Chapter II

Review of Related Literature

Sincere efforts have been made by the research scholar to locate the related literature. This chapter deals with literature related to present study. The research scholar had gone through the literature available in the library of Dr. Babasaheb Ambedkar Marathwada University, Aurangabad. It was raveled that number of studies has been conducted on the relevant literature to the present study has been abstracted to provide background material for selection of its methodology and ultimate interpretation of findings. The research scholar found relevant studies in the various sources, whatever he could get are enumerated in this chapter.

2.1 Reviews Related to Different Starting Style:

Race analysis of the 1991 pan pacific championships (Mason and Cossor 2000)\(^1\) has revealed that starts times (time to 15M) are significantly related to race him in most events regardless of the stroke. This would be expected for short distance events but. Surprisingly, includes the men’s and women’s 400m free styles events.

In events other than relays, the grab starts has become favored over the arms swing or conventional start among elite competitive smimmer. At the 2000 Sydney Olympic the arm swing start was not used by any finalist. The general explanation is that the grab start
permits the center of mass to be further forward and thereby reduces the time required to attain a position in which large horizontal forces can be applied to generate motion horizontally. The track start is basically a variant of the grab start. In the track start one foot is further forward then the other. Within track starts variants have been identified. These are the forward weighted track starts and the rear weighted “slingshot track start.”

Welcher et.al. (1999)² compared the grab start, forward weighted track start and weighted track start (slingshot) and found that there were no significant differences between the three techniques for time to 5M. A view starting technique has been developed with the introduction of the ‘Anti wave Super Block’. The blocks are designed to enable a swimmer to place position prior to the start by having a handle above the flat surface of the block.

Person et. al. (1998)³ found that performance to 7M for the handled start were equal to these grab start, which was the subjected preferred technique. They found that there was not significant difference between the grab starts and the handle starts despite the fact that the subjects were un experienced in using this start of the time of testing. Thus, it was recognized that with practice the handled blocks may yield improved performance.

Blanksby, Nicholson, and Elliott accepted (2001)⁴ conducted on intervention study to determine whether any of the grab, track or handle swimming start yielded a faster time to 10m among elite swimmers no significant differences between dive groups in time to
10m reaction, movement, block and flight times all improved irrespective of the technique used. This indicates that it doesn’t really matter which technique is used. The important aspect is that swimmers can improve with any technique with some intensive practice. The researcher states that the fact that the handled start group improved the most, and was not practiced previously.

Pearson et.al. (1998)\textsuperscript{5} conclusion that the handled start may yield an advantage once the swimmer becomes highly skilled in its use.

Vilas Boas et. al., (2007)\textsuperscript{6} compared the two variants of the tract start technique. Eleven variants. Although the track start with a rear weighted placement of the CG resulted in greater horizontal impulses and there by greater horizontal velocity than the start with the forward placement of the CG. This advantage was off set by an increased block time however, the researchers observed that any advantage in horizontal velocity at entry was quickly lost during immersich and gliding.

A study of the university of Edinburge (Bonner, 2001)\textsuperscript{7} Compared the track and grab starts of two groups with equivalent 50H. times no significant differences were found between the two graphs in time to 9.5m or in block times flight time, time to entry horizontal velocity at take off, or vertical velocity of take off. A very important finding was that 96\% of the variance in time to 9.5m.

This was very similar to the findings of Guimaers and Hay (1985)\textsuperscript{8} that glide time accounted for 95\% of the variance in starting
time. The implication is that the better starters spent less time from entry to 9.5m than the less competent starts.

These findings are also supported by data obtained from race analysis of finalists and semi-finalists during the 2000 Olympics by Cossor and Mason (Accepted in 2001). They found that one of the variables comment significantly related to time to 15 M. was the underwater distance. The findings froms the Bohnar T. Gumaeres and Hay, and Cossor and Muson studies all suggest that the underwater phase of a start is highly important in start performance. In order to interpret why this is so, one needs to look at the factors that would affect the time spent under the water. These are horizontal speed, distance traveled.

Thus a logical explanation would be that the better starts have a greater horizontal speed at entry and are therefore going faster at the beginning of the underwater period or better starts enter the water further out from the block and therefore have less distance to travel under the water.

However, the correlation on between the horizontal speed at take off and the time from entry to 9.5m was very low ($r = 0.254$) further. The correlation was positive, that is, the correlation indicated that, if anything an increased horizontal speed resulted in an increased time from on to 9.5m.

Work by Kruger et. al., (2003) has shown that the back muscles are preactivated all following a more powerful extension of
the body to occur after the starting signal. The main contributors to
the take off force were found to be the knee and hip extensors.

Some have suggested that grab start is superior to track start
Tsiorsky et. al., 1979)\textsuperscript{11}.

Consilman (et.al. 1979)\textsuperscript{12} work on different start techniques and
proved that grab start is superior.

Regardless of the type of dive start used, the ultimate goal is the
same. The swimmer must react to the starting signal and leave the
blocks rapidly at an appropriate take off angle and with as much
forward velocity as can be generated. Previous studies comparing dive
start techniques have usually produced conflicting results. T.wick et.
al. (2003)\textsuperscript{13}.

Other studies have found no different between the grab and
trace starts (Blanksby et.al. 2002)\textsuperscript{14}.

Hay (1988)\textsuperscript{15} started that the studies examining the comparison
of different dive starts are flawed as no control is exercised over the
influence of differences in the amount of practice or complexities of
the techniques. In other words, the adage of what one does most; one
does best applies. It is very hard to compare techniques when
swimmers have their own preferred start that is practiced almost
exclusively.

It is only when a new technique yields better results, despite
being more complex and lawless practiced than the one currently
used, that any useful conclusion can be drawn from the study. Hence,
most of the results demonstrating that one type of starting technique is superior to the other may usually be associated with the swimmers’s preference rather than a real mechanical advantage.

Dr. Andrew Luttle (2002)\textsuperscript{16} found no significant difference in 10m start time between the track and grab starts before and after a training intervention. They did find a significant improvement in dive start performance for both technique as a result of the continued dive practice which indicates that it not necessarily be the dive technique but the amount of dive practice that a swimmer received that influence their dive performance.

Greater vertical force experienced in the front let at the beginning reflects the forward position of the swimmers CG. The aggressive arms and the rear leg motion are used to generate forward momentum in the early part of the dive but the major propulsive force should be developed by the explosive effort from the front leg.

This interaction of the front and rear legs and their relative force contribution during the track start was investigated recently by Benjanuvatra et. al. (2004)\textsuperscript{17}. The results indication strategies were used by some of the national and international swimmers.

The Circular comswing has been replaced by a faster method, the grab start. The grab start, was introduced by Hanauer (1972)\textsuperscript{18} several research studies have verified that the grab start is faster than other methods (Jorganson 1971\textsuperscript{19} Roffer and Nelson 1972, Bowers and Cavanagh 1975). The grab start is superior because can get your body moving forward the water faster by pulling against the starting
platform with your hand them by swinging your arms backward. Once your enter the water there is greater loss of momentum with the grab start because your arms do not generate as much force as would be produced by a circular arms swing.

However, studies indicate that the ability to get your body quickly in motion with a grab start out weights any loss of momentum that occurs after entry. When starting speed was times from a gun to point where the first stroke was taken, the grab start was usually faster.

Thorsen (1975)\textsuperscript{20} found the horizontal and vertical velocities were greater with the conventional start. Yet the grab start was faster by 0.1 seconds to the point of entry.

Covangangh et. al. (1975)\textsuperscript{21} suggest that swimmers leave the block faster with a grab start because they begin applying force before the gunshot. The researcher fitted a starting platform with a strain gauge to measure horizontal and vertical forces created by the hand and legs. They found swimmers anticipated the start by tensing their leg muscles before the gunshot. They were able to avoid a false start because they were gripping the block with their hands.

Although research has verified the grab start as the faster method for free stylers and buffer flyers, there has been some doubt that it is the best starting style for breast stroke race. The deep entry and long underwater slide used with the breaststroke dive allows more time for deceleration. Thus, some coaches and swimmers have reasoned that if might be advisable to sacrifice a quick departure form
the starting platform and use a circular armswing to gain more momentum during the slide.

Beritzhoff (1974)\textsuperscript{22} Tested this theory by comparing the starting speeds of breast stroke swimmers using the grab start and the circular back swing start. The grab start was faster breast stroke swimmers reached a point 12-1/2 yards from the starting end of the pool an average of 0.150 seconds faster when they used a grab start. This advantage was noted despite the fact that all but one of the subjects had preferred the circular back swing start I competitions prior to taking parting the study.

The purpose of the study was to investigate the relationship of selected physical factors and physiological variables of fifty meters backstroke swimming performance.

This study was can fined to 15 male, middle school and high school students, ranging in age between 11 to 18 years from Amrawati city, strength, flexibility, vital capacity and blood pressure were measured. Product moment correlation was computed to establish the relationship with the 50 meters back stroke swimming performance.

On the basis of the obtained data it was concluded that strength, flexibility and vital capacity were significantly correlated with swimming performance, whereas blood pressure did not correlate significantly with swimming.

Jha, Ashok Kumar M.J.S Day (1988)\textsuperscript{23} “Comparison of selected muscular strength, flexibility and body composition of swimmers, soccer and volleyball players.” - Mr. J. S. Dey
This purpose of this study was to generalize compare and contrast the muscular strength, flexibility and body composition among swimmers, soccer players and volleyball players.

Total 45 male intercollegiate players (15 from each game) were selected from the degree college of Physical Education, Amravati. Selected muscular strength, flexibility and body composition measures were recorded and analysis of variance (F test) was used to determine the differences.

The result of the study indicated that there were significant differences in each selected muscular strength, flexibility and body composition of swimmers, soccer players and volleyball players.


The purpose of the study was to determine and compare the explosive power of volleyball players and swimmers.

Total 40 male intercollegiate volleyball player and swimmers (20 from each) age longed from 17 to 25 were selected randomly from the degree college of Physical Education, Amravati. The data were obtained for each group by the test of six metes start and run. Standing broad jump, vertical jump and standing shot put t-Test was calculated for the analysis.
The statistical analysis of the study revealed that the explosive leg and arm power was greater in volleyball players than that of swimmers.

2.2 Reviews Related to Different Resistive and Weight Training Methods

Chandhari, (1970)\(^{25}\) through a systemic investigation suggested Suryanamaskar for the sprinters in athletics. In his research there were 23 men athletes who were the students of L.N.I.P.E. (Laxmibai National College of Physical Education.), Gwalior. The subjects were distributed in to two groups by using simple random sampling technique. One group underwent a training programme of Suryanamaskar which consist of eight verities of asana. The second group was treated as the control group. This investigation assessed flexibility levels of various joint in the body in relation to the stride length in sprint running. The findings revealed that there was statistically significant gain in stride length of sprinters participated in this study. The results conclude that Suryanamaskar is an acceptable training method to improve the length of stride among the athletes participating in sprinting event.

Shire, et. al. (1977)\(^{26}\) Studied the effect of high resistance slow rate (HR-SR) and low resistance fast rate (LR-FR) training on cardiorespiratory function and body composition. 34 college women (Age 17 to 22 years) were randomly assigned to one of the three groups: HR-SR (n=3); LR-FR (n=11); or C (control, n=10) Assessment of cardiorespiratory function (using a progressive load
bicycle ergometer test to maximal exertion) and body composition (anthropometric and underwater weight) was made before and after 10 weeks physical training programme. The experimental subjects trained on a bicycle ergometer three days per week, with the time pertaining session progressively increased from 20 to 25 minute over the 10 week period. The workload for the each subject was set to elicit approximately 70% of that subjects pertaining Vo2 max to equate the total mechanical work of the two pertaining groups. Both training groups HR-SR and LR-FR significantly increased relative to the control group in Vo92 max (12%, 12%) O2 plus max (12%, 12%) work output (79% to 60%) and total ride times (57% to 51%), but difference between the training groups was not significant. No significant alteration in body weight or body composition was found. These results suggest that the cardiorespiratory adoptions measured are independent of those modes of training.

Tamarkar, et. al. (2001)\textsuperscript{27} determines the effects of plyometric training, weight training and their combination on the development of speed, strength and explosive power. The criterion measure was fifty yard dash, leg and back dynamometer and Sarjent jump respectively. The students for the study were twenty four Intervarsity players studying in B.P.Ed. and M.P.Ed. in physical education department of Guru Nanak Dev University, Amritsar, Punjab (India). The average age was twenty one years, ranging from twenty to twenty five years. Four groups were formed three experimental and one control consisting of 6 subjects each to collect data using random sampling technique. Experimental groups participated in three different training
programs i.e. weight training, plyometric training and combination training for eight weeks and the control group performed the routine work. The data was collected in the beginning and at the end of 8 weeks experimental period in terms of pre and post test. ANCOVA and T- test was applied to find out the differences in pre and post test scores of group A, B, C, and D. The significance was tested at 0.05 significance level. It was found that Plyometric training has improved speed whereas weight training and combination training has shown no effect. Combination training has increased leg strength but weight training and plyometric training have not contributed towards its development. And none of the protocol has been proved to enhance explosive power.

Nageswaran, (2000)\(^{28}\) in his study examine the effectiveness of power resistance and combined resistance and plyometric training in enhancing dynamic strength performance and speed. Forty five men intercollegiate players who participated in various sports, but who had not previously performed specific resistance or plyometric training and were assigned at random to one of the three groups (n=15) in which group II underwent combined resistance and plyometric training and group III acted as a control. The training for both the experimental groups underwent their respective training three days per week for eight weeks in addition to their regular activities. Both training groups were equally effective in enhancing strength parameters and speed; when compared to the control groups. There is no significant difference between the experimental groups, but trends are in favor of combined training.
Kapil, (1965)\textsuperscript{29} studied the effect of resistance in running in speed, leg strength, muscular endurance, ankle flexibility and agility to the effect of resistance running. He selected 30 male students of L.N.C.P.E. Gwalior. The data was collected in 6 weeks initial test of speed, leg strength, muscular endurance, ankle flexibility were administered. On the bases the subjects were randomly assigned in to A and B group. A group was under resistance running and B group was under sprint running and the post test was administered statistically significant ‘t’ ratio. Mean of both group found to be significant at 0.05 level of confidence. Finally it has been concluded that distance running or running has brought about significant increase in improving leg strength as compare to the sprint running.

Shenbagavalli, (2008)\textsuperscript{30} in his study find the effects of conventional resistance training, progressive resistance training and variable resistance training on speed, agility and explosive power. To facilitate the study 45 physical education students were selected at random, who participated in the intercollegiate competitions. They were divides in to three groups and each group followed the stipulated training for the period of 12 weeks. The analysis of covariance was use to find out the adjusted mean difference among the treatment groups when the result was the significant, the Scheffees post hoc test was use to find out the paired mean differences. The study on the whole, revealed that there was improvement according to the means gains through conventional resistance training, progressive resistance training and variable resistance training.
Grace, (1991)\textsuperscript{31} conducted an investigation to compare the effect of resistance strength training program (PRSTP) on isometric lumbar extension strength of male and females. 58 healthy males (n=30) and females (n=28) 20 to 35 years of age completed the study. During the pretest and posttest, lumbar extension strength was measures isometrically through a full ROM at 7 angles on a MEDX tm lumbar extension machine. All subjects completed the 7 angle isometric exercise test. The exercise participating in the PRSTP trained dynamically one time/week for 12 weeks through a full ROM on a MEDX tm lumbar extension machine. The exercise group completed one set of 8-12 rep of variable resistance lumbar extension to volitional fatigue. The result of this investigation showed that males and females achieved significant strength gain in the lumbar region, measures in isometrically as a result of participant in a12 week PRSTP in which the muscle of lower back were isolated and exercised. There was a gender difference in isometric strength percentage increase and no gender difference in training resistance increases while training on a PRSTP for the muscle of the lower back.

Hommock, (1968)\textsuperscript{32} study to determine the effect of a selected progressive resistance running programme on circulo-respiratory efficiency, power and free running speed. Forty-five male subjects were divided into three equated groups Interval running, resistance running (employing a exer-genic) and control. The effects of the six week training programme were determined by pre test, initial post test and final post test for oxygen debt, repaid, power developed by the legs, free running speed elapsed time for a 600 yard run. Significant
improvement was found in oxygen debt repaid (0.5 level) and elapsed
time for a 600 yard run (0.01 level) between the interval and control
groups.

Germers, (1987)\textsuperscript{33} study the effect of weight training and
playometric training on vertical jump, standing broad jump and 40
meter sprint. His study was to determine if playometric exercise
programme was better than weight training programme in improving
leg power as measured by vertical jump, Standing broad jump and 40
meter sprinting ability. The training consisted of playometric drills
two times a week and weight training exercise three times a week for
an eight week period. Pretest to the posttest showed mean gain for the
weight training, playometric training and control group respectively.
The playing standing long jump is equal to vertical jump is equal to
2.3 centimeters and 0.2 centimeter and forty meter sprint is equal to
minus 0.21 seconds, minus 0.20 seconds, minus 0.03 seconds. The
gains achieved by both treatment groups were significantly greater
than those experiments by the control group, but no difference
between the gains attained by the two treatment groups. It was
concluded that under the delimitations of this study there is no
difference between two programs in improving leg power.

Marzilli, (2008)\textsuperscript{34} in his study develop an eight week preseason
strength training programme and implemented on 14 female collegiate
basketball players. The purpose of the program was to increase the
overall strength of the athlete as well as to enhance sports specific
performance. Two testing sessions were administered throughout the
8 week training program. Testing sessions one was given one week
prior to the start of the training program while testing sessions two was given one week following the conclusion of the eight weeks training program. Each of the two testing sessions included the following battery of tests: One repetition maximum (1RM) for the bench press and squat, agility, standing vertical jump and approach vertical jump. Separate dependent t-test was computed for each of the 5 dependent variable. Following the 8 weeks strength training program there were significant (p<0.05) improvement for the bench press and squat, the standing vertical jump and the agility test. While 8 week may not be enough time to significantly affect muscle hypertrophy. These result provide evidence that is sufficient to reliability improve the neuromuscular dynamics related to overall strength as well as enhancement of sport specific performance.

Brady, (1987)\textsuperscript{35} used 57 high school males to compare the effects of weight training (Gr.1), weight training plus vertical playometrics (Gr.2) and weight training plus horizontal playometrics (Gr.3) A fourth group served as controls (Gr.4). the subjects (Ss) in groups 1-3 were imparted training 2-3 days per week for seven weeks. Controls engaged in other physical activities but not strength training. Post testing produced the following results. All group improved significantly more than group 4. There was no significant difference between groups 1-3. Similar results were found with the 1 RM SQT test except that the control group did not show a significant gain. In the standing long jump (SLJ) test there were no difference between any of the groups but group 1 and 3 had a significant improvement through the training period. From these results the investigator
concludes that the playometric training in conjunction with weight training alone on producing increase in VJ, SLJ, or 1RM squat. The experiment recovered trend specificity in adoption due to horizontal and vertical training.

Hodgson, (1964)^36 conduced a study on three groups of college students who were equated on the basis of the treadmill test. All three groups attended required physical educational classes in which badminton was the activity twice a week for 5 weeks. In addition, group I did circuit training group II did isometric training or of isometric exercises. The result revealed that badminton was no more effective in improving treadmill performance time than badminton alone. Circuit training caused a greater improvement in treadmill performance than isometric exercise.

Linda, (1984)^37 conducted a study to determine if the circuit training programme use at Jefferson Intermediate School in San Gabriel, CA, would significantly improve the students physical performance test scores. The subjects were divided in to control group and experimental group. The control group did not participate in circuit training, where as the experimental group participated in circuit training once a week for 15 weeks. The Fisher ‘t’ test for co-related means revealed that only one of the 6 different physical performance test showed significant improvement was obtained in 2 tests in the experimental group. Thus it was concluded that the circuit training did not have a significant effect on the physical performance test scores.
Johnson, (1971)\textsuperscript{38} selected 120 college freshmen to study the effect of continuous slow running, interval and pace training methods, on running performance. The subject trained once a day, three times a week for eight weeks. It was concluded that the treatment variables were highly effective in improving running performance of college freshmen. It was further concluded that slow continuous running was better than interval running and pace training methods for improving performance in slow pace runs.

Greenberg, (1966)\textsuperscript{39} studied the effect of two interval training program on running ability. Two experimental groups of thirty subjects were employed in the training programme which was conducted three times weekly for seven weeks. Both the groups trained over distance of 110, 220 and 330 yard. In one group speed running was held constant while the number of repetition of each distance was increased. The second group ran a fixed number of repetitions at progressively faster speed. Both experimental groups improved significantly over the control group. However, no significant difference in improvement of running ability over a 400 yards distance was found between the experimental groups.

Robinson,(1980)\textsuperscript{40} trained two groups of athletes for thirty minutes of running. One group was continuously running for the entire duration, whereas the other group practices on 100, 200 and 300 meters at intervals with a work rest ratio of 1:3, the control group continued with normal work practice. There result finding was that the means of VO2 max. scores increase 8.9 % for distance group and 3.1% and 3.2% for the interval and control group respectively. The
anaerobic threshold changes resulted in average increase of 15.6% for VO2 max at anaerobic threshold for distance groups and 11.3% for interval group and only 6.5% average increase for control group. Thus they conclude that both moderate and intensive training increases anaerobic threshold as well as endurance performance and also changes were more closely related to endurance performance than VO2 max changes.

Noon, (1965)\textsuperscript{41} reported the efforts of two interval training programmes during a 12 week period. He studied electro – cardio graphic recordings, blood tests and time for 5000 meters run. The finding indicated that speed training caused more repaid positive change in electro cardio graphic and blood test results and in running time 5000 meters. The over distance training caused the same changes but with fewer extreme result and at a slower rate. He concluded that both types of training should be employed in planning long-range work schedules, since there were positive physiological changes unique to both long and short distance training methods.

Brar, (1986)\textsuperscript{42} studied the effects of interval running with three different types of recovery during the relief interval, on cardio-respiratory endurance and selected physiological variables. The subjects were 80 untrained students of Kendriya Vidyalaya, Gwalior, studying in grades nine and ten. The subjects were equally assigned three experimental groups and one control group. The three experimental groups participated in an interval running programme for a period of ten weeks. The differential treatment factors for the three groups were the type of ten weeks. The differential treatment
factors for the three groups was the type of recovering during the relief interval i.e. the first group performed jogging the second a combination of walking and jogging and the third walking only. The data on cardio-respiratory and selected physiological variables of physical work capacity and resting pulse rate were recorded before and at the end of the experimental period of ten weeks. He concluded that: (1.) Interval training was an effective method in developing cardio respiratory endurance of the boys. The group, which performed jogging, or a combination of walking-jogging, produced better results when compared to the group, which performed walking alone during the relief interval. (2.) Interval running was an effective method in improving physical work capacity an effective in lowering pulse rate. The group which performed jogging during the relief interval was found superior to the groups which performed a combination of jogging, walking or walking alone, in increasing work capacity and in lowering the resting pulse rate. (3.) The control group did not show any significant changes in cardio-respiratory and selected physiological variables.

Colfer, (1975)\textsuperscript{43} has cited the following six variables in interval training distance or duration of the run, the length or duration of the rest interval, nature or type of recovery interval, and frequency of the interval training session. These variables when properly manipulated may, according to him, increase the aerobic and anaerobic capacities of an athlete and bring about desire changes in his physiological functioning.
Rameshpal, (1986) selected one hundred boys of 14 to 16 years of age for the study was divided into five groups i.e., A, B, C, D, and E, each consisting of twenty subjects at random. Group A, B, C, and D were subjected to different training programs and E acted as the control group. The training programs consisted of four different combinations of different proportions of aerobic and anaerobic training to develop endurance of the subjects. Group A was trained with the ratio of 70% aerobic and 30% anaerobic, group B with 60% aerobic and 40% anaerobic, and group C with 50% aerobic and 50% anaerobic and D with 40% aerobic and 60% anaerobic training. Subjects were trained thrice a week for a period of ten weeks. Interval training of extensive interval method was used to impact aerobic and anaerobic training respectively. The performance in 800 m run of the subjects were recorded to the nearest one tenth of a second, before and after of the completion of experimental period. He concluded the different proportions of aerobic and anaerobic training employed in the ratio of 70-30, 60-40, 50-50 and 40-60 percents adopted in this study proved to be effective for improving the performance of 800-m runners. The combination of 40% aerobic and 60% anaerobic training appeared to be most effective for improving performance in 800 m. run. Absence of improvement in the case of control group may be considered a reflection of inactivity.

Viru, (1972) and his associates trained student in nine groups employing different methods ranging from long uniform runs (20-30 minutes) to test interval training (40-50 minutes). They rotate a significant increase in heart volume as a result of interval training. A
continuous run fartlek method was more effective in increasing oxygen carrying capacity of the blood reduction in 800 mts. Run time made by the group trained on a 15 degree slope (-26.6 sec). While -13.6 sec was the least reduction made by the long uniform running group.

2.3 Maximal oxygen consumption—deep water running training studies

Those studies conducted utilizing endurance trained subjects have found DWR training to be successful in the maintenance of aerobic performance (Bushman et al., 1997; Hertler, Provost-Craig, Sestili, Hove, and Fees, 1992; Wilber et al., 1996). Wilber et al. recruited 16 trained male runners aged 20-40 years old to examine the effects of a 6-week DWR program on maximal oxygen consumption (VO2max), lactate threshold and running economy. The DWR training maintained maximal oxygen consumption (pre = 58.7 ± 4.7, post = 59.6 ± 5.4 ml/kg/min) in the highly fit subjects. These results are consistent with Bushman et al. who found similar maximal (pre = 63.4 ± 1.3, post = 62.2 ± 1.3 ml/kg/min) and sub maximal VO2 responses (pre = 44.8 ± 1.2, post = 45.3 ± 1.5 ml/kg/min) after only 4 weeks of DWR training in 11 competitive runners (males N = 10; females N = 1; mean = 32.5 yr). In the study conducted by Wilber et al. (1996), ventilatory threshold was sustained at approximately 80% of VO2max (Day 0 = 46.5 ± 6.14 ml/ kg/min, 79% VO2max, Day 42 = 47.4 ± 6.7 ml/kg/min, 80% VO2max), while VEmax (Day 0 = 120.1 ± 13.3 l/min, Day 42 = 131.1 ± 17.6 l/min) and treadmill run time to exhaustion (Day 0 = 16.6 ± 5.4 min, Day 42 = 17.3 ± 5.7 min) were
not significantly altered through DWR training. Although DWR uses different proportions of upper to lower body muscle mass compared to land-based running, Wilber et al. and Bushman et al. (1997) both concluded that chronic DWR training created the physiological stimuli necessary to facilitate the maintenance of running economy.

Wilber et al. (1996)\textsuperscript{47} exercised aerobically trained subjects 5 days a week, alternating high intensity shorter workouts (90-100\% VO\textsubscript{2}max for 30 minutes) with moderately intense longer sessions (70-75\% VO\textsubscript{2}max for 60 minutes). Similarly, Bushman et al. (1997) employed a training regimen consisting of DWR 5-6 days a week integrating two long and short interval days, one long run and an easy recovery run. These training schedules not only reflect actual training routines of these competitive athletes but more importantly insure adequate exercise intensity for the maintenance VO\textsubscript{2}max. Only one published training study investigated the effects of DWR with older adults (mean age of controls 57.5 ± 2.3 yr, mean age of experimental group = 63.1 ± 1.6 yr). In this investigation Long et al. (1996) reported significant VO\textsubscript{2}max improvements in a group of 35 sedentary older women after a 10-week DWR program.

Morrow, Jensen and Peace (1996)\textsuperscript{48} divided 11 subjects into either DWR (female = 3, males = 3) or land-based (female = 2, male = 3) exercise groups. Subjects trained three days a week for 35 minutes a session at 80\% of HR\textsubscript{max} as determined by mode specific VO\textsubscript{2}max tests. Additionally, subjects performed a timed 2.4-k run. Both training groups significantly improved in VO\textsubscript{2}max (p < 0.01). DWR training also decreased run time (p = 0.06). No mode specific
differences between the two training methods (land vs. water) were observed indicating that DWR can improve VO2max in a similar fashion as land-based exercise.

Michaud and colleagues (1995) had 10 inactive volunteers (female = 8; males = 2; mean = 32 yr) complete maximal treadmill and DWR tests prior to and following an 8-week aerobic interval DWR program. Improvements in VO2max of 10.7% and 20.1% for treadmill and DWR respectively were observed after DWR training. Recruits exercised 3 times per week with workouts ranging from 25-45 minutes a session. Interval length varied from 30 seconds to 7 minutes in duration, with exercise heart rates averaging 63% to 83% of maximal treadmill heart rate. Michaud and associates propose the large increases resulted from a combination of the high intensity workouts, unfit subjects, and the specificity of training and testing involved in the study. By measuring pre-and post-training VO2max while DWR a specificity of testing and training was clearly established. Furthermore, this research also supports a significant crossover effect of DWR to land-based training in untrained volunteers. The results of these training studies support the use of DWR as an alternative form of exercise to land-based training for maintenance of aerobic capacity in trained athletes as well as possible VO2max improvements for unfit participants.
2.4 Resting Heart Rate

One physiological adaptation to regular cardiovascular exercise is a reduction in heart rate at rest. However, little research has been conducted to support this decrease following shallow or deep water exercise. Currently, two research projects have observed reductions in resting heart rate after chronic shallow water exercise training (Hoeger et al., 1992; Simpson and Lemon, 1995). Simpson and Lemon found resting heart rates were reduced by 11 bpm (before = 77.7 ± 2.4 bpm; after = 66.3 ± 1.7 bpm) (p < 0.01) upon completion of an 8-week deep water exercise training program. An 8-week training study by Hoeger et al. compared the heart rate responses following an identical shallow water and land-based (low-impact) aerobics program. Both shallow water and land-based aerobics programs led to similar decreases in resting heart rate (water pre = 77 ± 9.3 bpm, post = 70 ± 7.5 bpm, land = 76 ± 10.8 bpm, post = 70 ± 7.7 bpm). These research projects confirm the idea that sedentary individuals may attain decreases in resting heart rate which average approximately one bpm for each week of training during the initial weeks of exercise training.

2.5 Body Composition

Quinn and colleagues (1994) had untrained females perform 6 weeks of land-based running prior to 4 weeks of DWR. An initial 6.7% decrease in body fat was noted following the 6 weeks of land-based training. However, after 4 weeks of DWR training, body fat increased by 2.1% (pre-training = 24.6 ± 3.5 %, post-land-based
running = 22.9 ± 4.2%, post-DWR = 23.4 ± 4.3%). In contrast to Quinn et al., Michaud and associates (Michaud et al., 1995) found that 8 weeks of DWR training in 10 healthy untrained subjects provided an adequate stimulus for body fat reduction. Subjects exercised 3 days a week for 8 weeks at intensity between 63-83% of HRmax. Post-testing via skin fold measurements found a 2.6% decrease in body fat.

Simpson and Lemon (1995) used bioelectrical impedance to assess body fat percentage finding a 2.7% relative decrease in percent fat after 8 weeks of deep water aerobic exercise. Gaspard et al. (1995)\(^\text{52}\) used hydrostatic weighing before and after 7 weeks of aqua step training to assess body composition in 21 untrained college aged females. Results showed no significant differences within the experimental group or when compared to controls.

Abraham et al., (1994)\(^\text{53}\) significant decreases in body fat have been observed in several studies conducted on shallow water aerobics. Training 3 days per week for 50 min a session, an 11-week training program completed by sedentary college-aged women (pre = 24.2 ± 3.3 kg, post = 22.8 ± 3.0 kg) produced a 5.6% relative decrease in body fat. In agreement with Abraham, Hoeger et al. (1992) reported decreases in body fat with previously sedentary women exercising 3 days a week, 20 minutes a day at 70-85% of heart rate reserve for 8 weeks. A 7.5% change in percent fat (pre = 26.4 ± 7.4%, post = 24.4 ± 6.7%) as measured by skin fold thickness were similar to the 5% decreases seen in the land-based low-impact aerobics group (pre-test = 21.8 ± 5.0%, post-test = 20.7 ± 4.5%). No changes occurred in the control group.
Sanders and Rippee, (1994)\textsuperscript{54} examined the effects of shallow and deep water exercise on body fat of young (28 ± 6.5 yr) and older (52 ± 8.3 yr) women. All subjects achieved significant reductions in body fat following the 8-week community based program with decreases of 11.9\% for the young and 5.8\% for the older participants.

2.6 Muscular Strength and Endurance

Hamer and Morton (1990)\textsuperscript{55} tested changes in musculoskeletal parameters before and following 8 weeks of shallow water running (1 meter in depth). An interval training program was conducted 3 days per week for 20-45 minutes per workout. Testing employed isokinetic resistance (Cybex II dynamometer) equipment to measure peak power, and initial and final peak torque during repeated maximal contractions of knee extensors and flexors. Subjects completed a muscular fatigue test which consisted of 50 maximal contractions at 120 degrees/s-1 in a 2 minute period. Differences occurred between the training group and controls in final mean peak torque (final three contractions) for knee extensors (experimental group = 98 Nm; controls = 85 Nm).

Simpson\textsuperscript{56} has found strength benefits from aerobic exercise in deep water. After 8 weeks of training subjects (n = 18) improved isokinetic quadriceps (pre = 50.5 ± 3.2 Nm, post = 55.2 ± 3.3 Nm) and hamstring (pre = 35.4 ± 2.4 Nm, post = 41.9 ± 3.0 Nm) strength (p < 0.01).

Hertler, et al. (1992)\textsuperscript{57} found that experienced runners were capable of maintaining leg strength through DWR. Researchers had
runners complete a 4-week land-based running program prior to dividing the subjects in half with participants either continuing the land-based training or engaging in a deep water running. Isokinetic testing measured concentric and eccentric contraction of upper and lower leg and found no difference in leg strength between DWR and land-based running after training.

2.7 Flexibility

Only four training studies have addressed this often overlooked aspect of health-related fitness. The primary test used by all of the investigators to test flexibility was the sit-and-reach test, which evaluates low back and hamstring flexibility.

Hoeger, et al. (1992)\(^{58}\) observed a 10.5% improvement in the modified sit-and-reach measurements (pre = 37.9 ± 7.6 cm; post = 41.9 ± 8.9 cm) following 8 weeks of shallow water aerobics. This was not surprising to the researchers since low back and hamstring exercises were integrated into the stretching and warm-up phase of the program.

Seedfeldt and Abraham (1996)\(^{59}\) also incorporated flexibility exercises into the total conditioning program during 11 weeks of aqua step training. Twenty-two subjects were assessed on the sit-and-reach test with 5.4% improvement being achieved, which approached significance (pre = 18.4 ± 3.4 in, post = 19.4 ± 5.4 in). Findings do not seem to be limited to shallow water aerobics.

Simpson and Lemon (1995)\(^{60}\) also noted a 7.3% increase, although not significant (p > 0.07), in the sit-and-reach flexibility test.
(pre = 34.1 ± 2.1 cm, post = 36.6 ± 1.8 cm) after 8 weeks of deep water aerobic training.

Sanders and Rippee (1994) combined both shallow and deep water exercise during 8 weeks of water aerobics. As part of the experiment subjects were separated into young (28 ± 6.5 yr) and older (52 ± 8.3 yr) adults. Results revealed small, non-significant, improvements in the sit-and-reach for the younger (pre = 15.9 in, post = 16.0 in) and older (pre = 12.8 in, post = 13.5 in) subjects.
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