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Comparison of the effects of aquatic and landing plyometric exercise (training)on defence jumping and attack, agility and muscular contusion in female volley ball players

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A B S T R A C T

The present research was carried out to compare the effects of aquatic and landing plyometric exercise (training) on defence jumping and attack, agility and pain feeling in female volleyball players. 41 elite volleyball players from shiraz clubs participated in the research voluntarily and were divided randomly in three groups of landing exercide (12), aquatic exercise (12) and the control group (13).The control group attended in the exercise of their own volleyball team. The empirical groups were doing plyometric exercise for eight (8) weeks in addition to volleyball. Agility, defence jumping and three step jumping of attack were measured in three stages. 3×3 variance analysis was used for comparing sizes and groups, and independant T-test was used for repeated sizes and measuring level of pian feeling. The results showed that in defence jumping and attack, progress of aquatic group was higher in comparison to land group and the difference was significant (P‹%5). The level of muscular contusion was not significant at the end of eighth week (P›%5). Also in the agility test no signigicant difference was observed (P›%5). With respect to the progress of most subjects (cases) in the level of jumping height and agility in the aquatic group in comparison to land group, and also reduced injuries in them, it could be said that aquatic plyometric exercise is better than plyometric exercise on land because of adhesio and buoyancy properties of water.

Introduction

Volleyball as a sport is full in fast and explosive motions and techniques, along with power which is performed by each player repeatedly. These explosive and fast

motions along with maximum power and muscular ability is performed in shorter than one second, and the number of motions in one game (rally) is very high.

For strengthening the techniques of this field all players are selected with tall stature, and having tall stature and extended hands is an important factor in finding talented volleyball players (aptitudes). Therefore, with respect to the fact that all players are tall explosive power and jumping height are effective in their success rate on the net.

On the other hand, players who jump well lose less energy, and their energy reserve takes longer to evacuate, and consequently they feel less pain and after a longer time. Therefore strengthening of jumping is an integral component in body-building programmes in the field of volleyball(2). Plyometric means placing muscles in tension at the beginning of contraction and the tension energy is reserved in the muscles and subsequently, the reserved energy improves power (strength) and speed in the next contraction.

However, there are concerns over plyometric exercise because of the possibility of injuries during practice. As some researchers have mentioned various cases of intensive injuries of athletes world wide (all over the world), instances such as muscular strain, birds knee and tendon injuries have been observed during exercise(3). Also scientists have reported increase of hydroxiprolin (muscular injury index) in serum after a course of plyometric exercise (25).

An interesting topic in the science of practice is « transfer of practice effects». The case means that whether exercise in a different environment (such as water or height) could improve the individuals ´function (performance) in the desired environment, and this is the question which has evenly attracted the attention of researchers.

Previous research cases indicated increased jumping as a result of plyometric exercise on land (2,4,7,22), and few research cases have focused on similar studies in deep waters(20).

Also several research cases have been carried out in shallow waters in which assessment of jumping has not been taken into consideration , and the effects of plyometric exercise on some other factors such as muscular injury indices(26),muscular mass index(10) and performance of quadriceps muscle(4) have been studied.

Also a research was carried out by Robinson etal. In relation to doing plyometric exercise in water and comparing it´s performance on land. In the research they studied the effects of the aquatic exercise an ability , speed and level of muscular pain in women, and showed that the effects of aquatic plyometric exercise on improvement of speed functioning and ability is the same as land performance , and the difference is that the aquatic gtoup reported less sentivity to pain and muscular pain, and the difference was significant(17).

Miller etal. Studied the difference of effects of plyometric exercise in waist-high deep waters and chest-high deep waters on vertical jumping and reported the results as follows : the same rate of jumping improvement were observed in both methods of exercise(12).

Tsovrlov etal. Studied the effects of 24 weeks of resistance exercise on 12 elderly women over sixty in shallow waters and found the positive effects of nervo-muscular function and muscular strength in them , without feeling pain (24).

In his research, Thomas studied the effects of plyometric exercise on the agility of young football players and reported a significant difference. He believes that the strength of feet muscles have an important role in the rate of agility(25).

Barens assessed the correlation rate of muscular strength and agility on female volleyball players and reported a positive significant correlation(1).

As a result of playmetric exercise muscular strength is increased remarkably(13,18). Alami studied the effects of plyometric exercise on the agility of young badminton players. He states that plyometric exercise increase agility and recommends the use of such exercise in all athletic fields which need agility (22). with eight weeks of plyometric exercise by female volleyball players Lenert has reported the reduction rate of the time between pre-test and post-test in the agility test to be 31/0 of a second, showing that plyometric exercise improves agility , but the difference is not significant(9).

In his research, Starly studied the effects of plyometric exercise on land and in water on the strength of femural muscle, speed of running and vertical jumping of speed runners and concluded that: there was no significant statistical difference in pre-test between the three groups(aquatic exercise – land exercise and control) in the three dependant variables. Statistically,there is a significant difference between improvement of running speed in aquatic exercise group with land and control group. A significant difference was observed in the strength improvement of femural muscle between aquatic exercise group and not in the land exercise group. Statistically, there was no significant difference between improvement of vertical jumping in the two exercise groups, while in comparison to the control group, the difference was significant(20). Also in another research case, Stem etal. Compared the effects of six weeks of aquatic and on land plyometric exercise on jumping of 21 young male athletes . these individuals were divided in three groups of exercise in shallow water , knee-high depth ,on land exercise and control group . At the end of assessments they reported that both group had the same rate of progress in the improvement of jumping(21).

A study on the effects of plyometric exercise on jumping in waist-high deep water, with chest-high deep water showed that : both exercise methods improve jumping to the same rate(12) . Also in a study on the effects of six weekes of aquatic and land plyometric exercise on ability, agility and muscular pain of eighteen young students, Shaffer showed that at the end of the exercise course, increase in the jumping rate has been the same in both aquatic and land groups, and the difference between the two groups, has been in the level of muscular pain(18).

Ploeg and his collegues studied the effects of plyometric exercise at the high level and low level in water and low level on land on the jumping rate , power and muscular torque, And after six weeks of practice , they reported that: the average of jumping in both aquatic groups (high level and low level) had increase , but in the high level group the increase was significant , while in the land group a little reduction was observed(15).

Because of injuries caused by these exercises,the researchers decided to do the exercise in water to prevent injuries, and to find the best method for practice. But because these research cases are few, at present we can not say decisively that aquatic plyometric exercise is firstly as effective on improving muscular ability as doing it on land, and secondly prevents injuries,and further research is necessary on different athletic fields especially volleyball. With respect to the lack of research in this field especially on women, the researcher decided to carry out the present one, with the objective of comparing the effects of plyometric exercise on land and in water, on the agility, defence jumping and attack and also comparing the level of muscular pain after exercise.

Methodology of research

The present research is a semi-experimental one. The statistical community includes all athlete girls playing volleyball in the selected teams and clubs of shiraz city. Among the community 75 volunteers enrolled to participate in the research, among whom 41 athletes were selected based on estimation rules of sample volume (based on Burg and Gall table), with an age range of 18 to 30 years, having at least three years background in the field and not having any articular muscular injuries in the past six months, and were randomly divided in three groups of control (13), land exercise(12) and aquatic exercise(12). After filling consent forms, the selected athletes also filled a questionnaire on the background of injuries and disease.

Tools of measurement

A tape meter installed on wall,with %1 accuracy was used to measure the stature height of the subjects, Japan made(Q&Q) chronometer was used for time –recording of agility test.

Graduated board installable on wall with %1 accuracy was used for measuring defence jumping and attack jumping . with the purpose of measuring the pain feeling rate at the end of every week , the subjects were given a questionnaire including 10 point visual analogue scale along with body soreness chart based on which the rate and locality of muscular contusion were measured immediately after exercise and 24 hours later (delayed contusion).

Method of research and data collecting

The subjects in the exercise groups , were doing plyometric exercise for eight(8) weeks and three (3) session in a week , in addition to volleyball exercise. The land group did exercise on single days (Sunday,Tuesday,Thursday) in a hall and the exercise of aquatic group which were strictly similar to land group were done on couple days(Saturday,Monday,Wednesday) in a pool , and in shallow part with chest high depth of the athletes . The average temperature of water in the pool was 31 centigrades . To iradicate the effects of day and night rate both groups did the exercise at half past four to six p.m.

While the control group did only volleyball exercise and did not take part in any body-building and or plyometric exercise . with the purpose of recucing the effects of intervening variable(menstrvation) in the aquatic group , during the span of exercise, a windy pool (air pool) was used with dimensions 3×1/75 , and 50 cm depth in which the depth of water was exactly knee-high for the athletes. All subjects in the research received the time-table one session prior to exercise, and got aquainted with the manner of exercise.

Method of agility test

Line touch test which is special for volleyball players was used to measure agility . the subjects stand in a ready (prepared) state on the middle point of two lines which are drawn with three(3) meters from each other. By the order of the examiner, chronometer starts and the athlete moves between the two lines with full speed in a shuttle manner within a given span and touched the lines. The testing time was one minute, and the number of touches were considered as a record for the athlete . The test was repeated twice with three(3) minutes resting interval, and the best scores were recorded for him (Qarakhanloo,1385). In all tests, with the purpose of eliminating personal viewpoints, and change in sensitivity and accuracy of judgement, only one examiner was used in each test, and the same examiner did the measurements of the three stages of research.

Method of defence jumping test

The subjects were keeping both their hands up while standing in front of a graduated board in a defending state, leaving their finger-prints impregnated with plaster, and then jumped upwards in a defending state on the net, and put (left) marks on the graduated page with both hands. The motion was repeated three times with one minute rest intervals, and the best scores were recorded for them. The difference of maximum height of hand in standing state, and the highest jumping point of players in space were calculated and recorded(2).

Method of attack jumping test

For this test, the subjects stationed in front of a graduated board, and in a standing state and put marks with their superior hand in an extended state and impregnated with plaster. Then , by taking three steps in a given distance jumping upwards and touched the board with their superior hands,and their finger prints were recorded by observers. The motion was repeated three(3) times with one minute rest and the best scores were recorded.

The records were obtained by subtracting the maximum height of hand in standing state from the highest point of jumping by the athletes in space(2). It is noticeable that during all tests the examiner was stationed on a high platform to be better able to see and record the height of jumping.

Method of assessing the range of feeling pain

To measure the range of feeling pain in this research VAS norm was used. Visual Analogue Scale(VAS) is a tool for measurement which tries to show a method by means of which the range , continuity and value of something could be measured easier and better which is not possible to be measured directly.

The range of pain folt by patients is one of these items which is not possible to be measured directly. The rate of feeling is in the range of painless to endless pain . visual analogue scale is very high . Wewers & Lowe visual analogue scale norm were used in the present research.

A number (1-10) was provided for each point , and the patients specified the number while showing theit pain rate. Therefore , by having the numbers it was much easier and better to collect data and statistical reports(27).

Data analysis

Descriptive statistics were used in this research to determine average and standard deviation , and the statistical method of combined repeated tests in the inferential statistics was used for determining the effects of values and resistance in one group , and comparing groups with each other and interaction between groups and values. Also dependant T-test was used for comparing values and Scheffe test was used for comparing the groups. Also independant T-test was used to study the comparison of pain feeling in the athletes . all statistical stages were done using SPSS software serry 16.

Table.1 Protocol of 8 week plyometric traines in this research

Week	Tape of train	set	repeat	week	Tape of train	set	repeat
First	Trot jump Elastic jump Side jump (1leg) Sckut jump	2 2 2 2	15 15 15 10	5th	Rocket jump Sckut jump Zikzak jamp Side jump over balk 30 Side hop jumping	5 3 6 6 4	6 6 10 5 5
Sec	Elastic jump Side jump (1leg) Sckut jump Jump over conses	2 2 2 6	15 15 10 5	6th	Rocket jump Tweezer jump Side jump over balk 30 Zikzak jamp over conses Side hop jumping	5 3 6 4 4 4	6 6 5 5 10 5
3th	Elastic jump Side jump (1leg) Jump over conses Sckut jump Side jump (1leg)over conses	2 2 6 2 6	15 15 5 6 10	7th	Sckut jump Tweezer jump Side jump over balk 50 Zikzak jamp over balk 30cm Side hop jumping	3 3 3 4 4	6 6 5 10 5
4th	Side jump (1leg) Elastic jump Jump over balk30cm Side jump over balk 30	2 2 6 6 2	12 12 5 10 6	8th	Sckut jump Side jump over balk 50 Zikzak jamp over balk 30cm Side jump 2leg	3 3 4 4 4	6 6 5 10 10

Results and findings of the research

Repeated valuest F-test was used to study the effects of plyometric exercise on land and in water on the agility of volleyball players. The results obtained in F-test have been reported in table 2. According to the table , there is a significant difference both between values and groups , with less than 5% probability. Therefore scheffe pursuance test was used to study the difference between the groups.

Table.2 F-test corvelated to agility variable

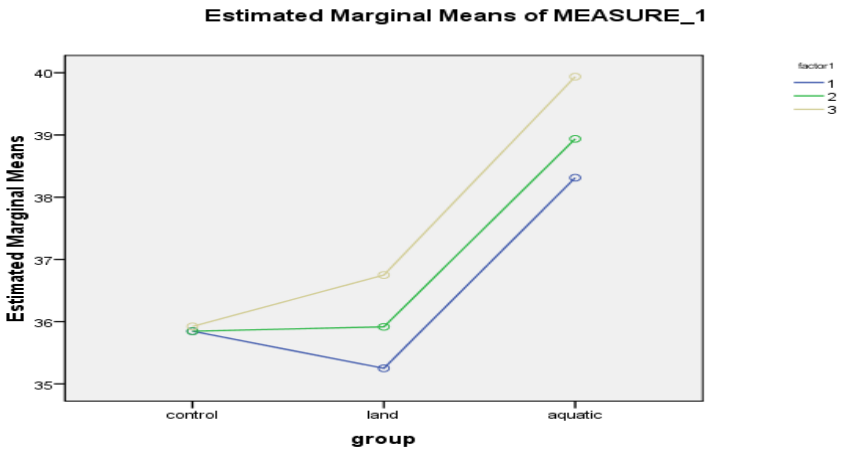
Unfore seen	P	F	Average squares	Degree of freedom	Total squares	Source of changes	
	0/010 0/41 ----	4/94 0/99 ----	12/51 2/52 2/52	2 4 76	25/02 10/08 192/22	Values interact error	Inside groups
	0/016 ----	4/65 ----	144/61 31/07	2 38	289/22 1180/81	Groups error	Between groups

The results obtained in scheffe test also showed that there is a difference between experimental group (land and water) , but the difference is not significant.

Table.3 Scheffe pursuance test to study the effects of plyometric exercise on agility, on land and in water(aquatic)

P	Standard error	Average difference	Statistical index group
0/03	1/20	3/19	Water Control
0/99	1/28	0/10	Control Land
0/05	1/22	3/09	Water land

Diagram.1 Paired comparison of test stages in the three(3) groups



2) F-test repeated values were used to study the effects of aquatic and land plyometric exercise on the defence jumping of volleyball players. As it is shown in table 4 there is no significant difference between values(size) and their interaction , but there is a significant difference between groups for the study of which scheffe persuance test was used.

Table.4 F-test , related to defence jumping variable

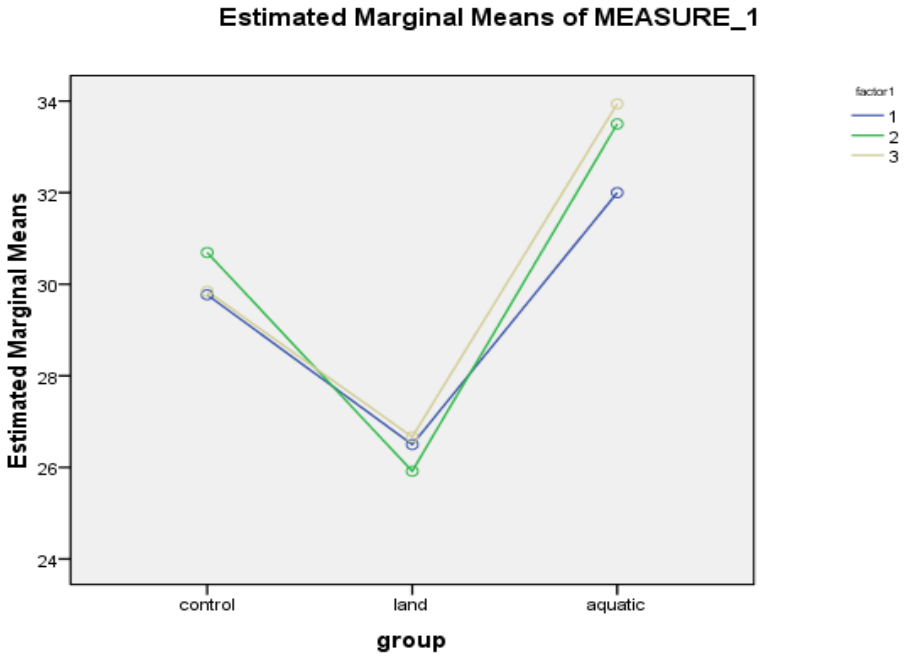
P	F	Average squares	Degree of freedom	Total squares	Source of changes	
0/32 0/43 ----	1/15 0/95 ----	8/22 6/78 7/12	2 4 76	16/43 27/14 541/74	Values Interact Error	Inside groups
0/00 ----	7/19 ----	473/72 65/80	2 38	947/44 2500/54	Groups Error	Between groups

The result obtained in scheffe test was that there is a significant difference between aquatic and land groups.

Table.5 Scheffe pursuance test to study the effects of plyometric and land exercise on defence jumping

P	Standard error	Average difference	Statistical index groups
0/15	1/87	3/74	Control Land
0/23	1/74	3/04	Aquatic Control
0/00	1/78	6/78	Aquatic Land

Diagram.2 Paired comparison of test stages in the three groups



3) F-test of repeated values were used to study the effects of aquatic and land plyometric exercise on attack jumping of volleyball players.

As it is shown in table 6 , the results obtained in F-test show that there is no significant difference between values and their interaction with a probability of less than five percent (‹0/05), but the difference is significant between the groups. Therefore , to study the case in groups scheffe pursuance test was used.

Table.6 F-test related to the variable of three step attack jumping

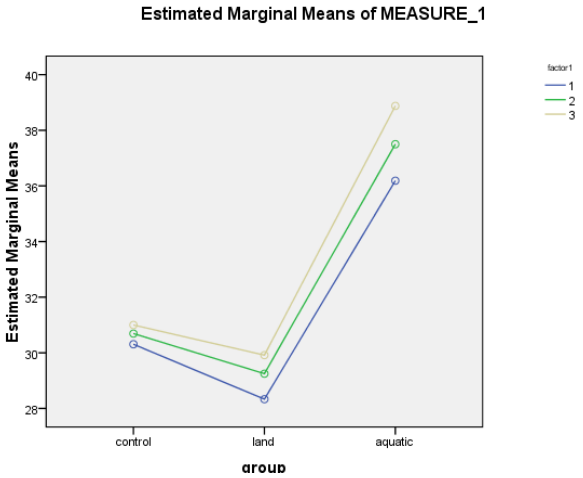
P	F	Average squares	Degree of freedom	Total squares	Source of changes	
0/04 0/82 ----	3/21 0/38 ----	30/57 3/64 9/56	2 4 76	61/51 14/57 726/58	Values Interact Error	Inside groups
0/003 ----	6/91 ----	860/59 124/49	2 38	1721/18 4730/97	Groups Error	Between groups

According to the report obtained from scheffe test and with probability of less than five percent (‹0/05) , P= 0/00 between aquatic and land groups showing that there is a significant difference between the two groups.

Table 7: scheffe pursuance test to study the effects of aquatic and land plyometric exercise on attack jumping

P	Standard error	Average difference	Statistical index groups
0/02	2/40	6/85	Aquatic Control
0/84	2/57	1/50	Control Land
0/00	2/46	8/35	Aquatic Land

Diagram.3 Paired comparison of test stages in the three groups



4) independent T-test was used to study the effects of aquatic plyometric exercise in comparison to land on less post- exercise muscular pain .
Based on the results the test shown in table 8 , it could be said that in the final week a difference was observed between the two groups , but not significant. Therefore, it could be said that muscular pain caused by plyometric exercise in water is less than performing the exercise on land.

Table.8 Comparison of average results obtained by causing (creating) muscular pain after plyometric exercise on land and in water

Independent T-test			aquatic		Land		groups
			Standard deviation	average	Standard deviation	average	
P	T-value	Degree of freedom	_____	_____	_____	_____	Stages of test
0/19	1/32	26	1/09	1/43	1/47	1/00	Pre-test
			0/89	0/56	2/10	1.33	Post-test

A session of water-aquaintance was arranged for the aquatic group before beginning exercise with the purpose of maintaining equilibrium in water. The exercises were in the form of increasing, and took 30 to 45 minutes for the same reason, and the timing was in addition to ten minutes of warming or cooling , and every session took one hour or longer.
All exercises were done after 10 minutes of warming in a jacking state and traction motions , and at the end also 10 minutes of traction motions were done to return to the first state. Every subject participated in the tests three times : before beginning exercise(pre-test), after four(4) weeks of exercise (midtest) , and after eight(8) weeks of exercise(post-test).

The effects of plyometric exercise on the agility of players

To assess performance ,the agility test was used which is specific for volleyball players. In a span of one minute , the frequency of going and returning of athletes on a distance of three(3) meters were counted. In this tesearch a progress in agility was observed between pre-test and post-test in both groups (P=0/01). The progress was observed to be higher between mid-test and post-test(P=0/006), showing the effects of plyometric exercise on increasing agility of athletes, and the rate of increase in aquatic group was observed to be a little higher, but however the difference between the two groups was not significant.

Also scheffer did not observe any difference in the agility of his subjects in the two groups after six weeks of plyometric exercise(18). In his research , Thomas studied the effects of plyometric exercise on young football players , and reported a significant difference. He believes that the strength of leg muscles has an important role in the rate of agility(25).
Barens assessed the correlation of muscular strength on female volleyball players and reported a positive significant correlation(1) . plyometric exercise cause a remarkable increase in muscular strength(13,18) . Alemi studied the effects

of plyometric exercise on the agility of young badminton players. He stated that plyometric exercise increases agility with eight(8) weeks of plyometric exercise by female volleyball players(22), Lenert reported the reducing rate of time between pre-test and post-test in agility test to be 0/31 of a second,showing that plyometric exercise improves agility but the difference is not significant(9).

The results obtained in these research cases, are in conformity with the results of present research . Therefore accordingly , it could be said that : it is probable that both types of aquatic and land exercise have nearly similar effects on improving the strength of leg muscles and consequently agility.

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Actually it could be probable that both groups have had the same resistance at the time of their exercise , the aquatic group resistance to water , and the land group attraction of earth. Of course the aquatic gtoup have enjoyed the attraction of earth in addition to reseistance to water, and maybe the same thing is the reason of their relative superiority over land group.

Effects of plyometric exercise on the rate of defence and attack jumping of players

In this research, the difference in the rate of defence jumping (P=0/002) and attack jumping (P=0/003) between the groups was significant.

The improvement rate of defence jumping in the average of aquatic group was 1/93 cm, while this progress was only 0/16 of a cm in the average of land group . Also in the average of attack jumping , progress of aquatic group was 2/69 cm , and in the average of land group 1/58 cm . Therefore in both cases , defence jumping and attack jumping in the aquatic exercise group progress was better and higher than land group. Miller has reported the improving effects of plyometric exercise on defence and attack jumping between 3/44 to 5/39 cm , a result which has been reported between 2 to 6 cm in a research by Hagel(5,11). In his research Polhemus reports the progress to be 8/12 cm(18). The highest rate of progress reported so far has been about 10/67 cm in a research by Adams and his colleagues(19).

Of course, they had used combined plyometric and resistance exercise . Briefly previos and the present research which were carried out in two aquatic and land environments show that plyometric exercises are effective on the progress of defence and attack jumping of volleyball players, and in the present research , the progress was observed to be better and higher in the aquatic group , and the reason maybe because the subjects have used adhesion properties and hydrostatic pressure of water as a resistance during the exercises, which caused increased muscular strength of their lower limbs higher than the land exercise group. But , research in this field is still insufficient and for better conclusion further research must be carried out.

Effects of plyometric exercise on the rate of pain feeling

Previous research cases showed tendon injuries(1) , stiffness of ligaments and injuries to muscles caused by plyometric exercise(14,26). These injuries are followed by pain and muscular stiffness. During the present research at the end of every week , the rate of pain feeling was measured using standard questionnaires VAS and Body Chart.

The results showed that, in the first week both groups experienced the same rate of muscular pain on (anterior & posterior of thigh) femur, leg and ankle and there was no difference between the two experimental groups . But from the second week on wards the rate of pain feeling came down in the aquatic exercise group until the fourth week the difference reached it´s maximum level and the rate of difference remained significant until the sixth week, but again, the rate of pain difference was not significant in the seventh and eighth weeks. Also pain was there only on the front part(anterior) of leg and ankle . in the first week that both groups had the same rate of pain , it could be because both groups had not already performed plyometric exercise, sudden increase of pressure caused by exentric contraction arison from the exercises ,have similarly stimulated the muscles of both groups.

But in the subsequent weeks, because of doing exercise in water, the aquatic group have suffered less injuries , and the rate of demolition and pain in the aquatic group was observed to be less. Probably, the water temperature has an important role in feeling pain.

The aquatic group did the exercise in a pool in which the water temperature was about 31 centigrades, a temperature which is helpful for muscular function and activities. Because the mentioned temperature improves blood circulation in veins (because of expansion of veins) and oxygenated blood reaches muscles better. Although, the expansion of veins occurs also in the land group, because the expansion is accompanied by muscular function, increase of oxigen is not the same as the aquatic group and accumulation of lactic acid occurs sooner in the land group(9,16,21).

Of course, in the land group the rate of progress thus continued until the fourth week that reached the highest point, and from the sixth (6^{th}) week on wards, probably by increase of physical preparedness in the land exercise group, the rate of feeling pain in them also reduced. These results are in conformity with the data obtained in the previose research cases(11,20). Although Miller observed the difference between groups in expressing muscular pain, he did not announce the difference to be significant. In his research, he used body-chart to show the exact location of pain, and reported most pain in the muscles of back part and front part(posterior & anterior) of thigh and gasteoscnemius muscle, and announced that, the response was different between the two groups to touching these three(3) parts and the difference was significant(11).

Robinson reports that even 48 to 96 hours after exercise the land group had more muscular pain in comparison to the aquatic group(16). In his research Shaffer announced an overall significant difference in the rate of pain feeling of subjects between the first to sixth weeks. He also announced that separately in all weeks no significant difference has been observed between the two experimental aquatic and land groups, but in the third and fourth weeks the difference has been significant. He has reported the highest rate of muscular pain in the first week, he also believes that because in the first week muscular activity has suddenly increased this rate of pain appeared. Shaffer also used body- chart in his study and stated that in the first weeks pain feeling has been in the front and back muscles of thigh(femur), and by intensifying exercises in the fourth week, leg pain was observed in the land group(17).

Plag used a pain feeling questionnaire in his research. he also reported a significant difference between the two aquatic and land exercise groups. but in his research, the most interesting difference between the two groups has occurred in the first week , and in the sulosequent weeks the difference was not significant. Maybe becaused Plag has used low-intensity plyometric exercise for the land group in his research, and the lows intensity has affected his remarkable conclusion(14) . Starley states that he has not collected statistical data of pain feeling , but only the repeated oral reports of subjects on expressing muscular pain , articular stiffness and ankle sprain in the land group , while these concerns were not present in the aquatic group , and he came to the probability that aquatic plyometric exercise will be followed by less injuries (23). with respect to the results obtained in the present and previous research cases, it could be said that , heat and buoyancy properties of water prepares a good environment for plyometric exercise , and the subjects will be able to perform flexibility motions will full ability, strength and also rehabilitation of injured muscles.

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