CHAPTER – II

REVIEW OF RELATED LITERATURE

A study of relevant literature is an essential step to get a full picture of what has been done with regard to the problem under study. Such a review brings out a deep and clear perspective of overall field.

The review of literature is instrumental in selecting the topic, transaction of hypothesis and deductive reasoning leading to the problem. It helps to get a clear idea and supports the findings with regard to the problem under study.

The following materials collected from the views expressed by the personalities provide background information to the study and help us to understand the various combinations of track, sand and water running on motor fitness, physiological and athletic performance variables of high school boys. The experts and research workers in the field of physical education are given primary importance to the present study.

2.1 STUDIES ON CONTINUOUS RUNNING ON DIFFERENT TERRAINS AND MOTOR FITNESS VARIABLES

Markovic et al., (2011) compared the running performance of school children on three different surfaces (parquet floor, asphalt and grass) which are mostly used for physical education classes. The study sample consisted of 97 healthy schoolchildren (age 11±0.5 years) divided into two groups in relation to sex: 42 boys (group 1) and 45
The speed was evaluated by two tests: the 30m sprint with a high start and a 3x10m agility run. The results indicate statistically significant differences in terms of running performance in relation to the surface for both groups. The best average results on both tests were achieved on the asphalt surface, while the weakest average results were determined for the 3x10m agility test in both groups on the parquet floor. The obtained results regarding the influence of different surfaces should be used to prevent injury and provide security for school children, and as a factor when testing motor skills in this age group.

**Zamparo (1992)** assessed oxygen uptake (Vo$_2$) at steady state, heart rate and perceived exertion on nine subjects (six men and three women) while walking (3-7 km.h$^{-1}$) or running (7-14 km.h$^{-1}$) on sand or on a firm surface. The women performed the walking tests only. The energy cost of locomotion per unit of distance (C) was then calculated from the ratio of Vo$_2$ to speed and expressed in J.kg$^{-1}$.m$^{-1}$ assuming an energy equivalent of 20.9 J.ml O$_2^{-1}$. At the highest speeds C was adjusted for the measured lactate contribution (which ranged from approximately 2% to approximately 11% of the total). It was found that, when walking on sand, C increased linearly with speed from 3.1 J.kg$^{-1}$.m$^{-1}$ at 3 km.h$^{-1}$ to 5.5 J.kg$^{-1}$.m$^{-1}$ at 7 km.h$^{-1}$, whereas on a firm surface C attained a minimum of 2.3 J.kg$^{-1}$.m$^{-1}$ at 4.5 km.h$^{-1}$ being greater at lower or higher speeds. On average, when walking at speeds greater than 3 km.h$^{-1}$, C was about 1.8 times greater on sand than on compact terrain. When running on sand C was approximately independent of the speed, amounting to 5.3 J.kg$^{-1}$.m$^{-1}$, i.e. about 1.2 times greater than on compact terrain. These findings
could be attributed to a reduced recovery of potential and kinetic energy at each stride when walking on sand (approximately 45% to be compared to approximately 65% on a firm surface) and to a reduced recovery of elastic energy when running on sand.

**Rao (2010)** experimented the effect of sand running on speed and cardio respiratory endurance. To achieve this, 30 male students studying in the department of physical education and Sports Sciences, Acharya Nagarjuana University, Nagarjuna Nagar, Andhra Pradesh, India, were selected as subjects at random. The age of the subjects ranged from 18 to 24 years. The selected subjects were divided into two equal groups of 15 subjects each, such as sand running group and control group. Group I underwent sand running programme for 3 days/week for 12 weeks. The speed and cardio respiratory endurance were assessed as criterion variables. All the subjects of two groups were tested on selected criterion variables prior to and immediately after the training programme by using 50-m run and Cooper's 12-min run/walk test, respectively. The results of the study revealed that there was significant difference between sand running group and control group on selected speed and endurance parameters, namely speed and cardiorespiratory endurance.

**Karve and Tiwari (2010)** revealed the effect of running on different surfaces on performance of athletes. This study shows that a 6-week sand running programme may result in the most physiological and performance changes in young men. Sample 120 PU college athletes from different colleges of Gulbarga District were selected as subjects by random sampling method and divided into four equal groups of 30
athletes in each group: Ex. Group I running training on sand, Ex. Group II running training on red mud track, Group III running training on cinder track and Group IV served as control group. To study the effect of different running surfaces training on the performance of athletes. To assess the effect of training on different running surfaces on the calf and thigh circumference of athletes. To analyse the differences in the performance of 12 min run and walk test and vertical jump test of three different experimental groups and control group. Methodology Before the training on different running surfaces, the performances of 12 min run and walk test and vertical jump and also calf and thigh circumference of each athlete is measured as pre-test results. Eight weeks training programme on different surfaces is conducted to all the three groups simultaneously and no training was given to control group. After the training the calf and thigh circumference of each athlete is measured as post-test results, further vertical jump test is administered and also Cooper's 12 min run and walk test is conducted on the cinder track. There is a significant effect of running training on different surfaces on the performances of three groups. There is a significant effect of running training on different surfaces on the performance of Group III (running training on sand) as compared to other two groups. Calf and thigh circumference increased significantly in sand runners. Both treatment groups showed a similar significant increase in vertical jump. The 12-min run/walk was significantly increased in sand runners. This kind of basic intervention training programme (ie, training on different running surfaces) would help to find a marathon runner.
Chatterjee and Bandyopadhyay (1993) analyzed the effect of endurance training. The study was conducted on a group of 41 East Indian boys aged 10-14 years and was compared with 25 untrained boys of the same age. A continuous slow-running method was adopted for 12 weeks. The intensity of the training was 80-85% of maximum heart rate and frequency was 3 days per week. The boys were trained for a 1500-m event and therefore they covered three to five times their racing distance. For psychological reasons the training was carried out in a playground. The investigations included different physical and motor fitness tests: measurement of flexibility, agility, speed, leg muscle strength etc. Their performance times were also recorded before and after training. From statistical analysis it was concluded that this particular type of training programme did not produce any detrimental effects on 10-14-year-old boys. On the other hand, this type of training did have some influence on improving physiological parameters in this age group of boys when compared with untrained boys of the same age.

Impellizzeri et al., (2008) compared the effects of plyometric training on sand versus a grass surface on muscle soreness, vertical jump height and sprinting ability. Parallel two-group, randomized, longitudinal (pre test-posttest) study. After random allocation, 18 soccer players completed 4 weeks of plyometric training on grass (grass group) and 19 players on sand (sand group). Before and after plyometric training, 10 m and 20 m sprint time, squat jump (SJ), countermovement jump (CMJ), and eccentric utilization ratio (CMJ/SJ) were determined. Muscle soreness was measured using a likert scale. No training surface × time interactions were found for
sprint time (p>0.87), whereas a trend was found for SJ (p=0.08), with both groups showing similar improvements (p<0.001). On the other hand, the grass group improved their CMJ (p=0.033) and CMJ/SJ (p=0.005) significantly (p<0.001) more than players in the sand group. In contrast, players in the sand group experienced less muscle soreness than those in the grass group (p<0.001). It was conclude that the Plyometric training on sand improved both jumping and sprinting ability and induced less muscle soreness. A grass surface seems to be superior in enhancing CMJ performance while the sand surface showed a greater improvement in SJ. Therefore, plyometric training on different surfaces may be associated with different training-induced effects on some neuromuscular factors related to the efficiency of the stretch-shortening cycle.

Binnie et al., (2012) compared the effect of sand and grass training surfaces during a common pre-season interval training session in well-trained team sport athletes (n=10). Participants initially completed a preliminary testing session to gather baseline (BASE) performance data for vertical jump (VJ), repeated sprint ability (RSA) and a 3 km running time trial (RTT). Three days subsequent to BASE, all athletes completed the first interval training session, which was followed by a repeat of the BASE performance tests the following day (24 h post-exercise). Seven days later, the same interval training session was completed on the opposing surface, and was again followed 24 h later by the BASE performance tests. During each session, blood lactate (BLa), ratings of perceived exertion (RPE) and heart rate (HR) were
recorded. Additionally, venous blood was collected pre-, post-, and 24 h post-exercise, and analysed for serum concentrations of Myoglobin (Mb), Creatine Kinase (CK), Haptoglobin (HP) and C-Reactive Protein (CRP). Results showed significantly higher BLa and HR responses experienced during the SAND session (p<0.05), with no differences observed between surfaces for the blood markers of muscle damage, inflammation and hemolysis (p>0.05). Twenty-four hours later, the RTT was performed significantly faster following the SAND session compared to GRASS (p=0.001). These results suggest that performing interval training on a sand (versus grass) surface can result in a greater physiological response, without any additional detriment to next day endurance performance.

Dowzer et al., (1998) determined the magnitude of loss in stature compared with running on land and running in water. Fourteen runners completed three 30 minute runs on separate days in deep water, shallow water, and on a motor driven treadmill. During the three conditions, runners exercised at 80% of their exercise mode specific peak oxygen consumption. Subjects rested in the Fowler position for 20 minutes before and after exercise. Measurements of changes in stature were taken before resting, before running, after 15 minutes of running, after 30 minutes of running, and after the post-exercise rest in the Fowler position. Changes in stature were recorded using a stadiometer accurate to 0.01 mm. Loss of stature values were 4.59 (1.48), 5.51 (2.18), and 2.92 (1.7) mm (means (SD)) for running on the treadmill, and in shallow and deep water respectively. Running in deep water caused significantly lower creep than in the other trials (p<0.05), with no difference between
the shallow water and treadmill conditions. Loss of stature was greater in the first half of the run for all conditions (p<0.05). Ratings of perceived exertion did not differ between the three exercise conditions. Results support the use of deep water running for decreasing the compressive load on the spine.

Shahana et al., (2010) determined the effect of a 12-week aerobic exercise programme on health-related physical fitness components, which are cardiorespiratory endurance, flexibility, abdominal strength endurance and body fat in middle-aged women. A total of 60 middle-aged women from Karyavattom panchayath of Trivandrum district in Kerala state between the age group of 35 and 45 years were selected as subjects for the study. They were tested to collect the data on selected variables. The cardiorespiratory endurance, flexibility, abdominal strength endurance and body fat percentage were selected variables. Further, 30 subjects were randomly assigned as experimental group and 30 as control group. The experimental group underwent aerobic exercise training thrice a week for 12 weeks. The control group did not attend any training programme. The post-tests were conducted on both groups to collect the data on the variables of the study. The data pertaining to health-related physical fitness components were analysed by paired ‘t’ test to determine the difference between initial and final mean for experimental and control groups. Significant difference seen at the 0.05 level with 29 degree of freedom is 2.045 and at 0.01 level with 29 degree of freedom is 2.756 in experimental group following 12 weeks of aerobic training programme for cardiorespiratory endurance, flexibility, muscular strength endurance and skin fold thickness (body fat %). In the case of
control group no significant changes were seen in any of the selected variables. The conclusions of this study are improved cardio respiratory endurance, flexibility, muscular strength endurance and decreased skin fold thickness (body fat %) among the experimental group of middle-aged women after 12 weeks of aerobic training.

Sanders (1993) assessed the effects of age on improvements in cardiovascular fitness following an shallow water aerobics program. Divided twenty female (40 ± 13.99 yr) volunteers into young (28 ± 6.5 yr) and older (52 ± 8.3 yr) adults. Training included 8 weeks of shallow and deep water workouts using aquatic exercise equipment. Heart rates were maintained between 74-84% of predicted heart rate maximum during exercise. Post-training submaximal treadmill tests (Astrand-Rhyming) revealed increases in aerobic capacity of 13.7% and 8.8% for both the young and old, respectively. The study suggest that an initial lack of muscular strength may have been responsible for the differences observed in younger and older subjects. Nevertheless, these findings support the use of shallow water exercise for cardiovascular improvements in the aging population.

Sanders and Rippee (1994) found improvements in both strength and endurance in young (28 ± 6.3 yr) and older (52 ± 8.3 yr) women through water aerobic training. Subjects participated in an 8-week community based program with exercise sessions being a combination of shallow and deep water aerobic exercise using aquatic equipment. Bench press and curl-ups were evaluated pre- and post-training to assess muscular fitness. Although no specific muscular strength and
endurance exercises were incorporated into the aqua aerobics routine, increases in these muscular fitness parameters occurred. In the bench press, an astonishing 136% improvement (pre = 14.2 ± 1.95 kg, post = 33.6 ± 4.91) was observed in the young while the older subjects improved their lift by 180% (pre = 6.8 ± 7.4 kg, post = 19.1 ± 2.9 kg). Similarly, muscular endurance was also enhanced in both groups as determined by the one minute curl-up (Y’s Way to Fitness) test. The younger participants improved curl-up pre-test scores of 19.1 ± 2.9 repetitions to 34.89 ± 2.86 on the post-test, while the older subjects significantly increased the number of successful curl-ups completed from an initial score of 1.75 ± 1.08 to 13.25 ± 4.25 on the post evaluation. Based on these results, both young and old improved muscular fitness through shallow water training. However, it is noted that the dramatic increases in musculoskeletal fitness observed in these studies can be partially credited to the initially low level of fitness of the subjects.

2.2 STUDIES ON CONTINUOUS RUNNING ON DIFFERENT TERRAINS AND PHYSIOLOGICAL VARIABLES

Pinnington and Dawson (2001) compared the energy cost (EC) (J x kg(-1) x m(-1)) of running on grass and soft dry beach sand. Seven male and 5 female recreational runners performed steady state running trials on grass in shoes at 8, 11 and 14 km x h(-1). Steady state sand runs, both barefoot and in shoes, were also attempted at 8 km x h(-1) and approximately 11 km x h(-1). One additional female attempted the grass and sand runs at 8 km x h(-1) only. Net total EC was determined from net aerobic EC (steady state VO₂, VCO₂ and RER) and net anaerobic EC (net
lactate accumulation). When comparing the surface effects (grass, sand bare foot and sand in shoes) of running at 8 km x h(-1) (133.3 m x min(-1)) in 9 subjects who most accurately maintained that speed (133.3 +/- 2.2 m x min(-1)), no differences (P>0.05) existed between the net aerobic, anaerobic and total EC of sand running barefoot or in shoes, but these measures were all significantly greater (P<0.05) than the corresponding values when running on grass. Similarly, when all running speed trials (n = 87) performed by all subjects (n = 13) for each surface condition were combined for analysis, the sand bare foot and sand in shoes values for net aerobic EC, net anaerobic EC and net total EC were significantly greater (P<0.001) than the grass running measures, but not significantly different (P>0.05) from each other. Expressed as ratios of sand to grass running EC coefficients, the sand running barefoot and sand in shoes running trials at 8 km x h(-1) revealed values of 1.6 and 1.5 for net aerobic EC, 3.7 and 2.7 for net anaerobic EC and 1.6 and 1.5 for net total EC respectively. For all running speeds combined, these coefficients were 1.5 and 1.4 for net aerobic EC, 2.5 and 2.3 for net anaerobic EC and 1.5 and 1.5 for net total EC for sand running barefoot and in shoes respectively. Sand running may provide a low impact, but high EC training stimulus

Kamalakkannan et al., (2010) examined 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 Schefee’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.

Lejeune (1998) examined the mechanical work performed by human subjects during walking and running on sand and on a hard surface. Force platform and cinematographic analyses were used to assess the mechanical works and oxygen consumption was used to determine the energetic cost of walking and running under the same conditions. Walking on sand requires 1.6-2.5 times more mechanical work than does walking on a hard surface at the same speed. In contrast, running on sand requires only 1.15 times more mechanical work than does running on a hard surface at the same speed. Walking on sand requires 2.1-2.7 times more energy expenditure than does walking on a hard surface at the same speed; while running on sand requires 1.6 times more energy expenditure than does running on a hard surface. The increase in energy cost is due primarily to two effects: the mechanical work done on the sand, and a decrease in the efficiency of positive work done by the muscles and tendons.
Fellingham et al., (1993) compared water running, cycling, and running for maintaining Vo$_2$ max and 2-mile run performance over a 6-week training period. Thirty-two trained subjects between the ages of 18 and 26 were evaluated for maximum oxygen uptake (Vo$_2$ max) and 2-mile run performance. Subjects were stratified by a 2-mile run pretest into high, medium, and low performance levels and then randomly assigned to water running, cycling, or running training. The three groups trained with similar frequency, duration, and intensity over a 6-week period. After 6 weeks of training, all of the groups made a small but statistically significant decrease in fitness (Vo$_2$ max), but no change in 2-mile run time. However, there were no differences with respect to either training modality or pre training performance level. It was concluded that over a 6-week period, runners who cannot run because of soft tissue injury can maintain Vo$_2$ max and 2-mile run performance similar to running training with either cycling or water running.

Koorma (2010) examined the effect of running and swimming activities on coronary heart disease risk factors. Thirty male teachers aged between 35 and 40 years who knew swimming were selected for the study. Subjects were divided into three equal groups, each group consisted of 10 subjects in which group I underwent running activity and group II underwent swimming activity, 3 days per week for 12 weeks, and group III acted as control, who did not participate in any training. The subjects were tested on selected criterion variables such as total cholesterol, high-density lipoprotein, systolic and diastolic blood pressure prior to and immediately after the training period. The analysis of covariance was used to find out the
significant difference if any, between the experimental groups and control group on selected criterion variables separately. The selected criterion variables such as high-density lipoprotein were improved significantly for both the training groups when compared with the control group and the systolic blood pressure was reduced significantly only for running activity group and swimming activity group. The diastolic blood pressure and total cholesterol were not changed significantly for both the training groups.

Upadhyay et al., (2010) documented effects of low to moderate intensity training on aerobic fitness are well documented. The relative impact of short, HIT versus slow, long distance training has been debated for decades. This study seeks to compare the effect of \( V_o_{2\max} \), a measure of endurance capacity, on school-going males. Twenty-two school-going non-athlete males between 14 and 17 years of age with no history of systemic illness were randomly divided into HIT group (n=12) and slow continuous training (SCT) group (n=10). The HIT group was imparted thrice weekly training of six bouts of 2-min high-intensity run alternated with 2-min rest while SCT group was made to run five times every week for 60 min of slow continuous run (75% of HR \( \text{max} \) for age). Both groups were trained for 6 weeks. Pre-and post-training \( V_o_{2\max} \) were recorded for each group by bleep test. Pre-training mean \( V_o_{2\max} \) was 40.3 ml/kg/min. Subsequent to training, HIT group showed mean improvement in \( V_o_{2\max} \) by 4.5 ml/kg/min (11.7%) while SCT group showed mean improvement in \( V_o_{2\max} \) by 2.2 ml/kg/min (6.0%). High intensity interval training is an effective endurance training tool in non-athletic school going male population and provides better improvement in \( V_o_{2\max} \) than SCT.
Carter et al., (2000) examined the effect of endurance training on oxygen uptake (Vo$_2$) kinetics during moderate [below the lactate threshold (LT)] and heavy (above LT) treadmill running. Twenty-three healthy physical education students undertook 6 wk of endurance training that involved continuous and interval running training 3–5 days per week for 20–30 min per session. Before and after the training program, the subjects performed an incremental treadmill test to exhaustion for determination of the LT and the Vo$_2$ max and a series of 6-min square-wave transitions from rest to running speeds calculated to require 80% of the LT and 50% of the difference between LT and maximal Vo$_2$. The training program caused small (3–4%) but significant increases in LT and maximal Vo$_2$ (P < 0.05). The Vo$_2$ kinetics for moderate exercise was not significantly affected by training. For heavy exercise, the time constant and amplitude of the fast component were not significantly affected by training, but the amplitude of the Vo$_2$ slow component was significantly reduced from 321 ± 32 to 217 ± 23 ml/min (P < 0.05). The reduction in the slow component was not significantly correlated to the reduction in blood lactate concentration (r = 0.39). Although the reduction in the slow component was significantly related to the reduction in minute ventilation (r = 0.46; P < 0.05), it was calculated that only 9–14% of the slow component could be attributed to the change in minute ventilation. They conclude that the Vo$_2$ slow component during treadmill running can be attenuated with a short-term program of endurance running training.

Svedenhag and Seger (1992) compared running on land to vest-supported deep water running with 10 trained male runners (26 yr). Subjects ran at heart rates of
115, 130, 145, 155-160 bpm and also exercised to maximal exercise intensity. Maximal oxygen uptake (4.03 vs 4.60 l/min) and maximal heat rate (172 vs 188 bpm) was lower during water running. The authors suggest the lower maximal heart rates may be attributable to an increase in heart blood volumes, while the influence of different test procedures in the water vs. land may partially explain the differences in \( \text{Vo}_2 \text{max} \). RPE values were higher for deep water running as were the blood lactate concentrations at any given \( \text{Vo}_2 \). These responses may be due to a decreased blood flow in the legs during deep water running as well as the altered leg muscle activation patterns of deep water running.

**Hoeger et al., (1992)** examined the training effects of an identical aerobics program performed on land (low-impact) and in the water. Forty-nine untrained female subjects (water n = 20; land n= 15; control n = 14) participated in the 8-week study with the experimental groups exercising 3 times per week. The aerobic portion of the training session was 20 minutes in duration with exercise intensity maintained between 70-85% of HRR. Both the land-based (low-impact) and shallow water aerobics groups made similar gains in aerobic fitness, with a 14.8% relative improvement in estimated \( \text{Vo}_2 \text{max} \) using a Bruce protocol (pre = 31 ± 6.8, post = 35.6 ± 7.0 ml/kg/min) observed in the shallow water aerobics group. Total treadmill time was also significantly increased (by one minute) following shallow water training.
Simpson and Lemon (1995) examined the effects of a chronic deep water aerobic training program. Eighteen adult females (22-39 years old) were buoyed in the water either by using foam waist belts or ankle cuffs. All subjects trained a minimum of 3 days per week for 50 minutes per session using various aqua aerobics movements. The exercise program in deep water significantly improved estimated \( V_{O_2} \text{max} \) (pre = 29.5 ± 1.8, post = 35.1 ± 1.9 ml/kg/min) in both groups as assessed from an Astrand-Rhyming submaximal treadmill test.

Hertler et al., (1992) compared treadmill exercise to deep water running training in 13 young runners (aged 18-26 yr). Subjects trained on land 3 days per week, for 4 weeks, and then half of the subjects began a deep water running program while the rest continued to run on land. To equalize the training, groups were matched for total exercise time and RPE. Post-training maximal treadmill tests indicated no changes occurred in \( V_{O_2} \text{max} \) between the treadmill and deep water running exercise training groups. This finding implies that deep water running training can be effective in maintaining \( V_{O_2} \text{max} \) in aerobically trained subjects

Quinn and colleagues (1994) found that untrained females were unable to sustain \( V_{O_2} \text{max} \) through deep water running. In their study, 7 young untrained females (mean = 21.7 yr) performed 6 weeks of land-based training (LBT) followed by 4 weeks of deep water running. Evaluation of \( V_{O_2} \text{max} \) occurred on three separate occasions: before and after the land-based running training and at the conclusion of the deep water running program. Participants trained 4 days a week for duration of 30
minutes per day. Untrained subjects improved $V_{O_2\text{max}}$ after 6 weeks of outdoor running (post-LBT = 42.9 ± 3.2 ml/kg/min) only to have these gains return to pre-training baseline values after 4 weeks of deep water running (pre-training = 39.9 ± 3.6, post- deep water running 40.0 ± 1.8 ml/kg/min). Similar to Eyestone et al. (1993), exercise training intensity during the deep water running training protocol may have also affected the outcome of this study. Unlike the land-based training protocol which varied exercise intensity from 60-80% heart rate reserve (HRR), the deep water running program employed only steady state exercise at one intensity (80% of HHR within 10 bpm). Since acute heart rate responses are decreased in water due to hydrostatic pressure, this steady rate intensity may not have been adequate to maintain $V_{O_2\text{max}}$. Upon completion of the project, the authors indicated the importance of adding interval, varying tempo and fartlek workouts to the deep water running training routine. This suggests that there may be a critical intensity or threshold which must be achieved if $V_{O_2\text{max}}$ is to be maintained or improved through deep water running.

Morrow et al., (1996) assessed the influence of DWR over $V_{O_2\text{max}}$, divided 11 subjects into either deep water running (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 max as determined by mode specific $V_{O_2\text{max}}$ tests. Additionally, subjects performed a timed 2.4-k run. Both training groups significantly improved in $V_{O_2\text{max}}$ (p < 0.01). deep water running 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 Vo$_2$ max in a similar fashion as land-based exercise.

Michaud et al. (1995) experimented deep water running and treadmill training on VO$_2$ max of 10 inactive volunteers (female = 8; males = 2; mean = 32 yr) complete maximal treadmill and deep water running tests prior to and following an 8-week aerobic interval deep water running program. Improvements in VO$_2$ max of 10.7% and 20.1% for treadmill and deep water running, respectively were observed after deep water running 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 Vo$_2$ max while deep water running a specificity of testing and training was clearly established. Furthermore, this research also supports a significant crossover effect of deep water running to land-based training in untrained volunteers. The results of these training studies support the use of deep water running as an alternative form of exercise to land-based training for maintenance of aerobic capacity in trained athletes as well as possible Vo$_2$ max improvements for unfit participants.

Davidson and McNaughton (2000) compared the effects of deep water running (DWR) training and road running (RR) training on the Vo$_2$ max of untrained
women. The subjects were 10 untrained women volunteers who were randomly assigned to either the deep water running or road running training programs after first undertaking a pre test VO\(_2\) max. All subjects participated in deep water running and road running 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 VO\(_2\) max and then each undertook a 10-week detraining program. Subjects were again tested for VO\(_2\) max and then undertook the opposite program. At the end of the final 4-week program, subjects again underwent a VO\(_2\) max test. Subjects were relatively unfit, with a pretraining VO\(_2\) max of 34.1 +/- 2.1 ml kg-1min-1. When a comparison of the 2 training methods was carried out, the difference was significant, while post hoc analyses indicated both the deep water running and road running training significantly (p < 0.001) increased VO\(_2\) max when compared to resting levels. A comparison of all post-DWR data revealed a VO\(_2\) max value of 42.5 +/- 1.5 ml.kg-1-min-1, while post-RR there was a VO\(_2\) max value of 42.9 +/- 1.5 ml.kg-1-min-1 and therefore, no significant difference between deep water running and road running training programs, in their ability to improve VO\(_2\) max. Thus, both deep water running and road running training improved cardiovascular fitness of young, sedentary women.

**Hamer and Slocombe (1997)** conducted a study on the psychophysical and heart rate relationship between treadmill and deep-water running, the relationship between ratings of perceived exertion and heart rate attained during sub maximal running tests on a treadmill and during deep-water running was investigated in 12
male subjects. Heart rate and rating of perceived exertion scores analyzed by analysis of covariance tested the equality of adjusted means and parallelism of the slope of this relationship. No significant difference existed between the slopes of the regression equations established for treadmill running and deep-water running. A paired t-test performed across the adjusted group mean heart rates revealed a significant difference between the two conditions. While the slope of the heart rate to rating of perceived exertion regression equations remained similar, the mean heart rate was 17 beats per minute lower in the deep-water running condition than during the treadmill run.

Matthews et al., (2001) conducted a study on comparison of ratings of perceived exertion during deep water running and treadmill running. Deep water running (DWR) is a form a aquatic exercise that simulates the action of land based running (LBR), but appears to cause less musculo-skeletal stress. Consequently, it has become a popular training modality for athletes recovering from injury. The psychophysical effects of deep water running and land based running respectively were investigated at three exercise intensities. Maximum heart rate (HR max) was established using a Cooper 1.5 mile run test and the Karvonen Heart Rate Reserve (HRR) method was used to calculate exercise intensity at 60%, 70%, and 80% HRR, respectively. Six males and four females with a mean age (±SD) of 28.1 ± 4.9 years and unfamiliar with deep water running undertook a 30-minute test in both deep water running and land based running conditions. Each test consisted of 3 x 10 minute periods at 60%, 70%, and 80% HRR respectively. Rating of Perceived Exertion (RPE) was recorded during the last minute of each period. A difference in RPE was
found between land based running and deep water running at 60% (11.4 Vs 12.8, p < 0.001), 70% (12.9 Vs 15.2, p < 0.001), and 80% HRR (14.5 Vs 17.7, p < 0.001). A significant difference in RPE was attributed to localized fatigue associated with the unfamiliarity of the task, reflected by increased cardio-vascular stress at any given heart rate. Athletes and trainers should exhibit caution when prescribing specific deep water running exercise intensity based on HR max date obtained from a land based test. A downward adjustment of 12 to 17 beats per minute is considered prudent to ensure that exercise intensity is appropriate to the goal of the training program and to the trainee’s current ability.

Ritchie and Hopkins (1991) analysed the intensity of exercise in deep-water running. The intensity of exercise during 30-min sessions of continuous deep-water running at a “hard” pace was determined by monitoring oxygen consumption (VO₂), respiratory quotient (RQ), heart rate, perceived physical effort and perceived aches and pains in the legs in eight competitive runners, six of whom had not previously practised the technique. The intensity was compared with that of 30-min runs on a treadmill at hard and “normal” training paces and a 30-min outdoor run at normal training pace. VO₂ during the last session of deep-water running (73% of maximum VO₂) was not significantly different from that of the treadmill hard run (78%), but was significantly higher than that of the treadmill normal run (62%). Similar results were obtained for RQ, perceived effort and pain. In contrast, heart rates for deep-water running were similar to those of normal training and significantly less than
those of the treadmill hard run. The disparity between VO₂ and heart rate for deep-water running may reflect cooling or increased venous return caused by water immersion. It is concluded that deep-water running can be performed at a sufficient intensity for a sufficient period to make it an effective endurance training technique.

Dowzer et al., (1999) analyzed the maximal physiological responses to deep and shallow water running, 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 max and HR max, 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 shallow water running and deep water running respectively. Peak heart rate for shallow water running and deep water running were 94.1 and 87.2% of the HR max reached in the treadmill running. Respiratory exchange ratio responses were similar between the three modalities. The observations suggest that the training stimulus provided by water is still adequate for supplementary training. While shallow water running is potentially an ancient 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.

Town and Bradley (1991) assessed the maximal metabolic responses of deep and shallow water running in trained runners. The purpose of this study was to compare the maximal metabolic responses of competitive runners during treadmill
running (TMR), deep water running (DWR), and shallow water running (SWR). Seven male and two female members of the Wheaton College varsity cross country team served as subjects. Maximal measures included oxygen consumption (\( \text{Vo}_2 \text{ max} \)), respiratory exchange ratio (RER), heart rate (HRmax), and lactic acid (HLA). Repeated-measures ANOVA revealed treadmill running to elicit higher \( \text{Vo}_2 \text{ max} \) and HRmax than both water tests (P less than 0.05). \( \text{Vo}_2 \text{ max} \) was also greater for SWR than for deep water running (P less than 0.05). \( \text{Vo}_2 \text{max} \) values for shallow water running and deep water running were 90.3% and 73.5% of TMR, respectively. HRmax for shallow water running and deep water running were 88.6% and 86% of TMR, respectively. RER and HLA did not differ among tests. These data suggest that shallow water running is capable of eliciting metabolic responses comparable to treadmill running. Shallow water running elicits higher metabolic responses than deep water running.

2.3 STUDIES ON CONTINUOUS RUNNING ON DIFFERENT TERRAINS AND ATHLETIC PERFORMANCE VARIABLES

Hamid and Abbas (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 pretraining (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). It was concluded that plyometric training in water can be an effective technique to improve sprint and strength in young athletes.

Lepers et al., (2000) examined concentric, isometric, and eccentric strength reductions in the quadriceps muscle following a prolonged running exercise. Before and after a 2 h run (28.4 ± 1.4 km) peak torque (PT) of the knee extensors at angular velocities of -120, -90, -60, 0, 60, 120, 180, 240° · s⁻¹ using an isokinetic dynamometer, electromyographic (EMG) activity of the vastus lateralis (VL) and vastus medialis (VM) muscles and height of a counter movement jump were recorded in twelve well-trained triathletes. Counter movement jump performances decreased by 10 % and PT values were all significantly lower (p < 0.01) at each angular velocity following the run. The torque loss was significantly (p < 0.01) greater under eccentric contractions (from 18 to 21 %) than under concentric ones (from 11 to 14 %). EMG activity (RMS) was lower in both VL and VM muscles after the 2 h run but no difference existed in RMS losses between concentric and eccentric contractions. The
present results demonstrate that 1) a prolonged running exercise more greatly affects eccentric force production in the quadriceps muscle, and 2) this specificity seems to be due to an impairment of the muscular contractile mechanism rather than a modification to the neural input.

Butts et al., (1991) investigated the maximal responses to treadmill and deep water running in 12 high school female cross country runners (mean = 15 yr). Subjects were taught DWR technique prior to testing, but had no previous experience with this form of training. Peak heart rate and oxygen consumption was higher on the treadmill than in water by 9% and 13%, respectively. The authors suggest the lower deep water running metabolic responses may be attributable to a number of factors, including the cooling effect of the water temperature (29°C [84°F]), the hydrostatic forces exerted by water, the low body fat of the subjects (mean = 17.6%), and mechanical differences observed in deep water running due to the buoyancy effect of water. It was concluded that deep water running provided numerous rehabilitation and training possibilities for athletes.

Hoeger et al., (1992) analyzed the effects of water exercise on muscular fitness. Shallow water aerobic exercise holds promise as a means of enhancing muscular strength in untrained participants. After 8 weeks, untrained females (26 ± 5.9 yr) who performed shallow water aerobics exercise achieved significantly greater gains in several strength measures such as left knee flexion at 300 degrees/s-1, left shoulder extension at 60, 180, 300 degrees/s-1, left shoulder flexion at 60 degrees/s-1
and right shoulder extension at 60, 180, 300 degrees/s-1 compared with the control group. In agreement, Sanders and Rippee (1994) found improvements in both strength and endurance in young (28 ± 6.3 yr) and older (52 ± 8.3 yr) women. Subjects participated in an 8-week community based program with exercise sessions being a combination of shallow and deep water aerobic exercise using aquatic equipment. Bench press and curl-ups were evaluated pre- and post-training to assess muscular fitness. Although no specific muscular strength and endurance exercises were incorporated into the aqua aerobics routine, increases in these muscular fitness parameters occurred. In the bench press, an astonishing 136% improvement (pre = 14.2 ± 1.95 kg, post = 33.6 ± 4.91) was observed in the young while the older subjects improved their lift by 180% (pre = 6.8 ± 7.4 kg, post = 19.1 ± 2.9 kg). Similarly, muscular endurance was also enhanced in both groups as determined by the one minute curl-up (Y’s Way to Fitness) test. The younger participants improved curl-up pre-test scores of 19.1 ± 2.9 repetitions to 34.89 ± 2.86 on the post-test, while the older subjects significantly increased the number of successful curl-ups completed from an initial score of 1.75 ± 1.08 to 13.25 ± 4.25 on the post evaluation. Based on these results, both young and old improved muscular fitness through shallow water training. However, it is noted that the dramatic increases in musculoskeletal fitness observed in these studies can be partially credited to the initially low level of fitness of the subjects.

Asadi (2011) compared the effects of depth jump (DJ) and countermovement jump (CMJ) training on sand on electromyography (EMG) changes and performance
in healthy subjects. Twenty-seven male collegiate students participated in this study and randomly divided into three groups: DJ, CMJ and control group (CG). Subjects in the DJ and CMJ groups performed 5 sets of 20 repetition jumps from a 45-cm box onto a 20-cm dry sand two days a week for 6 weeks. The EMG activities in the vastus medialis (VM), rectus femoris (RF) and vastus lateralis (VL) muscles, vertical jump (VJ) and 20-m sprint time were assessed pre and post training. The results showed significant increases in the EMG activities (IEMG) for the VM and RF following DJ and CMJ training on sand and compared with control group (P < 0.05). The DJ and CMJ groups showed significant improvement than control group in the VL muscle activities, and no statistically significant differences were found among groups (P > 0.05). The DJ and CMJ training on sand led to significant improvement in VJ and decreases in 20-m sprint time (P < 0.05). In conclusion, the DJ and CMJ training on sand improved EMG activities, power, and sprint performance and it is recommended that, coaches design plyometrics on sand for athletes or individuals, because these types of training on sand can be effective for increasing performance.

Baker and Nance (1999) stated that the force produced or the heights obtained during concentric jump tests appear to be very good predictors of sprint performance in uphill and downhill. The inclusion of training strategies that emphasis concentric strength or power may be advantageous in the improvement of all phases of sprinter performance. The relationships between lower body strength and sprint performance of twenty professional rugby league players were examined. Strength assessed by determining the 3 RM loads for the full squats and hangs clean and sprint
performance by the 10 m and 40 m sprint times. Absolute measures of strength in body exercises expressed non significant relationships ($r = 0.06$ & $r = -0.36$ for squat and power clean respectively) with both 10 m and 40 m sprint times. However, when the strength measures were expressed relative to body mass significant relationships occurred between the strength measures and sprint performances. Specifically, a relationship of $r = -0.66$ was reported between then 3RM squat and 40 m sprint time. The 3 RM power clean expressed relationship with both 10 m and 40 m sprint times with reported correlations of $r = -0.66$ was reported between 3 RM squat and 40 m sprint time. The 3 RM power clean expressed relationship with both 10 m and 40 m sprint times with reported correlations of $r = -0.56$ and $r = -0.72$ respectively. This further highlights the importance of sprinters having a high level of relative jump height and power.

_kukolj et al., (1999)_ examined the relationship between jumping power and hill running (uphill and downhill), sprint ability has qualified jump performance by the distance obtained in the vertical and horizontal jump. These studies have reported correlations between these measures between $r = 0.44-0.77$. However, reported that the use of vertical height measures to gauge performance level gymnasts was inadequate. In fact, of the few studies which has used more sensitive’s measures such as force and power developed during the jump task; all have reported stronger correlation with sprint performance. For example, reported very strong correlation between the mean peak power during the countermovement jump (CMJ) and 20 m sprint time ($r = -0.88$) whereas other reported correlations ranging between $r = 0.44$-
0.70 for countermovement jump height ability and sprint velocity of the acceleration phase (0 to 30m), and maximum sprinting speed \((r=-0.77)\) also observed a strong relationship between the maximum force developed during a weight squat jump (SJ) and sprint time to 2.5 m \((r=-0.86)\). Therefore, identifying the predictive ability of more sensitive kinetic measures with sprint performance from various types of jump assessments warrants further research. Due to the strong relationships overall with sprint performance the countermovement jump should be considered as a training exercise to enhance sprint performance especially during the acceleration phase. The squat jump (SJ) is considered a measure of leg explosiveness under concentric condition I such an assessment the athlete starts in a bent knee position (approximately 120° knee angle) with their hands on their hips. The athlete will hold this position for approximately four seconds and the attempt to jump as high as possible without any counter movement.

**Kristine et al., (2011)** analyzed speed regulation during over ground running on undulating terrain. After an initial laboratory session to calculated physiological thresholds, eight experienced runners completed a spontaneously paced time trail over three laps of an outdoor course involving uphill, downhill and level sections. A portable gas analyzer, global positioning system receiver, and activity monitor were used to collect physiological, speed and stride frequency data. Participants run 23% slower on uphill and 13.8% faster on downhill compared with level sections. Speeds on level sections were significantly different for 78.4 +/- 7.0 s following on uphill and 23.8 +/- 2.2 s following downhill. Speed changes were primarily regulated by stride
length, which was 20.5% shorter uphill and 16.2% longer downhill, whereas stride frequency was relatively stable. Oxygen consumption averaged 100.4% of runner’s individual ventilator thresholds on uphill, 78.9% on downhill, and 89.3% on level sections. Approximately 89% of group level speed was predicted using a modified gradient factor. It was hypothesized that altering stride frequency would change metabolic cost less during uphill and downhill running than during level running. To test this hypothesis, we collected force and metabolic data as nine male subjects ran at 2.8 m s\(^{-1}\) on the level, 3° uphill and 30 downhill. Stride frequency was systematically varied above and below preferred frequency (PSF ±8% and ±15%). ground reaction force data were used to calculate potential’ kinetic and total mechanical energy, and calculated theoretical maximum possible and estimated actual elastic energy storage and return. The study concluded that neither the overall relationship between metabolic cost and stride frequency nor the energetically optimal stride frequency changed substantially with slope. However, estimated actual elastic energy storage as a percentage of total positive power increased with increasing stride frequency on all slopes, inducting the muscle power decreases with increasing stride frequency. Combined with the increased cost of force production and internal work with increasing stride frequency, this leads to an intermediate optimal stride frequency and overall U-shaped curve.

Zafeiridis et al., (2005) investigated the effect of athletic training programs designed to enhance performance of all phases of sprinting and include a combination of plyometric training, sprint training (non-resisted, uphill, and downhill running,
resisted [chutes, sleds, weighted vests] and assisted towing), and resistance training. Studies have shown that non-resisted sprint training, uphill and downhill sprint training, and resisted sprint training significantly increased acceleration and sprinting speed. In addition, the combination of sprint and resistance training has been shown to be effective for enhancing maximal speed, speed endurance, power and strength of the lower body. Maximal strength, particularly for the squat and power clean exercise, has been shown to be significantly correlated with sprint performance. Resistance training increases the muscular strength and power and, in combination with sprinting training, enables the athlete to exert greater force with each foot contact, thereby increasing running acceleration and velocity. Thus, an integrated training approach seems most effective for maximizing sprinting speed.

**Tziortzis (1991)** speculated the effect of uphill and downhill training method was significantly more effective in improving the maximum sprinting speed and the associated kinematic characteristics of sprint running in active sports subjects than an equivalent horizontal training method, with little change in running posture. The correlation coefficient between MRS and resulting performance in the 100 m was reported as 0.90 and 0.96 for male and female sprinters respectively, indicating the importance of the maximum speed for high-level performance. Similarly, found a correlation 0.88 between MRS and resulting performance. Interpreting these results reported that MRS seems to be the most important factor in male sprinters in the 100 m race. So, it could be speculated that the combined uphill-downhill training method is more effective in improving performance in short distance sprinting events. This
study therefore provides further objective evidence substantiating the efficiency of the combined uphill and downhill training method for improving maximum horizontal sprinting speed, which is important in a range of sports, including athletes and a variety of major team games.

2.4 SUMMARY OF REVIEW OF LITERATURE

The reviews are presented under the three sections namely studies on continuous running on different terrains and motor fitness variables (n=11), studies on continuous running on different terrains and physiological variables (n=20) and studies on continuous running on different terrains and athletic performance variables (n=10). All the research studies that are presented in this section prove that continuous running on track, sand and water contribute significantly for better improvement in selected motor fitness, physiological and athletic performance variables.

Research studies using continuous running on different terrains revealed compatible results (Markovic et al., 2001, Rao 2010, Karve and Tiwari 2010, Dowzer et al., 1998, Shahana et al., 2010, Sanders and Rippee 1994). There was clear evidence that continuous running on motor fitness variables were one of the effective training methods to improve the selected criterion variables among the high school boys.

The studies suggested that continuous running on different terrains on physiological variables has been found to elicit greater changes in selected variables

The review of literature helped the researcher from the methodological point of view too. It was learnt that most of the research studies cited in this chapter on analysis and experimental design as the appropriate methods to find out the training. The present study may serve as a foundation and main ingredient for future research and investigate the proper training methods for future research and to investigate proper training methods for changing the motor fitness, physiological and athletic performance variables of high school boys.