MAKU J. Health Sci. Inst. 2023, 11(2): 212-220.
doi: 10.24998/maeusabed.1297698

Mehmet Akif Ersoy University
Journal of Health Sciences Institute
http://dergipark.gov.tr/maeusabed

Research Article / Araştırma Makalesi

Comparison of Effects of Water-Based and Land-Based High-Intensity Interval Training on Aerobic Capacity and Spinal Stabilization

Su içinde ve Karada Yapılan Kısa Dönem Yüksek Şiddetli Aralıklı Egzersiz Eğitiminin Aerobik Kapasite ve Spinal Stabilizasyon Üzerine Etkilerinin Karşılaştırılması

Neyran ALTINKAYA[1], Barış GÜRPINAR[2*], Nursen İLÇİN[3]

[1]Final International University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Mersin, Türkiye
[2]İzmir University of Economics, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, İzmir, Türkiye
[3]Dokuz Eylül University, Faculty of Physical Therapy and Rehabilitation, İzmir, Türkiye

Abstract: The purpose of the study is to examine the effects of a two-week period of high-intensity interval training (HIIT) in water and land-based running on aerobic capacity and spinal stabilization. Forty-one healthy young participants were divided into water-based exercise, land-based exercise, and control groups. Aerobic capacity was measured with 20-m Shuttle Run Test, and spinal stabilization was tested with 60° Flexion test and Sorensen test. Water and land-based exercise groups performed six sessions of HIIT program for two weeks. A significant improvement in aerobic capacity and spinal stabilization was found between the baseline and after two-week evaluations in both the water and land based HIIT exercise groups ($p<0.05$). The increase in aerobic capacity and extensor spinal muscle endurance were found similar in both exercise group yet increase in flexor spinal stabilization endurance was statically more significant in land exercises ($p= 0.038$). This study shows that the two-week period of HIIT exercises, both in water and on land, can be safely used to improve aerobic capacity and spinal stabilization, even in the short term.

Keywords: Aerobic capacity, Aquatic exercise, Core stability, HIIT.

Öz: Çalışmanın amacı, suda ve karada yapılan iki haftalık yüksek şiddetli aralıklı egzersizin (YŞAE) aerobik kapasite ve spinal stabilizasyon üzerindeki etkilerini incelemektir. Kırk bir sağlıklı genç katılımcı, su içi egzersiz, kara egzersizleri ve kontrol grubu olarak ayrıldı. Aerobik kapasite 20 m Mekik Koşusu Testi ile, spinal stabilizasyon ise 60° Fleksiyon testi ve Sorensen testi ile ölçüldü. Su ve kara egzersiz grupları iki hafta boyunca altı seanslık YŞAE programı gerçekleştirdi. Hem su hem de kara YŞAE egzersiz gruplarında başlangıç ile iki haftalık değerlendirmeler arasında aerobik kapasite ve spinal stabilizasyonda anlamlı bir iyileşme bulundu ($p<0.05$). Aerobik kapasite ve ekstansör spinal kas enduransındaki artış her iki egzersiz grubunda benzer bulunurken, fleksör spinal stabilizasyon enduransındaki artış kara egzersizlerinde istatistiksel olarak daha anlamlıydı ($p= 0.038$). Bu çalışma, hem suda hem de karada iki haftalık YŞAE egzersizlerinin kısa sürede bile aerobik kapasiteyi ve omurga stabilizasyonunu geliştirmek için güvenle kullanılabileceğini göstermektedir.

Anahtar Kelimeler: Aerobik kapasite, Su içi egzersizler, Core stabilite, YŞAE.

*Corresponding author : Barış GÜRPINAR   e-mail : baris.gurpinar@ieu.edu.tr
Geliş tarihi / Received : 16.05.2023   Kabul tarihi / Accepted: 14.07.2023

Introduction

Physical inactivity has an essential role in contemporary health problems. Moreover, it also causes many systemic diseases and infections (Lee et al., 2012). The various barriers to physical activity have been the subject of many studies to date; however, the most common cause of physical inactivity is 'timelessness' (Trost, Owen, Bauman, Sallis, & Brown, 2002).

To cite this article: ALTNKAYA N, GÜRPINAR B, İLÇİN N. (2023). Comparision of Effect of Water-Based and Land-Based High-Intensity Interval Training on Aerobic Capacity and Spinal Stabilization. MAKU J. Health Sci. Inst., 11(2), 212-220.

ISSN: 2148-2837/ MAKU J. Health Sci. Inst.

High-intensity interval training (HIIT) is a repetitive exercise stage consisting of severe exercise periods interspersed with recovery intervals. Depending on the severity of the exercise, the severe exercise period can extend from a few seconds to a few minutes, with recovery periods consisting of rest or low-intensity exercises (Gibala & McGee, 2008). HIIT has been mainly used for athletes; however, recent studies show that HIIT is used in clinics and also in healthy populations (Broman, Quintana, Lindberg, Jansson, & Kaijser, 2006; Gillen et al., 2014; Nagle, Sanders, & Franklin, 2017; Wilber, Moffatt, Scott, Lee, & Cucuzzo, 1996).

The essential characteristic of HIIT from other aerobic exercises is that it is effective in periods as short as two weeks. People report seeing similar effects on their body composition as they would over a longer time period (Gillen et al., 2014).

Although a growing body of research shows that HIIT is an effective, safe, time-efficient, and enjoyable exercise, there is no consensus on training protocol or exercise principles. It is possible to do HIIT in water as well as on land. Despite the publication of a number of studies of water-based HIIT exercises, we found none focused on the comparison of water-based and land-based HIIT in short term (Broman et al., 2006; Mohr et al., 2014; Nagle et al., 2017; Rebold, Kobak, & Otterstetter, 2013; Wilber et al., 1996).

Accordingly, we aimed to investigate the comparison of the effects of deep water running (DWR) as HIIT and land-based running on aerobic capacity and spinal stabilization over a two-week period.

Materials and Methods

This study was conducted between February 2016 and May 2016, at the Near East University, Department of Physiotherapy and Rehabilitation. The Olympic swimming pool on the university campus used for water-based exercise. Two specialist physiotherapists were involved, one applied the evaluation procedure, and the other carried out the training sessions. Both the participants and therapists were blinded in the trial. Written informed consent was obtained from all participants. The Ethical Committee approved the study protocol of Dokuz Eylül University in Izmir, Turkey (Approval No. 2016/06-40).

Participants

The power analysis was calculated by G*power software and based on the effect size 0.65 obtained, assuming a power of 0.8 at an alpha level of 0.05. The sample size computed was 13 or more subjects per group. Considering dropout's probability 15 volunteers were recruited in each group.

Forty-five healthy young voluntary participants, the ages of 18-25 years were included to this study. They were divided into three groups: water-based exercise, land-based exercise, and controls randomly.

After the elimination of the applicants, computer-generated randomization was used for the grouping of the individuals. The volunteers were excluded if they had cardiovascular or musculoskeletal disease, any obstacle for exercise, chlorine allergy, or difficulties with water immersion. The characteristics of the participants are summarized in Table-1.

Outcomes

Participants performed the 20 m Shuttle Run Test (SRT) to determine the aerobic capacity (VO_{2max}). In this test, participants run back and forth on a 20 m course, touching the 20 m line each time; at the same time, a sound signal is emitted from a pre-recorded tape. The frequency of the sound signals is increased by 0.5 km h^{-1} each minute from a starting speed of 8.5 km h^{-1}. When the subject can no longer keep the pace, the last stage number announced is used to predict maximal oxygen uptake (VO_{2max}) (S. Ahmaidi, K. Collomp, C. Caillaud, & C. Prefaut, 1992; Hızal, Açıkada, Hazır, & Tınazcı, 1997).

To cite this article: ALTNKAYA N, GÜRPINAR B, İLÇİN N. (2023). Comparision of Effect of Water-Based and Land-Based High-Intensity Interval Training on Aerobic Capacity and Spinal Stabilization. MAKU J. Health Sci. Inst., 11(2), 212-220.

ISSN: 2148-2837/ MAKU J. Health Sci. Inst.

Table 1. The characteristics of the participants

Variables	Land-based exercise $\bar{x}$ ±SD	Pool-based exercises $\bar{x}$±SD	Control $\bar{x}$±SD	p
Age (year)	21.66±2.97	22.00±2.97	20.35±1.08	0.21
Height (cm)	171.00±8.10	170.46±10.03	168.14±9.14	0.62
Weight (kg)	66.26±11.18	68.76±13.80	61.78±10.41	0.33
BMI (kg/m²)	22.54±2.41	23.66±4.45	21.70±1.65	0.35

Kruskal Wallis Variance Analysis, X:Mean, SD: Standart Deviation, BMI: Body Mass Index

VO2max was calculated by placing the result calculated with the age of the participant, and velocity determined by using the distance covered in 30 seconds during the last stage of the test (S Ahmaidi, K Collomp, C Caillaud, & C Prefaut, 1992).

VO2max = 31.025 + (3.238 x velocity) - (3.248 x age) + (0.1536 x age x velocity)

Spinal stabilization was tested a 60° Flexion test and Sorensen test.

60° Flexion test: Participants sat on the test bench and placed their upper body against a support with an angle of 60° from the testbed. Both the knees and hips were flexed to 90°. The arms were folded across the chest, hands were placed on opposite shoulders, and toes were tucked under the toe straps. Participants maintained this position while the researcher moved the supporting wedge back 10 centimeters from the subject's back to begin the test. Time until the upper body fell below 60° was recorded (Anderson, Barthelemy, Gmach, & Posey, 2013).

Sorensen test: Participants lied on an examination table in prone position with their lower body was strapped to the bench. The edge of table was aligned with the anterior–superior iliac spines. They were asked to hold the position as long as they could while their hands were folded across their chest. The test was terminated if they had no difficulty longer than 4 minutes.

Interventions

After a five-min warm-up (stretching and jogging), participants wore a waist belt attached to pool wall with rope and practiced high knee style DWR in a "5 m Olympic pool". They performed six sessions of HIIT program over two weeks. This training includes five sets of one-minute high-intensity running at 16-20, and three-minutes moderate-intensity running at 11/20, according to Borg Scale (Borg, 1982; Killgore, Wilcox, Caster, & Wood, 2006). Borg scale was explained and demonstrated to the participants in a separate session and was continually monitored during exercise sessions.

The same HIIT exercise protocol was used for the land-based group in the exercise room. There was no exercise training performed in the control group, who were asked to maintain their regular physical activity level. Assessments were performed by the same researcher at the beginning and the end of the two-week period.

Statistical analyses

SPSS Version 22.0 (IBM Corporation, Armonk, NY, USA) was used for all statistical analyses. The Shapiro–Wilk test indicated that the variables did not have a normal distribution. Kruskal Wallis variance analysis test was used to compare the three groups. Wilcoxon tests were applied to determine the results from dependent groups. The Mann-Whitney U test was used to compare the differences between two independent groups. Significant results were then analyzed by post-hoc tests (Wilcoxon signed ranks test with Bonferroni correction) in which the significance level was set at 0.017 (0.05/3) after Bonferroni correction.

To cite this article: ALTNKAYA N, GÜRPINAR B, İLÇİN N. (2023). Comparision of Effect of Water-Based and Land-Based High-Intensity Interval Training on Aerobic Capacity and Spinal Stabilization. MAKU J. Health Sci. Inst., 11(2), 212-220.

ISSN: 2148-2837/ MAKU J. Health Sci. Inst.

Results

Four participants were failed to show up to the last assessment therefore, forty-one participants with the mean age of 21.33±2.29 years and average BMI 22.61±3.04 kg/m² were concluded the study. There were no significant baseline differences between groups (p>0.05) (Table 1).

After two weeks of HIIT, aerobic capacity increased significantly in both water and land-based groups (p<0.05). There was no difference was found in aerobic capacity of control group.

Spinal stabilization was significantly increased in both exercises groups. There was no statistically significant difference regarding Sorenson Tests scores between two exercise groups (p= 0.038). However, 60° Flexion test scores were statistically higher in land exercise group than water exercise group (p< 0.001) (Table 2).

A comparison of baseline and two weeks later measurements revealed significant differences between the water and control groups, and also between land-based exercise and control groups (p<0.05).

Discussion

The results of our study show that both water and land based HIIT exercises are effective in the improvement of aerobic capacity and spinal stabilization even in a period as short as two weeks. Also, compared to water-based HIIT, land-based HIIT was more effective on spinal stabilization. However, there is no significant effect on the aerobic capacity results between the two groups. To our knowledge, this is the first study aiming to compare HIIT exercises in water and on land. The results showed that HIIT is safe and effective in increasing aerobic capacity and spinal stabilization, even over a two-week period.

In previous studies, it is well documented that HIIT is an effective method in improving aerobic capacity in water and land (Nagle et al., 2017; Talanian, Galloway, Heigenhauser, Bonen, & Spriet, 2007), and the results of our study were consistent with these.

Comparing exercise responses between water and land conditions is a complex subject as there are many influencing factors. The intensity of the aerobic exercise is generally monitored by heart rate; however, heart rate changes not only by immersion in water but also depending on water temperature (B. E. J. P. Becker, 2009). On the other hand, exercise intensity changes according to whether subjects are stationary or moving in the water. Due to viscosity, faster movements in water create greater resistance (B. E. Becker, 2020; Cole & Becker, 2004). Therefore, any change in the experiment design directly effects the exercise responses, which complicates the comparison of land and water exercises.

Comparisons of DWR and treadmill exercises in previous studies (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991) showed that treadmill exercises require higher maximum oxygen uptake (VO_{2max}), and ventilation volume. These studies restricted participants by attaching them to the pool wall, and exercise load on land was determined by the speed and inclination of the treadmill, whereas cadence was used in the water run. Authors noted that adjusting the workload in water was inefficient and awkward.

They also reported the heart rate was lower in DWR, yet they did not use the immersion heart rate lower than land. Michaud et al compared water and land running at the same exercise intensity (75% of VO_2 Peak) and found that blood lactate and perceived of excursion were significantly higher, whereas heart rate was significantly lower in DWR (Michaud, Rodriguez-Zayas, Andres, Flynn, & Lambert, 1995).

Town and Bradley, observed that both running in shallow water and treadmill HIIT increased VO_{2max} more than deep water running (Town & Bradley, 1991). Kruel et al found that treadmill exercises increased VO_{2max} and muscle activity more than DWR (Kruel et al., 2013).

To cite this article: ALTNKAYA N, GÜRPINAR B, İLÇİN N. (2023). Comparision of Effect of Water-Based and Land-Based High-Intensity Interval Training on Aerobic Capacity and Spinal Stabilization. MAKU J. Health Sci. Inst., 11(2), 212-220.

ISSN: 2148-2837/ MAKU J. Health Sci. Inst.

Table 2. The comparison of exercise effectiveness between the three groups.

	Aquatic Group (n=16) Median (Quartiles)		**Land Group (n=13)** Median (Quartiles)		**Control Group (n=17)** Median (Quartiles)		
	Before	**After**	**Before**	**After**	**Before**	**After**	**p value**
VO2max (ml/kg/dk)	28,7 (2250/31.3)	31.0*[c] (28.3/34.2)	28,4 (26.5/31.0)	30.8*[b] (27.4/35.2)	25.7 (24.2/26.6)	25.3 (23.7/26.5)	
Δ	2.2 (0.7/2.2)		2,3 (0.8/4.5)		-0.4 (-0.8/0.5)		**$p<0.001^{\#}$**
60° flexion test (sec)	51.0 (41.7/62.2)	70.4* [c] (55.6/85.7)	43.8 (36.9/50.7)	105.0*[a b] (80.8/121.9)	40.2 (33.3/48.1)	39.7 (31.4/47.9)	
Δ	19.4 (8.9/30.1)		61.2 (40.5/86.2)		-0.5 (-1.2/2.8)		**$p<0.001^{\#}$**
Sorensen Test (sec)	59.6 (47.4/71.8)	80.7* [c] (68.1/92.2)	35.6 (25.3/41.2)	86.7* [b] (66.7/102.4)	38.2 (29.1/47.2)	37.5 (8.3/46.8)	
Δ	21.0 (13.2/29.3)		51.0 (28.7/79.8)		-0.7 (2.3/3.5)		**$p<0.001^{\#}$**

VO2max: Maximum Oxygen Uptake; Kruskal Wallis Test #p<0.05; Wilcoxon Signed Rank Test *p<0.05 within groups;
a-c (post-hoc Mann–Whitney U test between groups test with Bonferroni correction resulting in a significance level of p< 0.017).
a Aquatic versus land; b Land versus control; c Aquatic versus control.

To cite this article: ALTNKAYA N, GÜRPINAR B, İLÇİN N. (2023). Comparision of Effect of Water-Based and Land-Based High-Intensity Interval Training on Aerobic Capacity and Spinal Stabilization. MAKU J. Health Sci. Inst., 11(2), 212-220.

ISSN: 2148-2837/ MAKU J. Health Sci. Inst.

The researchers underline two factors which limit VO_{2max} and spinal muscle activity improvement during DWR. The first is the lack of contact between the extremities and the floor. The other is the support of the belt, which takes the bodyweight during DWR (Masumoto, Applequist, & Mercer, 2013; Oddsson, 2019).

Masumuto et al. applied EMG tests on four muscles, and they showed that treadmill exercises increased muscle activity more than DWR. They observed that muscle activity was affected by the mode of DWR (Masumoto et al., 2013; Masumoto, Horsch, Agnelli, McClellan, & Mercer, 2014; Masumoto, Mefferd, Iyo, & Mercer, 2018; Masumoto, Takasugi, Hotta, Fujishima, & Iwamoto, 2005). Also, DWR and treadmill exercises gave similar results in rate of perceived exertion when applied at an equal heart rate. Unlike these studies, we used DWR and running as HIIT, thus found similar results. To our knowledge, no study has investigated the effects of water based HIIT on spinal stabilization. Bressel et al. gave 11 spinal stabilization exercises in shallow water (Eadric Bressel, Dolny, & Gibbons, 2011), and reported higher EMG activity of spinal stabilization muscles except for erector spines compared to land-based exercises. These results can be explained with the effect of hydrostatic pressure and buoyancy, which suggests that trunk muscles provide less stabilization in water. Pöyhönen and Avela explained the decrease of EMG activity as being due to hydrostatic pressure causing the presynaptic inhibition in inter-neuronal pathways by stimulating the body's mechanoreceptors (Poyhonen & Avela, 2002).

Meanwhile, according to their study results, the muscular temperature affected the frequency and magnitude in shallow water. Studies using EMG and computer techniques have shown that muscle endurance depends on the co-activation of all trunk muscles, and is not more effective on one muscle than on another (E. Bressel, Dolny, Vandenberg, & Cronin, 2012). Masumuto et al. examined the effect of land-walking and water-walking exercises on the trunk and lower extremity muscle activation (Masumoto et al., 2005). Also, they observed land exercise EMG results, which were found to be higher in all muscles except paraspinal muscles. They also argue that water exercise against a current increases muscle activity more than other types of water exercises. Our study results showed that 2 weeks HIIT DWR increased spinal muscle endurance, land based exercises were more effective for trunk flexors than water based exercises. It is due to the elimination of the gravitational force, which creates resistance on land during running, in the water. There were no statistically significant difference regarding trunk extensors between on land and in water this could be the result of increased paraspinal muscle activation (Masumoto et al., 2005) balancing elemination of gravitational forces.

As a result of our study, we can say that in parallel with the literature, the two-week HIIT training improves the aerobic capacity with the increase of the VO_{2max} level. In different populations, HIIT results were found to be similar. Studies have shown that HIIT increases VO_{2max} more than other exercise modalities in healthy people (Cicioni-Kolsky, Lorenzen, Williams, & Kemp, 2013; Helgerud et al., 2007), those with the cardiometabolic disease (Weston, Wisloff, & Coombes, 2014), athletes (Etxebarria, Anson, Pyne, & Ferguson, 2014; Yang, Lee, Hsu, & Chan, 2017) and adolescents (Costigan, Eather, Plotnikoff, Taaffe, & Lubans, 2015). According to the results of the lumbar stabilization tests in our study, we can say that short-term HIIT on land was more effective than water based HIIT. Bayraktar et al (Bayraktar et al., 2016) gave training to core stabilization in water and land for three days a week for eight weeks. The featured result was the improvement in the core stabilization parameters of both groups, and there was no difference between them. In literature, no study investigated the effect of HIIT on the core muscles. Another study about HIIT on low-back pain concluded that these exercises retained motivation leading to better rehabilitation (Verbrugghe et al., 2018). Our study was

To cite this article: ALTNKAYA N, GÜRPINAR B, İLÇİN N. (2023). Comparision of Effect of Water-Based and Land-Based High-Intensity Interval Training on Aerobic Capacity and Spinal Stabilization. MAKU J. Health Sci. Inst., 11(2), 212-220.

ISSN: 2148-2837/ MAKU J. Health Sci. Inst.

performed in healthy young individuals, compatible with literature.

Moreover, this study is distinct from the literature as it compares the effects of water-based and land-based HIIT. Although the examples of HIIT were previously studied in the water and on land using different groups, no studies were found comparing water and land to assess which is the most effective exercise environment. Our research shows that water and land based HIIT have similar results, and both are beneficial. The number of studies about the effects of HIIT in clinical populations is constantly increasing day, and this approach is widely used in the athletic group. However, there are no HIIT guideline for clinical or healthy populations (Taylor et al., 2019). The intention of the study was to compare the short-term effects of HIIT in water and on land that is why long-term effects could not be interpreted by this paper. There is therefore a need for studies to compare the effects of HIIT on land and in water on individuals in different diagnostic groups.

Another important aspect of our work is the comparison of land and water based HIIT as short-term effects. This study shows that HIIT has potential to increase cardiovascular fitness in healthy people. There are some limitations in our study: muscle strength could not be assessed objectively due to equipment failure, and aerobic capacity was calculated indirectly by the shuttle run test.

Conclusions

In summary, according to the results of this study, six sessions of HIIT have produced positive results in the core stabilization with no adverse effect. The two-week HIIT appears to increase spinal stabilization both in the water and on land, confirming our hypothesis. Another finding of this study was HIIT is widely used in the clinic because it increases aerobic capacity and spinal stabilization on land and in water, even when applied for a relatively short time. It provides motivation, time-saving, and enjoyment. HIIT will be a solution, especially for those who complain about lack of time.

For this reason, it is potentially a valuable option for the clinician in the athletic, clinical, and healthy population. This is an advantage when HIIT is performed in water, and especially as group exercises. A significant increase in muscle stabilization in the short term of HIIT may be considered as an important contribution to the literature. In view of the limited number of studies with water based HIIT, there is a need for further studies on HIIT in water and on land.

References

Ahmaidi, S., Collomp, K., Caillaud, C., & Prefaut, C. (1992). Maximal and functional aerobic capacity as assessed by two graduated field methods in comparison to laboratory exercise testing in moderately trained subjects. *Int J Sports Med, 13*(3), 243-248. doi:10.1055/s-2007-1021261

Anderson, David; Barthelemy, Lindsay; Gmach, Rachel; and Posey, Breanna. (2013). Core Strength Testing: Developing Normative Data for Three Clinical Tests. PhD, Sophia, the St. Catherine University repository website: https://sophia.stkate.edu/dpt_papers/21

Bayraktar, D., Guclu-Gunduz, A., Lambeck, J., Yazici, G., Aykol, S., & Demirci, H. (2016). A comparison of water-based and land-based core stability exercises in patients with lumbar disc herniation: a pilot study. *Disabil rehabil, 38*(12), 1163-1171. doi:10.3109/09638288.2015.1075608

Becker, B. E. (2020). Aquatic therapy in contemporary neurorehabilitation: an update. *PM&R, 12*(12), 1251-1259.

Becker, B. E. J. P. (2009). Aquatic therapy: scientific foundations and clinical rehabilitation applications. *Pm&r, 1*(9), 859-872.

Biering-Sorensen, F. (1984) Physical measurements as risk indicators for low-back trouble over a one-year period. Spine, 9, 106-107.

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Med Sci Sports Exerc, 14*(5), 377-381.

Bressel, E., Dolny, D. G., & Gibbons, M. (2011). Trunk muscle activity during exercises performed on land and in water. *Med Sci Sports Exerc, 43*(10), 1927-1932. doi:10.1249/MSS.0b013e318219dae7

To cite this article: ALTNKAYA N, GÜRPINAR B, İLÇİN N. (2023). Comparision of Effect of Water-Based and Land-Based High-Intensity Interval Training on Aerobic Capacity and Spinal Stabilization. MAKU J. Health Sci. Inst., 11(2), 212-220.

Bressel, E., Dolny, D. G., Vandenberg, C., & Cronin, J. B. (2012). Trunk muscle activity during spine stabilization exercises performed in a pool. *Phys Ther Sport, 13*(2), 67-72. doi:10.1016/j.ptsp.2011.06.002

Broman, G., Quintana, M., Lindberg, T., Jansson, E., & Kaijser, L. (2006). High intensity deep water training can improve aerobic power in elderly women. *Eur J Appl Physiol, 98*(2), 117-123. doi:10.1007/s00421-006-0237-2

Butts, N. K., Tucker, M., & Greening, C. (1991). Physiologic responses to maximal treadmill and deep water running in men and women. *Am J Sports Med, 19*(6), 612-614. doi:10.1177/036354659101900610

Butts, N. K., Tucker, M., & Smith, R. (1991). Maximal responses to treadmill and deep water running in high school female cross country runners. *Res Q Exerc Sport, 62*(2), 236-239. doi:10.1080/02701367.1991.10608716

Cicioni-Kolsky, D., Lorenzen, C., Williams, M. D., & Kemp, J. G. (2013). Endurance and sprint benefits of high-intensity and supramaximal interval training. *Eur J Sport Sci, 13*(3), 304-311. doi:10.1080/17461391.2011.606844

Cole, A. J., & Becker, B. E. (2004). *Comprehensive aquatic therapy*: Butterworth-Heinemann.

Costigan, S. A., Eather, N., Plotnikoff, R. C., Taaffe, D. R., & Lubans, D. R. (2015). High-intensity interval training for improving health-related fitness in adolescents: a systematic review and meta-analysis. *Br J Sports Med, 49*(19), 1253-1261. doi:10.1136/bjsports-2014-094490

Etxebarria, N., Anson, J. M., Pyne, D. B., & Ferguson, R. A. (2014). High-intensity cycle interval training improves cycling and running performance in triathletes. *Eur J Sport Sci, 14*(6), 521-529. doi:10.1080/17461391.2013.853841

Gibala, M. J., & McGee, S. L. (2008). Metabolic adaptations to short-term high-intensity interval training: a little pain for a lot of gain? *Exerc Sport Sci Rev, 36*(2), 58-63. doi:10.1097/JES.0b013e318168ec1f

Gillen, J. B., Percival, M. E., Skelly, L. E., Martin, B. J., Tan, R. B., Tarnopolsky, M. A., & Gibala, M. J. (2014). Three minutes of all-out intermittent exercise per week increases skeletal muscle oxidative capacity and improves cardiometabolic health. *PLOS ONE, 9*(11), e111489. doi:10.1371/journal.pone.0111489

Helgerud, J., Hoydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., . . . Hoff, J. (2007). Aerobic high-intensity intervals improve VO2max more than moderate training. *Med Sci Sports Exerc, 39*(4), 665-671. doi:10.1249/mss.0b013e3180304570

Hızal, A., Açıkada, C., Hazır, T., & Tınazcı, C. (1997). Modifiye Mekik Koşusu Testinin Güvenirliği Ve Geçerliği. *Spor Bilimleri Dergisi, 8*(4), 3-12.

Killgore, G. L., Wilcox, A. R., Caster, B. L., & Wood, T. M. (2006). A lower-extremities kinematic comparison of deep-water running styles and treadmill running. *J Strength Cond Res, 20*(4), 919-927. doi:10.1519/R-17465.1

Kruel, L. F., Beilke, D. D., Kanitz, A. C., Alberton, C. L., Antunes, A. H., Pantoja, P. D., . . . Pinto, S. S. (2013). Cardiorespiratory responses to stationary running in water and on land. *J Sports Sci Med, 12*(3), 594-600.

Lee, I. M., Shiroma, E. J., Lobelo, F., Puska, P., Blair, S. N., Katzmarzyk, P. T., & Lancet Physical Activity Series Working, G. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet, 380*(9838), 219-229. doi:10.1016/S0140-6736(12)61031-9

Masumoto, K., Applequist, B. C., & Mercer, J. A. (2013). Muscle activity during different styles of deep water running and comparison to treadmill running at matched stride frequency. *Gait Posture, 37*(4), 558-563. doi:10.1016/j.gaitpost.2012.09.019

Masumoto, K., Horsch, S. E., Agnelli, C., McClellan, J., & Mercer, J. A. (2014). Muscle activity during running in water and on dry land: matched physiology. *Int J Sports Med, 35*(1), 62-68. doi:10.1055/s-0033-1345131

Masumoto, K., Mefferd, K. C., Iyo, R., & Mercer, J. A. (2018). Muscle activity and physiological responses during running in water and on dry land at submaximal and maximal efforts. *J Strength Cond Res, 32*(7), 1960-1967. doi:10.1519/JSC.0000000000002107

Masumoto, K., Takasugi, S., Hotta, N., Fujishima, K., & Iwamoto, Y. (2005). Muscle activity and heart rate response during backward walking in water and on dry land. *Eur J Appl Physiol, 94*(1-2), 54-61. doi:10.1007/s00421-004-1288-x

Michaud, T. J., Rodriguez-Zayas, J., Andres, F. F., Flynn, M. G., & Lambert, C. P. (1995). Comparative exercise responses of deep-water and treadmill running. *J Strength Cond Res, 9*(2), 104-109.

Mohr, M., Nordsborg, N. B., Lindenskov, A., Steinholm, H., Nielsen, H. P., Mortensen, J., . . . Krustrup, P. (2014). High-intensity intermittent swimming improves cardiovascular health status for women with mild hypertension. *Biomed Res Int, 2014*, 728289. doi:10.1155/2014/728289

Nagle, E. F., Sanders, M. E., & Franklin, B. A. (2017). Aquatic high intensity interval training for cardiometabolic health: benefits and training design. *Am J Lifestyle Med, 11*(1), 64-76. doi:10.1177/1559827615583640

Oddsson, E. E. (2019). Effects of deep-water running and land-based running program on aerobic power, physical fitness and motivation on female youth footballers. MSc, Reykjavík University

Poyhonen, T., & Avela, J. (2002). Effect of head-out water immersion on neuromuscular function of the plantarflexor muscles. *Aviat Space Environ Med, 73*(12), 1215-1218.

Rebold, M. J., Kobak, M. S., & Otterstetter, R. (2013). The influence of a Tabata interval training program using an aquatic underwater treadmill on various performance variables. *J Strength Cond Res, 27*(12), 3419-3425. doi:10.1519/JSC.0b013e3182908a09

Talanian, J. L., Galloway, S. D., Heigenhauser, G. J., Bonen, A., & Spriet, L. L. (2007). Two weeks of high-intensity aerobic interval training increases the capacity for fat oxidation during exercise in women. *J Appl Physiol, 102*(4), 1439-1447. doi:10.1152/japplphysiol.01098.2006

Taylor, J. L., Holland, D. J., Spathis, J. G., Beetham, K. S., Wisloff, U., Keating, S. E., & Coombes, J. S. (2019). Guidelines for the delivery and monitoring of high intensity interval training in clinical populations. *Prog Cardiovasc Dis, 62*(2), 140-146. doi:10.1016/j.pcad.2019.01.004

Town, G. P., & Bradley, S. S. (1991). Maximal metabolic responses of deep and shallow water running in trained runners. *Med Sci Sports Exerc, 23*(2), 238-241.

Trost, S. G., Owen, N., Bauman, A. E., Sallis, J. F., & Brown, W. (2002). Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc, 34*(12), 1996-2001. doi:10.1097/00005768-200212000-00020

Verbrugghe, J., Agten, A., B, O. E., Olivieri, E., Huybrechts, X., Seelen, H., . . . Timmermans, A. (2018). Feasibility of high intensity training in nonspecific chronic low back pain: A clinical trial. *J Back Musculoskelet Rehabil, 31*(4), 657-666. doi:10.3233/BMR-170810

Weston, K. S., Wisloff, U., & Coombes, J. S. (2014). High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: a systematic review and meta-analysis. *Br J Sports Med, 48*(16), 1227-1234. doi:10.1136/bjsports-2013-092576

Wilber, R. L., Moffatt, R. J., Scott, B. E., Lee, D. T., & Cucuzzo, N. A. (1996). Influence of water run training on the maintenance of aerobic performance. *Med Sci Sports Exerc, 28*(8), 1056-1062. doi:10.1097/00005768-199608000-00017

Yang, M. T., Lee, M. M., Hsu, S. C., & Chan, K. H. (2017). Effects of high-intensity interval training on canoeing performance. *Eur J Sport Sci, 17*(7), 814-820. doi:10.1080/17461391.2017.1314553

To cite this article: ALTNKAYA N, GÜRPINAR B, İLÇİN N. (2023). Comparision of Effect of Water-Based and Land-Based High-Intensity Interval Training on Aerobic Capacity and Spinal Stabilization. MAKU J. Health Sci. Inst., 11(2), 212-220.