Chapter II

REVIEW OF RELATED LITERATURE

The review of literature is instrumental in the selection of the topic, formulation of hypothesis and deductive reasoning leading to the problem. It helps to get a clear idea and sports findings with regard to the problem under study. The researcher came across several books, periodicals and journals and published thesis, while searching for relevant facts and finding that were related to this present study, such as those were given below or the better understanding and to justify the study.

The purpose of this review of selected literature was to relate studies pertaining to the topic under study and to organize the collected into meaningful sub sections as listed below:

a) Studies of Aquatic Training on Physical Variables
b) Studies of Aquatic Training on Physiological Variables.

2.1 Studies of Aquatic Training on Physical Variables

Sergio Ricardo Pasetti and A. Aguinaldo Gonçalves, (2006), Sport Sciences researches have been contributing more and more to Physical Education to enlarge knowledge involving several area themes: high performance or benefits to health, through physical activities practice. Relevant contributions are more frequent in order to enhance scientific background, increasing professional performance quality. Technological resources and real-time communication are wider, easing bibliographical researches and interaction of several researchers and respective studies centers. In our area, this integration is present, but there are issues that are not fully explored. While foreign research centers largely publish work on determined
subjects, Brazilian ones seem not to be aware or not interested. One example of this situation is the Deep Water Running, carried out in a swimming pool, where practiser, submerged to shoulders, uses a floater attached to the waist to perform running movements with no contact with swimming pool bottom. Impact absence, contributions to injured athlete’s recovery, physical aptitude maintenance, physiological responses similar to those from ground running are interesting supports to new researches in this area. Considering its several possibilities and proposals, Deep Water Running should be more popular within academic sector to attract researchers.

Ewa Piotrowska-Całka and Justyna Karbownik-Kopacz, (2007), compared the influences of training by means of running on land and in shallow and deep water and aerobics exercises. Examples of how training in water enhances cardiovascular efficiency, muscle strength and endurance, stamina, flexibility and emotional well being of inactive individuals as well as actively training athletes. The results achieved and presented in the survey confirm the possibility of increasing physical fitness by training in water.

Mohammad Reza Kordi, et al. (2008) investigated the aquatic and Land plyometric training on performance and muscular injury in club wrestlers. For this reason 21 club wrestlers were selected voluntary and divided to two experimental groups (Land plyometric training (n = 7) Aquatic plyometric training (n= 7)) and
control group (n = 7) randomly. The mean (standard deviation) of age was 20.3 (3.6), height 169 (5.3), weight 65.3 (8.8). Experimental groups trained four main skills of plyometric training including depth, star, rocket and squat jumps for five weeks and 3 times per week and 40 to 45 min in per session and control groups had their routine training. For determination the effects of plyometric training were measured strength, speed, agility, Fatigue index, peak and mean power and to evaluate Pathogenesis of these training inflammatory enzymes including CK, LDH were measured. The analyzing of data by ANOVA and T test showed: There was no significant difference between 2 model of plyometric training (Aquatic and Land) in performance and risk of muscle injury in male club wrestlers. Aquatic plyometrics provided the same performance enhancement benefits as land plyometrics with less muscle soreness.

Kamalakkannan, Vijayaragunathan, Kalidasan, (2010) analysed the aquatic and land training on selected physical fitness variables among Volleyball players. To achieve the purpose 30 physically active and interested undergraduate engineering Volleyball players were selected as subjects and their age ranged between 18 and 20 years. The subjects are categorized into two groups randomly viz.; Aquatic Training group (ATG), land Training group (LTG) and each group had 15 subjects. The experimental group underwent the experimental treatment for 12 weeks, 3 days per week and a session on each day with 90 minutes duration. Speed, endurance and explosive power were taken as variables for this investigation. Fifty meters run, Cooper 12 minutes run and standing vertical jump were tests used to collect the relevant data. The data were collected prior and after the experimental treatment. The collected data was analyzed using analysis of covariance (ANCOVA). The result reveals that aquatic training group showed significant improvement in all the selected physical fitness variables.
Arazi and A. Asadi, (2011) compared the effect of eight weeks of aquatic and land plyometric training on leg muscle strength, 36.5 and 60 meters sprint times, and dynamic balance test in young male basketball players. Eighteen young male basketball players (age=18.81±1.46 years, height=179.34±6.11 cm, body mass=67.80±9.52 kg, sport experience=4.8±2.47 years) volunteered in this study and divided to three groups; aquatic plyometric training (APT), land plyometric training (LPT) and control group (CON). Experimental groups trained; ankle jumps, speed marching, squat jumps, and skipping drills for eight weeks and 3 times a week for 40 min. The data were analyzed by one way analysis of variance with repeated measures, a Tukey post hoc testing and independent-sample t-test. The results showed there were not any significant differences between the APT and LPT groups in any of the variables tested (P>0.05). Significant increases were observed in post training both APT and LPT groups in 36.5-m and 60-m sprint times record compare to pre training (P<0.05). There was a significant difference in relative improvement between the APT and CON in 36.5-m, 60-m, and one repetition maximum leg press (P<0.05). The result of the study concluded that plyometric training in water can be an effective technique to improve sprint and strength in young athletes.

Tsae-Jyy Wang et al. (January 2007) examined the effects of aquatic exercise on physical fitness (flexibility, strength and aerobic fitness), self-reported physical functioning and pain in adults with osteoarthritis of the hip or knee. Osteoarthritis is a common cause of disability and a primary reason for hip and knee joint replacement. Exercise is important for preventing and/or managing the functional limitations associated with joint disease. Aquatic exercise is thought to be beneficial and is often recommended for people with osteoarthritis; however, few
studies have examined the effects on people with osteoarthritis, and these have yielded inconsistent results. A two-group randomized controlled trial with a convenience sample was used. Participants were recruited from community sources and randomly assigned to a 12-week aquatic programme or a non-exercise control condition. Data for 38 participants were collected at baseline, week 6, and week 12 during 2003 and 2004. Instruments were a standard plastic goniometer, a handheld dynamometer, the 6-minute walk test, the multidimensional Health Assessment Questionnaire, and a visual analogue scale for pain. Repeated measures analysis of variance showed that aquatic exercise statistically significantly improved knee and hip flexibility, strength and aerobic fitness, but had no effect on self-reported physical functioning and pain. The exercise adherence rate was 81·7% and no exercise-related adverse effect was observed or reported. Beneficial short-term effects of aquatic exercise were found in adults with osteoarthritis of the hip or knee. Although the programme may not offer pain relief or self-reported improvements in physical functioning, results suggest that aquatic exercise does not worsen the joint condition or result in injury.

Takken (2003) reported that the nurses engaging in disease management and health promotion for these patients should consider recommending or implementing aquatic classes for patients. (To evaluate the effects of an aquatic training programme for JIA patients. Fifty-four patients with JIA (age range 5 to 13 yr) participated in this study and were randomized into an experimental (n=27) and a control (n=27) group. The children in the experimental group received a training programme consisting of a 1 h per week supervised training programme in a local pool of approximately 20 sessions. Effects were analysed on the following domains: functional ability, health-related quality of life, joint status and physical fitness.
Although all measures improved more in the experimental group than the control group, none of the differences was statistically significant. The current research found no significant effect of an aquatic fitness training programme in children with JIA. Since there were no signs of worsening in health status, one can conclude that this was a safe exercise programme.

**Jan H. Prins et al. (1994)** assessed the combination of swimming and specific activities involving resistive devices were used in an attempt to improve strength in persons who had symptomatic weakness related to poliomyelitis. Dynamic muscular force application in selected limb movements and range of motion were measured before and after an 8-week aquatic exercise intervention. Peak (PF) and average force (AF) were determined in the water using a differential pressure transducer attached to either the hand, foot, or a resistive device. Arm flexion, extension, adduction, abduction, and horizontal adduction and abduction along with combined hip flexion and knee extension were tested for both PF and AF Subjects were randomly assigned to experimental and control groups; complete data were available on nine experimental and four control subjects. PF and AF changes were greater (p ≤ 0.05) for experimental compared with control for right arm flexion (PF,
96 versus 6%) and extension (PR 105 versus 15%; AF, 76 versus 30%), respectively.

Changes were greater (p ≤0.05) in experimental than control for left arm extension (PF, 88% versus 19%) and horizontal abduction (PF, 127% versus 21%; AF, 122% versus 17%). Aquatic exercise training in subjects with poliomyelitis disability resulted in significant dynamic strength changes of the upper body while appearing not to exacerbate symptomatic fatigue or pain.

**Thomai Tsourlou et al. (2006)** determined the effectiveness of a 24-week aquatic training (AT) program, which included both aerobic, and resistance components, on muscle strength (isometric and dynamic), flexibility, and functional mobility in healthy women over 60 years of age. Twenty-two subjects were assigned randomly to either an AT (n = 12) or a control (C, n = 10) group. Volunteers participated in a supervised shallow-water exercise program for 60 minutes a day, 3 days a week; the exercise program consisted of a 10-minute warm-up and stretching, 25 minutes of endurance-type exercise (dancing) at 80% of heart rate (HR)(max), 20 minutes of upper- and lower-body resistance exercises with specialized water-resistance equipment, and a 5-minute cool down. Maximal isometric torque of knee extensors (KEXT) and knee flexors (KFLEX) were evaluated by a Cybex Norm dynamometer, grip strength (HGR) was evaluated using a Jamar hydraulic dynamometer, and dynamic strength was evaluated via the 3 repetition maximum (3RM) test for chest press, knee extension, lat pull down, and leg press. Jumping performance was evaluated using the squat jump (SJ), functional mobility with the
timed up-and-go (TUG) test, and trunk flexion with the sit-and-reach test. Body composition was measured using the bioelectrical impedance method. The AT induced significant improvements in KEXT (10.5%) and KFLEX (13.4%) peak torque, HGR strength (13%), 3RM (25.7-29.4%), SJ (24.6%), sit-and-reach (11.6%), and TUG (19.8%) performance. The AT group demonstrated a significant increase in lean body mass (3.4%). No significant changes in these variables were observed in the C group. The results indicated that AT, with both aerobic and resistance components, is an alternative training method for improving neuromuscular and functional fitness performance in healthy elderly women.

Juan C. Colado et al. (2009) investigated the effects of 24 weeks of resistance training with aquatic resistance devices or elastic bands (EB) on markers of cardiovascular health and physical capacity. Forty-six healthy, sedentary postmenopausal women participated. The groups were aquatic exercise (AE; n = 15), EB (n = 21), and control (n = 10). Venous blood chemistry included cholesterol, triglycerides, glucose, and apolipoprotein B. Physical capacity was assessed by the sit and-reach, knee push-up, 60-s squat, and abdominal crunch tests. Both AE and EB, respectively, showed a significant (P · 0.05) decrease in body fat (14.56, 11.97%) and diastolic blood pressure (8.03, 5.88%), and a significant increase in fat-free mass (2.88, 1.22%), sit-and-reach (27.94, 44.2%), knee push-ups (84.74, 51.59%), and 60-s squats (65.76, 46.04%). AE also showed a significant increase in abdominal crunches (28.11%). Aquatic resistance training can offer significant physiological benefits in health and performance that are comparable to those obtained from EB in this population.
Kamalakkannan, Vijayaragunathan and Kaukab Azeem. (2010) investigated the impact of aquatic training with and without weights on agility and explosive power among Volleyball players. Thirty male physically active and interested undergraduate Volleyball players between 18 and 20 years of age volunteered as participants. The participants were randomly categorized into three groups of 10 each: Group I (Control) was not exposed to any specific training / conditioning (CG), Group II was involved in aquatic training (ATG), and Group III was given aquatic training combined with weights (ATWG). The aquatic training package was designed by the investigators and was administered for a period of six weeks, three days a week; a session each day, each session lasted two hours. Both experimental groups underwent their respective experimental treatment. The aquatic training schedule was specifically designed to improve the fitness levels of the Volleyball players. The weight training was meted out for 60 minutes to group III. Aquatic training and weights were given on alternative days. Agility and Explosive power were selected as variables for this investigation. Shuttle run and standing broad jump tests were used to collect the data from the subjects. The pre and post test were conducted one day before and after the experimental treatment. Analysis of covariance was used to analyze the collected data. Scheffe’s test was used as a post hoc test to determine which of the paired mean differ significantly. The results of the study revealed that both aquatic training and aquatic training combined with weights produced positive impacts on the agility and explosive power among Volleyball players.

2.2 Studies of Aquatic Training on Physiological Variables

Leonardo Alexandre Peyre-Tartaruga et al. (May 2009) analysed whether trained competitive runners could maintain running kinematics, cardio respiratory
performance (VO2peak, ventilatory threshold, running economy) and on-land running performance by replacing 30% of conventional training with water run training during 8 weeks. Eighteen runners were divided in two groups: on-land run (OLR Group) and deep water run (DWR Group). The DWR Group replaced 30% of training volume on land with DWR, and the OLR group trained only on land (both groups undertaken workouts 6–7 d.wk\(^{-1}\) for a total of 52 sessions). No significant intra- or intergroup differences were observed for VO2peak in the DWR Group and OLR Group. Similarly, ventilatory threshold second was unaltered in the DWR Group and OLR Group. Regarding running economy (at 14 km.h\(^{-1}\)) also, no intra- or intergroup differences were found in the DWR Group (pre = 43.4 ±5.0, post = 42.6 ±3.85 ml.kg\(^{-1}\).min\(^{-1}\)) and OLR Group (pre = 43.9 ±2.5, post = 42.6 ± 2.6 ml.kg\(^{-1}\).min\(^{-1}\)).

Kinematic responses were similar within and between groups. Water running may serve as an effective complementary training over a period of 8 weeks up to 30% of land training volume for competitive runners.
Oliver Bellevue et al. (November 2009) assessed and compare the validity of both 300-yd and 500-yd shallow water run (SWR) tests to predict peak aerobic power (VO2peak). Participants included 18 women and 18 men who performed a graded exercise treadmill test to predict VO2peak and then performed a 300-yd and 500-yd SWR for time. In addition to SWR times, other independent variables included age, gender, body weight, height, leg length, percent body fat, and 300-yd and 500-yd SWR heart rate and rating of perceived exertion. Correlation coefficients with measured VO2peak were \( r = -0.84 \) and \( -0.87 \) for the 300-yd and 500-yd SWR times, respectively. Multiple regression analyses revealed that prediction of VO2peak from 300-yd SWR time improved by including gender and body weight (\( R = 0.919; \text{SEE} = 0.360 \text{L} \cdot \text{min}^{-1} \)). Similarly, prediction of VO2peak improved from 500-yd SWR time by including gender, body weight, and leg length (\( R = 0.940; \text{SEE} = 0.316 \text{L} \cdot \text{min}^{-1} \)). Equations were also developed for use in pools of varying water depths. In conclusion, the 300-yd and 500-yd SWR tests can provide accurate and valid estimates of aerobic power.

Antonio Cuesta-vargas et al. (November 2009) compared the physiological responses to deep water running (DWR) compared with treadmill running (TMR) by male international volleyball players. We compared the maximum, recovery, and resting heart rates, maximum blood lactate and ratings of perceived exertion between DWR and standard laboratory TMR tests. The maximum heart rate (HRmax) was 14.9 bpm lower in water than on land (\( p = .001, 95\% \text{ confidence interval, 7.74–22.06} \)). The recovery HR at three minutes was 16.4 bpm lower in water (\( p = .012, \text{CI 95\%, 4.57–28.23} \)). The differences in the maximum HR and the three-minute recovery HR likely reflected a cardiovascular response mediated by immersion in
water. The maximum blood lactate and the ratings of perceived exertion suggested that both tests were undertaken at the same effort levels. Before prescribing exercise intensity a water specific test should be performed.

Jacalyn J. Robert McComb, Daesung Roh and James S. Williams. (2006) developed a prediction equation that could be used to estimate maximal oxygen uptake (VO2max) from a sub maximal water running protocol. Thirty-two volunteers (n =19 males, n = 13 females), ages 18 – 24 years, underwent the following testing procedures: (a) a 7-site skin fold assessment; (b) a land VO2max running treadmill test; and (c) a 6 min water running test. For the water running sub maximal protocol, the participants were fitted with an Aqua Jogger Classic Uni-Sex Belt and a Polar Heart Rate Monitor; the participants' head, shoulders, hips and feet were vertically aligned, using a modified running/bicycle motion. A regression model was used to predict VO2max. The criterion variable, VO2max, was measured using open-circuit calorimetry utilizing the Bruce Treadmill Protocol. Predictor variables included in the model were percent body fat (% BF), height, weight, gender, and heart rate following a 6 min water running protocol. Percent body fat accounted for 76% (r = -0.87, SEE = 3.27) of the variance in VO2max. No other variables significantly contributed to the explained variance in VO2max. The equation for the estimation of VO2max is as follows: VO2max ml.kg⁻¹.min⁻¹ = 56.14 - 0.92 (% BF).

Karen Davidson and Lars McNaughton. (2000) compared the effects of deep water running (DWR) training and road running (RR) training on the V'O2max of untrained women. The subjects were 10 untrained women volunteers who were randomly assigned to either the DWR or RR training programs after first undertaking a pretest Vo2 max. All subjects participated in DWR and RR training programs
consisting of a 4-week, 3-day-a-week, progressive aerobic interval program. After training in either medium, subjects were again tested for Vo2 max and then each undertook a 10-week detraining program. Subjects were again tested for Vo2 max and then undertook the opposite program. At the end of the final 4-week program, subjects again underwent a Vo2 max test. Subjects were relatively unfit, with a pre training Vo2 max of 34.1 ± 2.1 ml·kg21·min21. When a comparison of the 2 training methods was carried out, the difference was significant, while post hoc analyses indicated both the DWR and RR training significantly (p < 0.001) increased Vo2 max when compared to resting levels. A comparison of all post- DWR data revealed a Vo2 max value of 42.5 ± 1.5 ml·kg21·min21, while post-RR there was a Vo2 max value of 42.9 ± 1.5 ml·kg21·min21, and therefore, no significant difference between DWR and RR training programs, in their ability to improve Vo2 max. Thus, both deep water running and road running training improved cardiovascular fitness of young, sedentary women.

Cassady and D.H. Nielsen (July 1992) evaluated the oxygen consumption (VO2) and heart rate response curves for standardized upper- and lower-extremity exercise on land and in water. Forty healthy subjects performed one upper-extremity and one lower-extremity exercise at three selected cadences on land and in water. Steady-state heart rate was determined by electrocardiographic radio telemetry and expressed as a percentage of age-predicted maximal heart rate (% APMHR). Percentage of age-predicted maximal heart rate was used as the criterion measure of relative exercise intensity. Oxygen consumption was determined by the open-circuit method. Results indicated systematic increases in VO2 from 2 to 9 metabolic equivalents (METs) (1 MET = 3.5 mL O2.kg-1.min-1) and % APMHR from 45% to 73% with increased cadence. The VO2 responses were highest during water exercise,
whereas % APMHR was greater during land exercise. Based on the magnitude of the responses, water calisthenics appear to be of sufficient intensity to elicit training adaptations. Training studies are needed to document these changes.

**Hall et al. (1998)** compared the cardio respiratory responses of eight healthy women (mean age 30.25 years) to sub maximal exercise on land (LTm) and water treadmills (WTm) in chest-deep water (Aquaciser). In addition, the effects of two different water temperatures were examined (28 and 36 degrees C). Each exercise test consisted of three consecutive 5-min bouts at 3.5, 4.5 and 5.5 km x h(-1). Oxygen consumption (VO2) and heart rate (HR), measured using open-circuit spirometry and telemetry, respectively, increased linearly with increasing speed both in water and on land. At 3.5 km x h(-1) VO2 was similar across procedures \[\text{chi} = 0.6 (0.05) \text{l x min} (-1)\]. At 4.5 and 5.5 km x h (-1) VO2 was significantly higher in water than on land, but there was no temperature effect (WTm: 0.9 and 1.4, respectively; LTm: 0.8 and 0.9 l x min (-1), respectively). HR was significantly higher in WTm at 36 degrees C compared to WTm at 28 degrees C at all speeds, and compared to LTm at 4.5 and 5.5 km x h(-1) \(P \leq 0.003\). The HR-VO2 relationship showed that at a VO2 of 0.9 l x min (-1) x HR was higher in water at 36 degrees C (115 beats x min [-1]) than either on land (100 beats min [-1]) or in water at 28 degrees C (99 beats x min [-1]). The Borg scale of perceived exertion showed that walking in water at 4.5 and 5.5 km x h (-1) was significantly harder than on land (WTm: 11.4 and 14, respectively; LTm: 9.9 and 11, respectively; \(P \leq 0.001\)). These cardio respiratory changes occurred despite a slower cadence in water (the mean difference at all speeds was 27 steps/min). Thus, walking in chest-deep water yields higher energy costs than walking at similar speeds on land. This data has implications for therapists working in hydrotherapy pools.
Greene et al. (June 2011) compared cardio respiratory responses to exercise on an underwater treadmill (UTM) and land treadmill (LTM) and derived an equation to estimate oxygen consumption (VO2) during UTM exercise. Fifty-five men and women completed one LTM and five UTM exercise sessions on separate days. The UTM sessions consisted of chest-deep immersion, with 0, 25, 50, 75, and 100% water-jet resistance. All session treadmill velocities increased every 3 min from 53.6 to 187.8 m x min (-1). Cardiorespiratory responses were similar between LTM and UTM when jet resistance for UTM was 50%. Using multiple regression analysis, weight-relative VO2 could be estimated as: VO2 (mLO2 c kg(-1) x min(-1)) = 0.19248 x height (cm) + 0.17422 x jet resistance (% max) + 0.14092 x velocity (m x min(-1)) -0.12794 x weight (kg)-27.82849, R2 = .82. Our data indicate that similar LTM and UTM cardio respiratory responses are achievable, and we provide a reasonable estimate of UTM VO2.

Clare N. Dowzer et al. (1999) compared the maximal physiological responses to treadmill running (TMR), shallow water running (SWR) and deep water running (DWR) while wearing a buoyancy vest were compared in 15 trained male runners. Measurements included oxygen consumption (VO2 max), respiratory exchange ratio (RER) and heart rate (HR). Treadmill running elicited VO2 ma x and HRmax, which were higher than the peaks attained in both water tests (p< 0.01). VO2 peak averaged 83.7 and 75.3% of VO2 max for SWR and DWR respectively. Peak HR for SWR and DWR were 94.1 and 87.2% of the HRmax reached in the TMR. RER responses were similar between the three modalities. The observations suggest that the training stimulus provided by water is still adequate for supplementary training. While SWR is potentially an efficient method of maintaining cardiovascular...
fitness, it needs to be investigated further to establish if it is a viable technique for the injured athlete to employ.

**Piero Benelli et al. (2004)** compared the heart rate (HR) and blood lactate (BL) responses in young healthy women performing the same routine of aerobics exercise in 3 different conditions: on land, in shallow water (0.8 m), and in deep water (1.4 m). The average age and body mass index (BMI) of the group were 27.4 years and 22.6 kg [middle dot]m-2, respectively. The highest HR and BL values were reached during land aerobics (median HR values were 138.0 and 161.5 b[middle dot]min-1, and lactate values were 3.10 and 5.65 mmol[middle dot]L-1 at slow and at faster pace, respectively). These parameters were progressively reduced going from shallow water (121.5 and 154.0 b[middle dot]min-1, 1.75 and 3.15 mmol[middle dot]L-1) to deep water (97.5 and 113.5 b[middle dot]min-1, 1.70 and 1.75 mmol[middle dot]L-1). The HR measured as percentage of maximum HR varied from 48.43% to 77.53% depending on the water depth and the pace. These data indicate that exercise in water significantly reduces HR and BL production compared with the same exercise performed on land.

**Yasuto Nakanishi, Tetsuya Kimura and Yoshinori Yokoo. (1999)** investigated the effects of age factors on physiological responses to deep water running (DWR) compared with those of treadmill running (TMR) while the water and ambient temperatures were kept in thermo neutral conditions. Fourteen young healthy non-smoker males (Age = 20.4 – 3.3 years, Height = 170.7 – 6.2 cm, Weight = 65.1 – 11.4 kg) and fourteen middle aged healthy non-smoker males (Age = 38.6 – 4.4 years, Height = 171.8 – 4.7 cm, Weight = 75.4 – 9.6 kg) were selected for the study. Two maximal tests, one on the treadmill and the other running in deep water using the Wet
Vest (Lincoln life jacket) were completed by each subject. The order of trial was counterbalanced with half of the subjects in each group completing TMR first and the rest of those completing DWR first. Although the young males had significantly (P<0.05) higher relative VO2\text{max}, HR\text{max} than the middle aged males, there were no significant differences in absolute VO2\text{max}, respiratory exchange ratio (RER), maximal ventilation (V\text{E}\text{max}), ratings of perceived exhaustion (RPE), and peak blood lactate values between the two groups. In conclusion, the VO2\text{max}, HR\text{max}, V\text{E}\text{max}, and peak blood lactate value in response to DWR were significantly lower than those to TMR in both the young and the middle aged males in the thermo neutral conditions. However, there was no significant interaction between age and exercise modes other than RPE of legs at maximal efforts in the present study. We found that the decrease in the maximal physiological responses to DWR compared to TMR is not different between the young and middle aged males.

Barbara A. Avellini, Yair Shapiro and Kent B. Pandolf. (1983) examined fifteen unconditioned young men, who were similar in maximal aerobic power (VO₂ \text{max}), were divided into three groups (n=5 each) and physically trained for one month on a cycle ergometer either on land (I) or immersed to the neck in water of either 32 ± C (II) or 20 ± C (III) to determine if physical training (PT) in water and air differ. PT consisted of one-hour daily exercise, 5 times/wk, with exercise intensity readjusted each week to maintain a constant training stimulus of ~ 75% VO₂ \text{max} (determined on land). Throughout the training period, heart rates (fc) of III averaged 20 and 10 beats·min⁻¹ less than I and II, respectively, despite working at the same VO₂ and % VO₂ \text{max}. Training elicited a 16% increase in VO₂ \text{max} in I compared to increases of 13 and 15% for II and III, respectively. It was concluded that PT in water produces
similar physiological adaptations as does training on land. In cold water, VO\textsubscript{2} max is improved despite training with significantly lower than that on land.

**Aletta Maria Esterhuyse. (2009)** reported that acute and chronic aerobic and resistance exercise results in decreased blood pressure (BP) in hypertensive individuals. There is little evidence that water exercise has a similar effect on BP response. There is also no certainty regarding the magnitude and duration of post exercise hypotension (PEH) after either land or water-based exercise. Most studies were also performed under controlled laboratory conditions and very few characterized the PEH response under real life conditions. The current study endeavored to examine the magnitude and duration of PEH after an acute session of water- and land-based exercise during free living conditions in persons with mild to moderate hypertension. Twenty-one men and women (aged 52 ± 10 years) volunteered for the study. All participants were pre-hypertensive or hypertensive. Participants completed a no exercise control session, a water exercise session and a combined aerobic and resistance land exercise session in random order. After all three sessions, participants underwent 24 hour monitoring using an Ergo scan ambulatory BP monitoring device. Systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP) and heart rate (HR) were monitored to determine changes from resting values after each session and to compare the PEH responses between land and water exercise. Overall, the land exercise treatment caused a 3.6 mmHg lower average SBP over 24 hours than the control treatment (\(P = 0.04\)). The average difference over 24 hours between the water and control treatments was 2.2 mmHg and between land and water exercise it was 1.5 mmHg (\(P > 0.05\)). During daytime, both land and water exercise resulted in significantly lower SBP (12.7 and 11.3 mmHg) compared to the control session (2.3 mmHg). The PEH response lasted
for 24 hours after land exercise and nine hours after water exercise. There was no difference in the daytime DBP for the three treatments (P > 0.05). Although all three groups showed significant reductions during night time, both exercise treatments showed greater nocturnal falls in SBP, DBP and MAP than the control treatment. There were iv significant correlations between changes in the work day SBP after land (r = 0.46) and water (r = 0.47) exercise and control day SBP. The results show that water and land-based exercise result in significant PEH during daytime hours. Although there was no significant difference in the magnitude of PEH between the land and water treatments, it seemed that land exercise resulted in a longer duration of PEH than the water exercise. This is the first study to show that the magnitude of the PEH response is similar for land and water exercise, although the duration of PEH may be longer for land exercise. These results suggest that water exercise is a safe alternative exercise modality for hypertensive individuals. Furthermore, it was shown that the magnitude of the change in SBP after land and water exercise is related to resting SBP value. Therefore, not only will individuals with the highest pre-exercise SBP values benefit the most from exercise, but they will also benefit greatly by morning exercising.

**Brubaker et al. (2011)** determined the cardio-respiratory responses of UTM vs. land treadmill (LTM) exercise, particularly with respect to the relationship between heart rate (HR) and oxygen consumption (VO2). This quantitative original research took place in sports medicine and athletic training facilities at Wake Forest University. 11 Wake Forest University student athletes (20.8 ± 0.6 y, 6 women and 5 men). All participants completed the UTM and LTM exercise-testing protocols in random order. After 5 min of standing rest, both UTM and LTM protocols had 4 stages of increasing belt speed (2.3, 4.9, 7.3, and 9.6 km/h) followed by 3 exercise
stages at 9.6 km/h with increasing water-jet resistance (30%, 40%, and 50% of jet capacity) or inclines (1%, 2%, and 4% grade). A Cosmed K4b2 device with Polar monitor was used to collect HR, ventilation (Ve), tidal volume (TV), breathing frequency (Bf), and VO2 every minute. Ratings of perceived exertion (RPE) were also obtained each minute. There was no significant difference between UTM and LTM for VO2 at rest or during any stage of exercise except stage 3. Furthermore, there were no significant differences between UTM and LTM for HR, Ve, Bf, and RPE on any exercise stage. Linear regression of HR vs VO2, across all stages of exercise, indicates a similar relationship in these variables during UTM (r = .94, y = .269x - 10.86) and LTM (r = .95, y = .291x - 12.98). These data indicate that UTM and LTM exercise elicits similar cardio-respiratory responses and that HR can be used to guide appropriate exercise intensity for college athletes during UTM.

Kamalakannan et al. (2010) analysed the effect of aquatic training with and without weight on selected physiological variables among volleyball players. To achieve this 60 physically active and interested undergraduate engineering volleyball players are selected as subjects and their age ranged between 18 and 20 years. The subjects are categorized into three groups randomly viz. Control group (CG), Aquatic training with weight group (ATWG), Aquatic training without weight group (ATWOG) and each group comprises of 20 subjects. Control group was not exposed to any training. Both experimental groups underwent their respective experimental treatment for 12 weeks, 3 days per week and a session on each day. Breath holding time, resting pulse rate were taken as variables for this study. The collected data was analyzed using analysis of covariance (ANCOVA) and Scheffe’s post hoc test. The result reveals significant differences in all the selected physiological variables among
ATWG and ATWOG pointing towards the use of aquatic training for performance improvement.

Kasee Hildenbrand et al. (2011) examined the impact of a new aquatic exercise protocol on physiological variables in a group of asthmatics. Participants were medically diagnosed and managed asthmatics in a rural community. A total of 8 males and 12 females were accepted into the study with 7 males and 9 females completing the 12-week study. Physiological measures were taken pre- and post treatment with paired t-tests used for analyses. Increases in VO2max, pretreatment mean (M) = 31.244 SD = 9.772; post-treatment M = 33.431, SD = 10.387; partial $\chi^2 = 0.257, p < 0.038$; lean body muscle mass, pretreatment M = 119.606, SD = 28.210; post treatment M = 122.012, SD = 30.475; partial $\chi^2 = 0.237, p < 0.047$; and blood glucose, pretreatment M = 83.937, SD = 7.584; post-treatment M = 89.812, SD = 7.799; partial $\chi^2 = 0.603, p < 0.000$, were seen from pre- to post treatment. The exercise protocol was successful as seen by the increase in VO2max and lean body mass. The protocol was well tolerated and enjoyed by the participants suggesting it is useful in the asthmatic population. Our results predicted a need for larger sample sizes in future research ranging from 8 to 218 participants depending upon the dependent measure.

Alberton et al. (2011) correlated the rating of perceived exertion (RPE) with cardio respiratory and neuromuscular variables during the execution of stationary running in water at different cadences. The sample consisted of 12 apparently healthy women (age: 22.33 ± 0.57 years). During the assessment session, the subjects performed the stationary running exercise in water at 3 different cadences: 60, 80, and 100 bpm. The heart rate (HR), oxygen uptake ($V\overline{O}_2$), ventilation (Ve), and
electromyographic (EMG) signal of the vastus lateralis (VL), biceps femoris (BF), rectus femoris (RF), and semitendinosus (ST) muscles were measured during the exercise, and the overall body RPE was measured immediately following the end. Pearson's linear correlation and multiple linear regression were used, with $p < 0.05$. The analyses demonstrate a high and significant relationship between RPE and HR ($r = 0.65; p < 0.001$), RPE and %HR maximal ($r = 0.65; p < 0.001$), RPE and $V\text{O}_2$ ($r = 0.60; p = 0.001$), RPE and %$V\text{O}_2$ maximal ($r = 0.71; p < 0.001$), and RPE and Ve ($r = 0.77; p < 0.001$). However, there was no relationship between the RPE and the EMGs of the VL, BF, RF, and ST muscles. With regard to the regression, the model was significant ($p < 0.001$) with an $r^2 = 0.79$, whereas the variables that explained better the RPE were %$V\text{O}_2$ maximal and Ve. Hence, these results suggest an association between the perception of exertion and cardio respiratory variables, which was not the case with the neuromuscular variables evaluated in this study. Therefore, the Borg scale of RPE can be used when prescribing stationary running exercise in water for young women.

Nikolaos Chrysagis et al. (2009) examined the effects of a 10-week aquatic program on the gross motor function, on the range of motion and on spasticity of children with cerebral palsy (CP). Six students served as subjects for the experimental group and another 6 were assigned to the control group. The aquatic program was taking place twice a week and consisted of a warm up, the main training session and a cool down phase. Measuring instruments were the Gross Motor Function Measure (GMFM) (dimensions D and E), a goniometer and the modified Ashworth Scale. Pre-test and Post-test were executed before and after the intervention program. Significant interaction effect was found with respect to: the active shoulder flexion ($p = .052$), the active shoulder abduction ($p = .052$), the passive hip abduction ($p = .001$) and the
passive knee extension (p = .045). Interaction effect was found for spasticity of the hip adductors (p = .002) and knee flexors (p = .049). Results of the present study indicated that an aquatic program might have a positive effect in gross motor function as well as in range of motion and spasticity in students with spastic cerebral palsy.

Nasser Rahimi, Sayyed Mohammad Marandi and Mehdi Kargarfard. (August 2011) experimented the effect of eight-week aquatic training on selected physiological factors and blood sugar of patients who suffer from type II diabetes. In this semi-experimental research, 30 men with type II diabetes in Khomeinishahr Township, Iran, were put in two groups of intervention (15 patients) and control (15 patients). The intervention was an eight-week aquatic training (3 sessions in week, each session 45-60 minutes and with intensity of 60-80 percent of maximum heart rate). Whereas the control group had no regular or systematic physical activity. Weight, body mass index (BMI), maximum consuming oxygen, systolic and diastolic blood pressure, fasting blood sugar and also glycated hemoglobin were measured before and after the intervention in both groups. These data was analyzed by ANCOVA test. A significant difference was observed in maximum oxygen consumption, systolic and diastolic blood pressure, fasting blood sugar and glycated hemoglobin between intervention and control groups, whereas this difference in weight and BMI in the two groups was not significant (P < 0.05). The findings of this research indicate that an aquatic training program causes a significant improvement in blood sugar of patients with type II diabetes.

Tiago M. Barbosa et al. (2009) conducted the head-out aquatic exercises became one of the most important physical activities within the health system. Massive research has been produced throughout these decades in order to better
understand the role of head-out aquatic exercises in populations’ health. Such studies aimed to obtain comprehensive knowledge about the acute and chronic response of subjects performing head-out aquatic exercises. For that, it is assumed that chronic adaptations represent the accumulation of acute responses during each aquatic session. The purpose of this study was to describe the “state of the art” about physiological assessment of head-out aquatic exercises based on acute and chronic adaptations in healthy subjects based on a qualitative review. The main findings about acute response of head-out aquatic exercise according to water temperature, water depth, type of exercise, additional equipment used, body segments exercising and music cadence will be described. In what concerns chronic adaptations, the main results related to cardiovascular and metabolic adaptations, muscular strength, flexibility and body composition improvements will be reported.

2.3 SUMMARY OF RELATED LITERATURE

The investigator reviewed several journals, research articles were presented the above related studies in two broad areas namely, studies of aquatic training on physical variables and studies of aquatic training on physiological variables. From the reviewed studies it was inferred that there was scope for further research in selected physical and physiological variables.

Based on the experience the investigator gained, the investigator selected the suitable methodology to be followed in this research, which is presented in Chapter III.