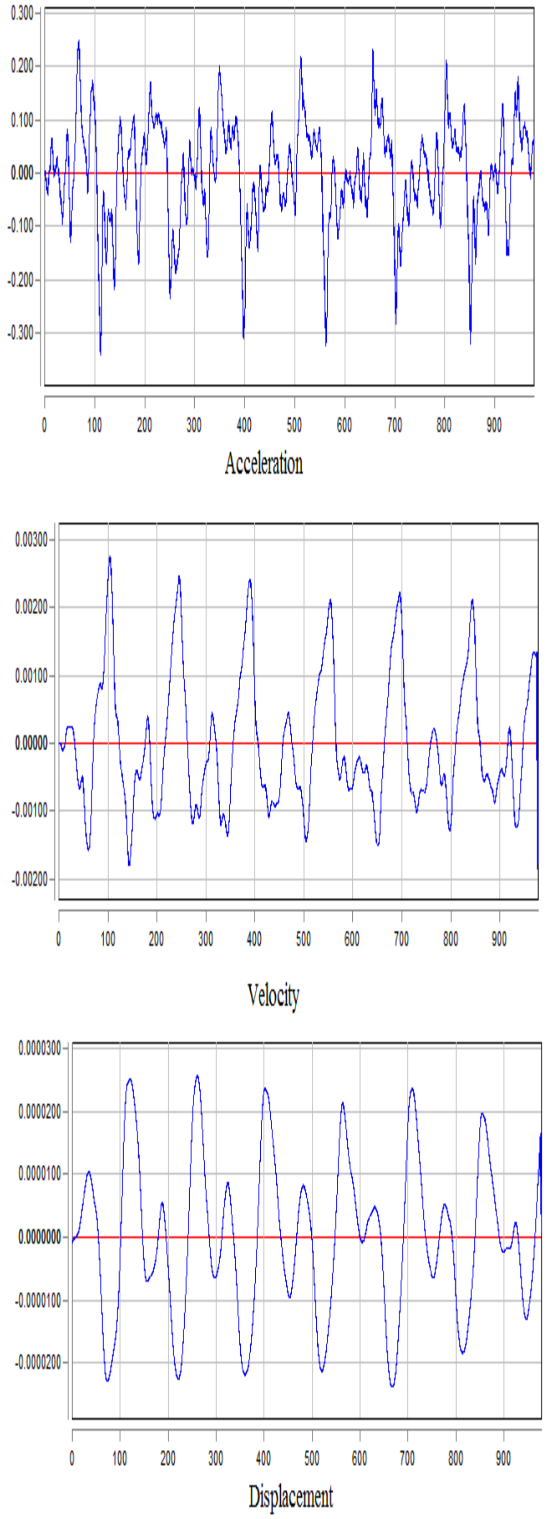


Figure. (7))Vibration data acceleration ,velocity and displacement at hip region with respect to time in z- direction using the Athletic shoe ground air++ Silicon damping as a damping unit

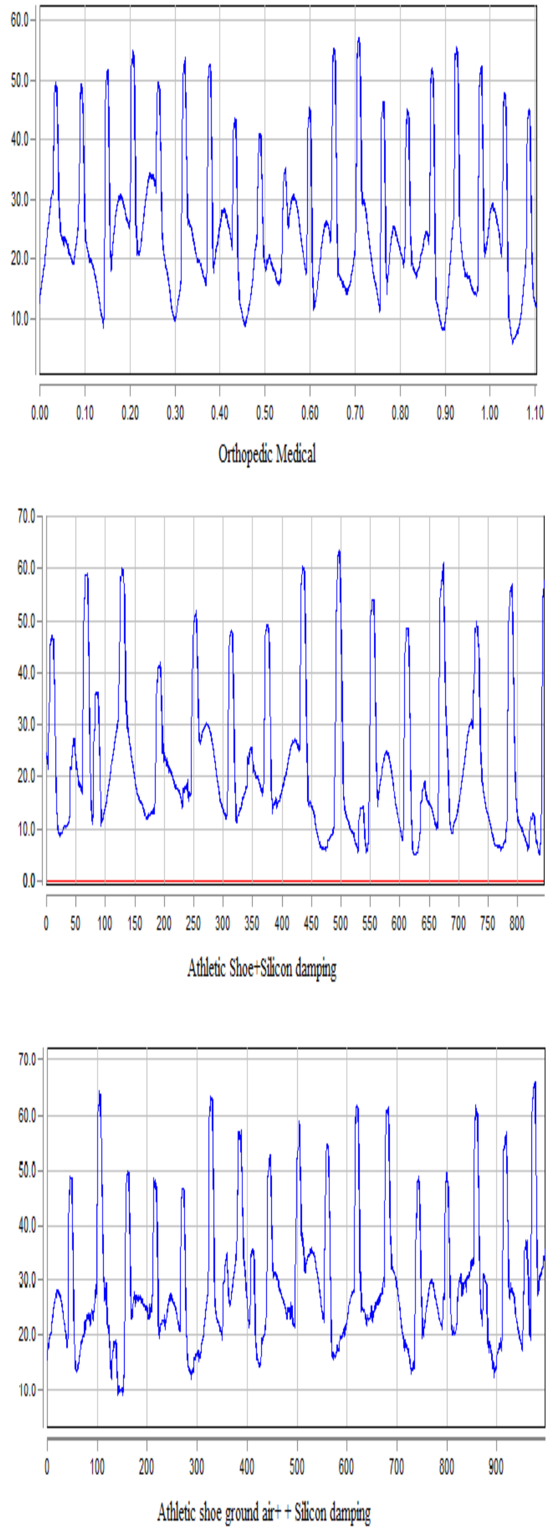


Figure. (8) Staining of heart muscle when usimg Orthopedic Medical, the Athletic Shoe + Silicon damping, and Athletic shoe ground air++ Silicon damping as a damping unit aspect to time in x- direction using the marble as grand foundation

Table (1)
RMS Vibration data and heart straining for the patient with replaced artificial hip using different damping unit

		Foot		Knee		Hip		Heart Straining (Uv)
Type of Damping	**axis**	**Acc. g (m/s^2)**	**Frequency (HZ)* 10^{-3}**	**Acc.g (m/s^2)**	**Frequency (HZ)**	**Acc.g (m/s^2)**	**Frequency (HZ)**	
Without damping	X	6.07	0.93	1.18	0.16	0.25	0.08	43
	y	1.63	0.18	0.84	0.05	0.7	0.04	
	z	1.05	0.1	0.82	0.07	0.2	0.05	
Orthopedic Medical	x	3.48	0.22	0.94	0.16	0.34	0.07	29
	y	1.31	0.23	0.91	0.11	0.54	0.04	
	z	0.46	0.07	0.5	0.08	0.21	0.04	
Orthopedic Medical+ Silicon damping	x	2.62	0.19	0.99	0.16	0.28	0.08	30
	y	1.16	0.18	0.9	0.09	0.37	0.04	
	z	0.62	0.08	0.63	0.08	0.22	0.04	
Leather shoes	x	3.12	0.2	1.24	0.21	0.37	0.07	30
	y	1.21	0.19	0.7	0.12	0.52	0.04	
	z	1.01	0.08	0.5	0.1	0.24	0.04	
Leather shoes+ Silicon damping	x	2.12	0.22	1.08	0.15	0.31	0.09	25
	y	1.65	0.23	1.14	0.1	0.46	0.09	
	z	0.64	0.1	0.59	0.07	0.26	0.04	
Athletic Shoe	x	1.87	0.15	0.8	0.16	0.28	0.1	27
	y	1.86	0.14	0.8	0.09	0.62	0.05	
	z	1.85	0.06	0.73	0.09	0.23	0.05	
Athletic Shoe+ Silicon damping	x	2.43	0.13	1.02	0.2	0.30	0.09	21
	y	1.67	0.14	0.66	0.11	0.27	0.04	
	z	1.69	0.06	0.46	0.11	0.19	0.05	
Athletic shoe+ ground air	x	2.46	0.15	1.04	0.21	0.42	0.08	31
	y	1.22	0.18	0.93	0.12	0.37	0.05	
	z	1.5	0.08	0.72	0.09	0.21	0.04	
Athletic shoe ground air++ Silicon damping	x	2.22	0.1	0.74	0.19	0.38	0.08	32
	y	1.56	0.16	0.75	0.1	0.39	0.04	
	z	0.93	0.06	0.59	0.08	0.21	0.04	

4. Conclusions

The values of acceleration and frequency are increased with the decreasing the distance of sensor point from the treadmill conveyor belt. When using the orthopedic medical shoe as a damping unit, the reductions in acceleration at foot, knee ,and hip in comparison with the case of without damping were (38.6%, 19.6%, and 56.2%), (20.3%, -8.3%, and 39%), and(-36%, 22.8%, and -5%) for X,Y, and Z direction, while the heart straining muscle was reduced by 32.5%. When using the orthopedic medical shoe + silicon as a damping unit , the reductions in acceleration at foot, knee ,and hip in comparison with the case of without damping were (56.8%,28.8%, and 40.9%),(16.1%,-7.1%, and 23.2%),and(-12%,47.1%, and -10%) for X,Y, and Z direction, while the heart straining muscle was reduced by 30.2%. When using the leather shoe as a damping unit, the reductions in acceleration at foot, knee ,and hip in comparison with the case of without damping were (48.6%, 25.7%,and 3.8%),(-5%, 16.6%,and 39%), and (-46%, 25.7%, and -20%) for X,Y, and Z direction, while the heart straining muscle was reduced by 30.2%. When using the leather shoe +silicon as a damping unit , the reductions in acceleration at foot, knee ,and hip in comparison with the case of without damping were (58.9%,-12.2%, and 38%), (8.4%,-35.7%,and 28%),and(-24%,34.3%, and -30%) for X, Y, and Z direction, while the heart straning muscle was reduced 41.8%. When using the athletic shoe as a damping unit, the reductions in acceleration at foot, knee ,and hip in comparison with the case of without damping were (62.6%,-14%,and -76.2%),(32.2%,4.7%,and 10.9%),and(-12%,11.4%,and -15%)for X,Y, and Z direction, while the heart straining muscle was reduced 37.2%. When using the athletic shoe + silicon as a damping unit, the reductions in acceleration at foot, knee ,and hip in comparison with the case of without damping were (59.9%,-2.4%,and -60.9%), (13.5%,21.4%,and 43.9%), and (-20%,61.4%, and 5%) for X,Y, and Z direction, while the heart straining muscle was reduced 51.1%. Using the athletic shoe + ground air as a damping unit will lead to reductions in acceleration at foot, knee ,and hip in comparison with the case of without damping with (59.4%,25.1%,and–42.8%),(11.8%,-10.7%,and12.2%),and(-68%,47.1%,and -5%)for X, Y, and Z direction, while the heart straining muscle was reduced 27.9%. When using the athletic shoe + air ground + silicon as a damping unit, the reductions in acceleration at foot, knee ,and hip in comparison with the case of without damping were (63.4%,4.3%, and 11.4%), (37.28%,10.7%, and 28%),and(-52%,44.3%, and -5%)for X,Y, and Z direction, while the heart straining muscle was reduced 25.6%. The best reduction in acceleration is recorded in the case of using the athletic shoe + air ground + silicon as a damping unit with value of 63.4% while the best reduction in the heart straining muscle was recorded using the athletic shoe + silicon as a damping unit with percent of 51.1%.

Nomenclature

HAV = hand-arm vibration

WBV = whole-body vibration

DELV= daily exposure limit value

VEA = vibration energy absorption

VWF = vibration-induced white finger

Vx, y, z= velocity in x, y, z direction

$a_{x,y,z}$ = acceleration in x, y, z direction

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