*International Journal of Engineering & Technology*, 8 (1.4) (2019) 222-227

International Journal of Engineering & Technology

*Website: www.sciencepubco.com/index.php/IJET*

***Research paper***

# Effects on EMG Response of Lower limb and Heart Rate of walking in the water on Different Water Depth*

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**Abstract**

**Background/Objectives:**This studywas investigate changes in muscle activity and heart rate of the lower extremities when walking according to the depth of water in 20 years old male. The subjects of this study are seven male men who are healthy in their 20s and live in C city in Chungnam and who signed voluntary agreements. The subjects would be provided with sufficient preliminary explanations about the purpose of this study and the experimental procedures in advance so that they can give up their participation according to their own would.
**Methods/Statistical analysis:**To measure the subject's muscle activity, This study did use a surface wire EMG (Laxtha: Korea) and measure the EMG response before and after each experiment in an isometric squat posture. I would perform an isometric squat with a knee bent 90 degrees and would measure the iEMG value for 5 seconds.
**Findings:**Knee depth Walking in the Water increases the iEMG of the lower limb, and Walking in the Water in the waist deep reduces the iEMG. In addition, heart rate showed a greater increase in waist depth than Walking in the Water.
**Improvements/Applications:**Walking in the Water in the waist height is effective for recovery the muscle fatigue of the Lower Limb

***Keywords***:*Walking in the Water, Lower Limb, Heart Rate, iEMG, Muscle Fatigue.*

** This study was conducted as part of on operation of Hot Spring exercise program in Asan City.*

## 1. Introduction

Walking exercise is one of the aerobic exercises. It shows various positive effects such as cardiopulmonary endurance, blood pressure drop, improvement of body composition, increase of muscle mass, improvement of blood lipid, and can be easily reached regardless of age and gender[1]. In the American Academy of Sports Medicine, it is recommended that these walking exercises be performed 3-5 times per week, 30-60 minutes per session, and may result in a positive change in the body when performed at 50-85% of the maximum oxygen uptake[2]. Because of the buoyancy of water movement, the water characteristics like water pressure and resistance, exercise effect is higher than that on the ground, and safety is also excellent[3].Since water has a higher density than air, it has the advantage that it consumes more energy than aquatics exercise[4]. In addition, it is possible to perform various types of training by performing various directions and angles of motion such as assist, support, resistance, etc without giving any strain to joints in the water and by applying resistance by using the body of the user. Buoyancy of water reduces weight load during aquatic exercise. When the water depth is shoulder height, 90% of body weight is reduced, and at waist depth, it is reduced to 41% of body weight. This suggests that buoyancy during aquatic exercise results in injury reduction[5].

In 2001, Bandy et al studied the effects of exercise on body weight and body mass index. [6] Migita et al also reported in 1994, that about half of the treadmill walking is required for the response of the cardiopulmonary system to the normal treadmill walking in the water when walking at the water level of the waist in the water[7].

Water-based aquatic exercise can control the pressure exerted on the body[8].As a result of comparing the body reaction according to the difference of water depth, the oxygen intake and heart rate in the water at the walking speed of 53.3m / min or more were higher in the waist, knee and ankle than in the ground condition, The oxygen intake at 134.1 m / min was not different between the waist height and the ground conditions9.In addition, there was a significant correlation between depth and physiological variables, and the difference in water depth in aquatic exercise affected the exercise load and suggested that the training effect would vary according to the depth of water[10,11].

EMG(electromyogram) is a method for orienting the degree of contraction of the skeletal muscle that controls the movement of the body, and the analysis of the EMG is actively used for the study on the contraction activity of the human muscle[00]. iEMG(Integrted Electromyogram) refers to numerical integration over time and is used to evaluate the applied energy of the EMG signal to be analyzed and is used as an index for quantifying the cumulative usage of the muscle[12]

EMG is used to study exercise units, indirectly indentifying neural dominance patterns of muscles, and serves as an index to evaluate muscle contraction[13]. According to the previous research, when walking with treadmill aquatics, muscle activity of the torso and lower limb was significantly lower than when walking on the ground, and when there was resistance, muscle activity was significantly increased[14]. In 2007, Chevutschi et al investigated the effects of 5m 10m walking on the trunk extensor, the rectus femoris and the soleus at relaxed speeds in the ground and water. The study reported an increased muscle activity of the trunk extensor and decreased muscle activity on soleus during walking in the water [15].

.As this study have seen in the previous section, the buoyancy and resistance of water vary with the water depth and the walking speed, so walking speed and water depth are considered to be the factors that can control the exercise load and the exercise effect is also different. Therefore, studies on the treatment of aquatic exercise using the specific properties of water have been progressing in various ways and becoming popular[16]. Nonetheless, most studies on aquatic exercise have focused on musculoskeletal disorders, central nervous system disorders, and disability, and have focused mainly on research on knee, hip and body improvement.

Therefore, in this study investigate changes in muscle activity and heart rate of the lower extremities when walking according to the depth of water in 20 years old male.

## 2. Methods

### 2.1 Subject

We investigated the changes in muscle activity of the lower extremities and heart rate of 20-year old males when walking in knee-deep and waist-deep water. The subjects of this study are seven males who are healthy and in their 20s living in Asan city. The subjects signed voluntary agreements and were provided with sufficient preliminary explanations about the purpose of this study and the experimental procedures so that they could give up their participation according to their own will. One week prior to the experiment, you would be instructed to limit excessive activity and avoid smoking and drinking alcohol or taking medication.

### 2.2. Study design

The experiment was conducted at the outdoor hot water aqua center in Asan city. The subjects randomly crossed knee and waist deep pools and dry grounds. In all experiments, a ten-minute preparatory and post-experiment exercise were performed. The iEMG response of the lower extremity muscles before and after the walking exercise in the knee and waist depths were recorded. The heart rate was measured during walking on dry ground, walking on knee-deep water, and walking on waist-deep water. Two-way ANOVA was used to observe the effect of water depth on the exercise effect.

### 2.3. Water-Walking method

Walking in the water would be conducted at the Asan City Paradise Hot Spring Aqua Center (KOREA). Experimental conditions would include ground walking, walking in the water at the knee depth, and walking in the water at the waist depth. Walking would be done for three minutes, one step per second. This study would walk without bending the knee when walking, and instruct the swing phase to move the legs at full speed to the individual's ability. The temperature of the water would be kept at 28 to 30°C, which minimizes physiological changes and stabilizes the core temperature while being suitable for functional training. The walking method is shown in Figure 1.

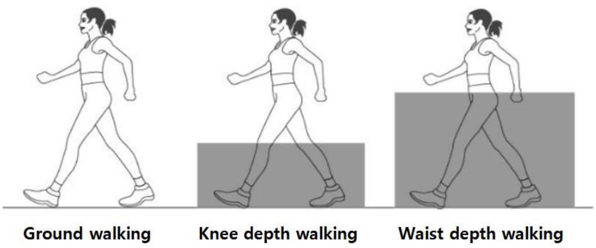


**Fig. 1:**Water-walking

### 2.4. EMG measurement

To measure the subject 's muscle activity, did use a surface wire EMG (Laxtha: Korea) and measure the EMG response before and after each experiment in an isometric squat posture. Did perform an isometric squat with a knee bent 90 degrees and would measure the iEMG value for 5 seconds. The EMG measurement procedure is shown in Figure 2.

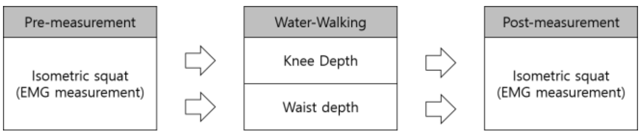


**Fig. 2:** EMG measurement procedure

The surface electrodes would attach to the Vastus lateralis, the Vastus medialis, the Tibialis anterior, and the Gastrocnemius medial head. In order to obtain high quality EMG data before the electrodes, each subject would be subjected to preliminary work to remove hair on the skin layer using a razor, and the surface of the skin would be cleaned with alcohol. The surface electrodes would be attached two at a distance of 1cm from the insertion site of the muscle near the insertion site, and the measurement time would be set to 15 seconds and the EMG data for the middle 5 seconds would be used16. The collected data would be calculated by setting the offset control to 0 and then setting the band pass filtering to 10 ~ 400Hz. The EMG attachment position is shown in Figure 3.


**Fig. 3:**Attachment of electrode

### 2.5. Heart rate measurement

The heart rate did be measured using the Polar (S610i, Finland) wireless heart rate monitor with a wireless transmitter on the chest.The heart rate was recorded in units of 10 seconds while walking in the ground and water for 3 minutes.

### 2.6. Analysis

The data obtained from the experiment were analyzed by SPSS 22.0 statistical program. Electromyography and heart rate were analyzed Repeated Two-way ANOVA before and after underwater walking. Statistical significance was .05.

## 3. Result

### 3.1. iEMG response before and after Walking in the Water in knee and waist depths

#### 3.1.1. iEMG response of the Vastus Lateralis

iEMG of the Vastus Lateralis was not significantly different between walking between the knee and the waist. The interaction effect between water depth and before and after Walking in the Water was statistically significant ($p < .05$). As a result, iEMG increased after Walking in the Water at the depth of the knee, and iEMG decreased at the waist depth after Walking in the Water.

**Table 1:**Results for iEMG of Vastus Lateralis difference before and after Walking in the Water exercise

| | | | | | (μV) |
|---|---|---|---|---|---|
| | Pre | Post | Source | F | p |
| Knee depth | 65.59 ±10.28 | 72.64 ±9.77 | Method(M) | 4.414 | .08 |
| Waist depth | 66.39 ±6.63 | 61.04 ±7.19 | Time(T) | 0.306 | .6 |
| | | | (M)X(T) | 28.352 | .002 |
| M±SD.<br>Pre – iEMG before underwater walking Post – iEMG after underwater walking | | | | | |

#### 3.1.2. iEMG response of the Vastus Medialis

There was no statistically significant difference in the iEMG of the Vastus Medialis between Walking in the Water in the depth of the knee and Walking in the Water in the waist. The interaction effect between water depth and before and after Walking in the Water was statistically significant ($p< .05$). As a result, iEMG increased after Walking in the Water at the depth of the knee, and iEMG decreased at the waist depth after Walking in the Water.

**Table 2:** Results for iEMG of Vastus Medialisdifference before and after Walking in the Water exercise

| | | | | | (μV) |
|---|---|---|---|---|---|
| | Pre | Post | Source | F | p |
| Knee depth | 61.24 ±4.47 | 68.02 ±6.37 | Method(M) | 27.245 | .002 |
| Waist depth | 61.23 ±4.07 | 54.40 ±4.40 | Time(T) | 0.001 | .98 |
| | | | (M)X(T) | 50.737 | .000 |
| M±SD.<br>Pre – iEMG before underwater walking Post – iEMG after underwater walking | | | | | |

#### 3.1.3. iEMG response of the Tibialis Anterior

There was no statistically significant difference in the tibialis anterior iEMG between the knee-deep water walking and the waist deep water walking ($p<.05$). The interaction effect between water depth and before and after Walking in the Water was statistically significant ($p<.05$). As a result, iEMG increased after exercise at the depth of the knee, and iEMG decreased at the waist depth after Walking in the Water.

**Table 3:**Results for iEMG of Tibialis Anteriordifference before and after Walking in the Water exercise

| | | | | | (㎶) |
|---|---|---|---|---|---|
| | Pre | Post | Source | F | P |
| Knee depth | 60.33 ±6.10 | 65.17 ±10.38 | Method(M) | 7.98 | .03 |
| Waist depth | 59.98 ±2.76 | 54.02 ±4.18 | Time(T) | 0.104 | .758 |
| | | | (M)X(T) | 7.088 | .037 |
| M±SD.<br>Pre – iEMG before underwater walking Post – iEMG after underwater walking | | | | | |

### 3.1.4. iEMG response of the Gastrocnemius Medial head

The iEMG of the Gastrocnemius Medialhead was not statistically significant between Walking in the Water between the knee and the waist, and there was no difference between the depth of the water and the walking before and after walking. The interaction effects between depth and pre and post-Walking in the Water were not statistically significant.

**Table 4:**Results for iEMG of Gastrocnemiusdifference before and after Walking in the Water exercise

| | | | | | (㎶) |
|---|---|---|---|---|---|
| | Pre | Post | Source | F | P |
| Knee depth | 2.03 ±0.04 | 2.04 ±0.03 | Method(M) | 0.902 | .379 |
| Waist depth | 2.01 ±0.23 | 1.96 ±0.18 | Time(T) | 0.148 | .713 |
| | | | (M)X(T) | 0.499 | .506 |
| M±SD.<br>Pre – iEMG before underwater walking Post – iEMG after underwater walking | | | | | |

## 3.2. Changes in Heart Rate During Walking in the Water by Water Depth

There was a statistically significant difference (p<.001) in heart rate during Walking in the Water due to water depth difference, and there was a statistically significant difference between before and after walking in water depth of each water depth (p<.001). The depth of water and the interaction effects before and after exercise were statistically significant (p<.001). As a result, it was found that both the depth of the knee and the depth of the waist increased the heart rate after exercise.

**Table 5:**Results for Heart rate difference before and after Walking in the Water exercise

| | | | | | (Time/min) |
|---|---|---|---|---|---|
| | Pre | Post | Source | F | P |
| Knee depth | 80.43 ±7.50 | 125.66 ±6.39 | Method(M) | 70.001 | .000 |
| Waist depth | 83.5±10.94 | 141.70 ±8.92 | Time(T) | 268.446 | .000 |
| | | | (M) X (T) | 30.409 | .000 |
| M±SD.<br>Pre – iEMG before underwater walking Post – iEMG after underwater walking | | | | | |

# 4. Discussion

Hydrostatic pressure, a characteristic of water, can reduce body edema and increase joint motion range.Hydrostatic pressure makes blood circulation smooth, reduces swelling and increases muscle strength of respiratory muscle[18]. Especially, hydrostatic pressure can be effective even if it enters the water[19].

The purpose of this study was to investigate the effect of Walking in the Water on the depth of water on the EMG response and heart rate of lower extremity muscles.The results of the analysis of heart rate and iEMG of the Vastus Lateralis, Vastus Medialis, Tibialis Anterior, Gastrocnemius Medialhead before and after walking for 3 minutes according to the water depth are discussed.In the submerged environment, it was reported that the three - dimensional resistance can move the main and antagonistic muscles at the same time, increases the walking speed, and increases the oxygen uptake and heart rate[14,20].

The buoyancy of water reduces the effect of weight-bearing when exercising. At the depth of the shoulder, 90% of the body weight is reduced, and at the waist down to 41% of the body weight5. Because of the decrease in weight load due to buoyancy, the movement can be made more freely in the water than in the ground,Biomechanical stresses resulting from interactions between internal and external forces are reduced, reducing the impact on joints and the risk of injury[21]. In addition, it has been reported that the buoyancy in water can reduce the weight burden of the lower limb relative to the ground, and the greater the velocity, the greater the exercise intensity[22].

EMG is a method to detect the potential difference caused by the ion exchange in the muscle fiber membrane from the central nervous system during muscle contraction, and the obtained signal can be used to measure the muscle force expression by calculating the integrated EMG in the machine[23,24]. The fact that the integral EMG are not increased in the resistance exercise means that the mobilization of the muscle fibers is less and the muscle force is more efficient[25].

There was a statistically significant difference in the interactions between the methods and between the methods, and between the methods. There was a significant difference in the iEMG of the Vastus Lateralis, Vastus Medialis during Walking in the Water with water depth. Also, there was a statistically significant difference between the methods and the interactions between methods.

Lower extremity iEMG values were found at waist depth than knee depth. The fact that the integral iEMG did not increase means that muscle fiber mobilization is less and less muscle fatigue appears. When walking from the depth of the waist to the front, the pulling force acts on the torso and the pulling force acts on the lower leg at the depth of the knee[22, 25].Therefore, the use of femoral extensor muscle may be increased when walking at the depth of the knee. In previous studies, the iEMG of the lower limb was lower than that of the ground treadmill when walking aquatics treadmill [26]. When the water depth is lower than the level of the thoracic spine 11 during exercise in the water, balance is regulated by the lower limb[27]. In the case of aquatics exercise, the weight of body is reduced to half at the depth of the waist, resulting in lower turbulence and attitude change at lower water depths14.This is because when the height of the water is lowered to the depth of the anterior superior iliac spine (ASIS), when the leg is lifted, the load acting on the lower limb is increased to cause the posterior tilt of the pelvis, along with the anterior trunk muscle seems that muscle groups have to generate more thrust[28].

As heart rate increases during exercise, the heart rate is inevitably increased in order to send the oxygen needed for the tissue. This increase is due to a rise in body temperature, changes in the chemical composition of the blood, tension in the heart-promoting center, and venous return, and thus the heart rate is known to vary with the difference in exercise intensity[29].

In all Walking in the Water conditions, heart rate increased after Walking in the Water, but in ground walking, heart rate increased slightly before Walking in the Water, and after knee depth and waist depth increased significantly after Walking in the Water. According to the previous research, it was suggested that the rapid increase of the water resistance and the increase of the exercise intensity could be caused by the rapid movement of the water in the water, and the increase in the oxygen uptake and the heart rate due to the increase in the load on the iEMG due to the viscosity[18,5]. Walking in the Water is reported that half speed is enough to obtain the same energy consumption level at the ground19. This study also shows that the speed in the swing phase in Walking in the Wateris similar to the ground walking.

## 5. Conclusion

The purpose of this study was to investigate the effect of Walking in the Water on the Heart rateand the iEMG of the Vastus Lateralis, Vastus Medialis, Tibialis Anterior, Gastrocnemius Medialhead. Seven men in their 20s who had no health problems were selected and they were allowed to walk for 3 minutes at a rate of 1 beep per second in water of the knee and water of the waist. During the Walking in the Water exercise, heart rate was measured, and iEMG of the Vastus Lateralis, Vastus Medialis, Tibialis Anterior, Gastrocnemius Medialhead were measured before and after Walking in the Water.The order of water walking according to depth of water was randomly distributed. The results obtained from the experiment are as follows.

First, the iEMG of the Vastus Lateralis, Vastus Medialis, Tibialis Anterior, Gastrocnemius Medialhead increased at the knee depth after the Walking in the Water rather than before the Walking in the Water, and decreased at the waist deep after the Walking in the Water rather than before the Walking in the Water.

Second, the heart rate increased with water depth before and after Walking in the Water, and the increase pattern in waist depth Walking in the Water motion was larger than the increase pattern in Walking in the Water in knee depth.

Therefore, it is Walking in the Water at the appropriate depth of water according to the purpose when walking aquatics using the characteristics of water, and it is desirable to train the fitness of the strength and the diversity of cardiopulmonary training appropriately.

## Acknowledgment

This study was conducted as part of on operation of Hot Spring exercise program in Asan City.

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