REVIEW OF RELATED LITERATURE

CHAPTER II

REVIEW OF RELATED LITERATURE

No research begins in a vacuum. The scanning of literature in considerate as systematic process and critical review of the most important published scholarly literature on a particular topic is at most essential. It helps the researcher to find out what is already known, what others have attempted to find out and what others have suggested on certain issues.

Sincere efforts have been taken by the research scholar to locate literature to the present study. The relevant studies found various sources, which the investigator has come across, are detailed below. The research scholar has also collected related literature reviews from internet, journals, books of physical education and sports literatures are available.

2.1 STUDIES RELATED TO NEUROMOTOR TASK TRAINING

Hubbard IJ et.al. (2009) documented that there is mounting evidence of the value of task-specific training as a neuromotor intervention in neurological rehabilitation. The evidence is founded in the psychology of motor skill learning and in the neuroscience of experience-dependent and learning-dependent neural plastic changes in the brain in animals and humans. Further, there is growing empirical evidence for the effectiveness of task-specific training in rehabilitation and for neural plastic changes following task-oriented training. In this paper, they positioned the evidence for task-specific training in the context of rehabilitation; review its relevance for occupation-based neurological rehabilitation, particularly in relation to upper limb function and everyday activities; and recommended evidence-driven strategies for its application. Though they recommended that task-specific training be routinely applied by occupational therapists as a component of their neuromotor interventions, particularly in management related to post-stroke upper limb recovery, specifically, they proposed five implementation strategies based on review of the evidence. These are: task-specific training should be relevant to the patient/client and to the context; be randomly assigned; be repetitive and involve massed practice; aim towards reconstruction of the whole task; and be reinforced with positive and timely feedback.

Levac D et.al. (2009) identified and described the application of 3 motor learning strategies (verbal instructions, practice, and verbal feedback) within 4 intervention approaches (cognitive orientation to daily occupational performance, neuromotor task training, family-centered functional therapy, and activity-focused motor interventions). A scoping review of the literature was conducted. Two themes characterizing the application of motor learning strategies within the approaches are identified and described. Application of a motor learning strategy can be a defining component of the intervention or a means of enhancing generalization and transfer of learning beyond the intervention. Often, insufficient information limits full understanding of strategy application within the approach. A greater understanding of the application, and perceived non-application, of motor learning strategies within intervention approaches has important clinical and research implications.

Wong YM and Ng G (2010) examined and compared two modes of weight training (bodybuilding and power-lifting) on the surface EMG of vasti muscles, knee joint position sense and isometric knee extension force in 48 able-bodied subjects. Subjects were randomly allocated into either a moderate loading and repetitions (bodybuilding) training or a high loading and low repetitions (power-lifting) training, or a no training control group. Training was conducted on alternate days with individual supervision. After 8 weeks of training, subjects from both training groups showed significantly earlier EMG onset timing and higher amplitude of vastus medialis obliquus relative to vastus lateralis ($p=0.005$ or <0.001), and improved knee joint position sense ($p<0.001$), but no such changes were found in the control group. However, the changes were not significantly different ($p>0.05$) between the two training groups. The findings suggested that the neuromotor control of the vasti muscles could be altered by regular weight training.

Niemeijer AS et.al. (2007) evaluated neuromotor task training (NTT), a recently developed child-centred and task-oriented treatment programme for children with developmental coordination disorder (DCD). A treatment and a non-treatment control group of children with DCD were included. Children were selected if they scored below the 15th centile on the Movement Assessment Battery for Children (MABC). The children in the treatment group were recently referred for physiotherapy (n=26; 20 males, 6 females; mean age 7y 2mo [SD 1y 3mo]). The parents of the non-treated children were concerned about their children's motor performance and responded to advertisements for free testing (n=13; 10 males, 3 females; mean age 7y 2mo [SD 2y 1mo]). Before and after nine weekly 30-minute sessions of NTT or at least 9 weeks of no intervention, the MABC and the Test of Gross Motor Development - 2 (TGMD-2) were administered. Therapists reported per session on treatment goals and tasks trained. The results indicate that motor performance does not improve spontaneously and that NTT is effective. During the intervention period, only the treated group improved on the MABC and the TGMD-2. Children improved most on tasks similar to those trained. In older children with poorer motor patterns, NTT's treatment success was higher. The Child Behavior Checklist subscales withdrawn, thought problems, anxious/depressed, and delinquency were determinants of effects on motor patterns.

Wheaton LA et.al. (2007) stated that numerous electroencephalography (EEG) studies have shown that neurophysiological signals change in response to visual and sensory adaptations in upper extremity tasks. However, this has not been clearly studied in the lower extremity. In this study, they evaluated how sensory loading affects brain activations related to knee movement. Thirty-two channel EEG was recorded while ten subjects performed knee extension in four different conditions: no weight and no visual target (NWNT), weight affixed to the ankle and no visual target (WNT), no weight and a visual target (NWT), and both weight and target (WT). Surface electromyography (EMG) was recorded from the vastus medialis and vastus lateralis muscles to determine onset of the movement. EEG was epoched from -4.5 s before to 1 s after EMG onset. Epochs were averaged to acquire movement-related cortical potentials (MRCPs) of each task condition. MRCP amplitude during the pre-movement period from -2 s to EMG onset was evaluated at electrodes over motor, sensory, frontal, and parietal areas. The amplitude of the pre-movement potentials for the conditions was different across areas of interest. Over the motor area, NWNT had lower amplitude than any other condition and WT had higher amplitude than any other condition. There was no difference between unimodal NWT and WNT conditions. Mesial frontal and parietal areas showed larger MRCP to the bimodal condition than either unimodal or NWNT conditions. The parietal cortex was the only region that showed a difference between unimodal conditions with greater amplitude for NWT condition. Information concerning added sensory demand is processed by the motor cortex in a way that may be indifferent to the type of modality, but is influenced by the quantity of modalities at the level of the knee.

Other brain structures such as parietal and premotor cortices respond based on the modality type to help plan appropriate strategies for motor control in response to sensory manipulations. This suggests that additional task demands in motor training may create a rich sensory environment that may be beneficial in promoting optimal neuromotor recovery.

Huang H et.al. (2006) documented that the original use of biofeedback to train single muscle activity in static positions or movement unrelated to function did not correlate well to motor function improvements in patients with central nervous system injuries. The concept of task-oriented repetitive training suggests that biofeedback therapy should be delivered during functionally related dynamic movement to optimize motor function improvement. Current, advanced technologies facilitate the design of novel biofeedback systems that possess diverse parameters, advanced cue display, and sophisticated control systems for use in task-oriented biofeedback. In light of these advancements, this article: (1) reviewed early biofeedback studies and their conclusions; (2) presented recent developments in biofeedback technologies and their applications to task-oriented biofeedback interventions; and (3) discussed considerations regarding the therapeutic system design and the clinical application of task-oriented biofeedback therapy. This review provided a framework to further broaden the application of task-oriented biofeedback therapy in neuromotor rehabilitation.

Schoemaker MM et.al. (2003) evaluated the effectiveness of a Neuromotor Task Training (NTT), recently developed for the treatment of children with Developmental Coordination Disorder (DCD) by pediatric physical therapists in the Netherlands. NTT is a task-oriented treatment program based upon recent insights from motor control and motor learning research. Ten children with DCD (intervention group) were tested before and after 9 and 18 treatment sessions on the Movement ABC and a dysgraphia scale in order to measure the effectiveness of treatment on gross and fine motor skills in general and handwriting in particular. Five children (no-treatment control group) were tested twice with a time lag of nine weeks on the Movement ABC in order to measure spontaneous improvement. No improvement was measured for the children in the no-treatment control group, whereas a significant improvement was found for children in the intervention group for both quality of handwriting and performance on the Movement ABC after 18 treatment sessions

Guilhem G et.al. (2010) presented the properties of an eccentric contraction and compare neuromuscular and muscle-tendon system adaptations induced by isotonic (IT) and isokinetic (IK) eccentric trainings. An eccentric muscle contraction is characterized by the production of muscle force associated to a lengthening of the muscle-tendon system. This muscle solicitation can cause micro lesions followed by a regeneration process of the muscle-tendon system. Eccentric exercise is commonly used in functional rehabilitation for its positive effect on collagen synthesis but also for resistance training to increase muscle strength and muscle mass in athletes. Indeed, eccentric training stimulates muscle hypertrophy, increases the fascicle pennation angle, fascicles length and neural activation, thus inducing greater strength gains than concentric or isometric training programs. Eccentric exercise is commonly performed either against a constant external load (isotonic) or at constant velocity (isokinetic), inducing different mechanical constraints. These different mechanical constraints could induce structural and neural adaptive strategies specific to each type of exercise. The literature tends to show that isotonic mode leads to a greater strength gain than isokinetic mode. This observation could be explained by a greater neuromuscular activation after IT training. However, the specific muscle adaptations induced by each mode remain difficult to determine due to the lack of standardized, comparative studies.

Masci I et.al. (2010) verified that skilled volleyball players present specific adaptations in both neuromuscular control and movement biomechanics, showing an improved neuromuscular control around the knee joint than in non-jumper athletes. Seven male volleyball players and seven male non-jumper athletes were recruited for the study. The following tests were performed in a random order: single countermovement jump (CMJ), single squat jump. At the end of the series, subjects performed a repetitive CMJ test. Electromyographic signals were recorded from vastus lateralis and biceps femoris muscles on both sides. Ground reaction forces and moments were measured with a force plate. Volleyball athletes performed better in all tests and were more resistant to fatigue than non-jumper athletes. Furthermore, volleyball athletes showed a reduced co-activation of knee flexor/extensor muscles. The results stand for a neural adaptation of the motor control scheme to training.

Taube W et.al. (2007) compared in young elite athletes, the influence of a sensorimotor training (SMT = balance training) on strength, jump height and spinal reflex excitability with adaptations induced by strength training (ST). Seventeen athletes were randomly assigned to either a SMT or a ST group. Before and after 6 weeks of training, maximal isometric strength (MVC) and rate of force development (RFD (max)) were determined. Changes in jump height and EMG activity were assessed during squat- (SJ), countermovement- (CMJ) and drop-jump (DJ). To evaluate neural adaptations, H-reflex recruitment was recorded at rest and during dynamic activation of the plantarflexors following stance perturbation. MVC was enhanced after ST but not influenced by SMT. RFD (max) was not affected by any training. Both SMT and ST significantly improved jump performance in SJ, CMJ, and DJ. Maximum H-reflex to maximum M-wave ratios (H (max)/M (max)-ratios) at rest remained unchanged. During stance perturbation, H (max)/M (max)-ratios were significantly reduced following SMT whereas ST augmented H (max)/M (max)-ratios ($p < 0.05$). In contrast to other studies, no changes in RFD were found. This may be explained by methodological and/or training specific differences. However, both SMT and ST improved jump performance in well trained young athletes but induced opposing adaptations of the H (max)/M (max)-ratio when measured during dynamic contractions. These adaptations were task-specific as indicated by the unchanged reflexes at rest. Decreased spinal excitability following SMT was interpreted as the attempt to improve movement control, whereas augmented excitability following ST accounts for the effort to enhance motoneuron output. Functionally, their results emphasized that SMT is not only beneficial for prevention and rehabilitation but also improved athletic performance.

McNeal JR and Sands WA (2006) documented that stretching exercises have been considered an essential component of physical training programs for decades. Cross-sectional studies have demonstrated that flexibility measures are related to performance in many sports, suggesting that using stretching to enhance flexibility may indirectly improve performance. However, observations by athletes and coaches have called into question the universal prescription of stretching for the purpose of enhancing sport performance, and this skepticism is being supported by a growing body of empirical data. Whereas the tissue responses and adaptations to stretching have been the most widely studied area of stretching research, comparatively little is understood regarding the neural influences on range of motion, which may have more applicability when the range of motion needs are related to skilled movements as in sport.

Koceja DM (2004) reported that in response to chronic physical training, the human neuromuscular system undergoes significant and specific adaptations. More importantly, these influences are the result of the type and quantity of physical activity. One of the simplest neuromuscular mechanisms is the spinal stretch reflex. The reflex system was previously viewed as inflexible, with a relatively fixed response that could vary only slightly. However, more recent data have identified an adaptive plasticity in the reflex system. In this respect, the reflex system can be used to assess training and aging adaptations of the human neuromuscular system. Due to their methodological simplicity, both the tendon-tap reflex and the electrically evoked Hoffmann reflex (H-reflex) can be used to assess training adaptations of the human neuromuscular system.

Judge LW et.al. (2003) assessed the effects of variations in the volume and intensity of resistance training in highly skilled athletes on neural adaptive mechanisms: the maximality and pattern of neural drive. The maximality of muscle activation was measured using a high-resolution sample and hold amplifier to record interpolated twitches. The pattern of neural drive was measured by analysing isometric torque-time curves and electromyographic (EMG) characteristics during the performance of rapid isometric contractions at maximal effort. The volume and intensity of training were varied at 4-weekly intervals to systematically emphasize the development of strength, power and motor performance in 14 highly skilled track and field athletes (e.g. discus, hammer, javelin, shot put and weight). Knee extension strength increased significantly by 15% during steady maximal isometric contractions and by 24% during rapid isometric contractions at maximal effort after the 16-week training programme ($P < 0.05$). Increases in EMG amplitude and rate of EMG activation indicated that improvements to the pattern of neural drive occurred with sport-specific resistance training ($P < 0.05$). The maximality and pattern of neural drive did not change in the control group.

2.2 STUDIES ON PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION

Cervantes SJ and Snyder AR (2011) documented that warming up before performing rigorous physical activity is typically done to increase range of motion and improve athletic performance. Common warm-up techniques in college athletics include static stretching, proprioceptive neuromuscular facilitation (PNF) stretching, dynamic warm-ups, and sport-specific activities. However, the type of warm-up routine used in the college setting varies based on a variety of factors including coaching or therapist experience, education, and preference. Recent studies have investigated the effectiveness of different types of warm-up on college athlete performance measures such as vertical jump, agility, and sport-specific activities (eg, sprint performance). Although a dynamic warm-up is generally thought to be superior to other common warm-up techniques, there remains uncertainty regarding the best method to prepare for intercollegiate athletic participation.

Pereira MP (2012) reported that Proprioceptive neuromuscular facilitation (PNF) is an attractive method to increase strength and proprioception of elderly individuals. However, a major clinical concern about the prescription of PNF is the belief that it can cause a cardiovascular overload, because it involves close-to-maximal loads and isometric contractions. Yet the acute effect of a PNF training session on cardiovascular response in elderly individuals is still unknown. The objective of their study was to evaluate the effect of PNF on diastolic and systolic blood pressure of healthy elderly people. Fifteen older women (mean age 72.40±6.82 years) performed three sets (five repetitions each) of three different PNF techniques (rhythmic initiation, dynamic reversion, and isotonic combination), executing a single movement pattern. Diastolic and systolic blood pressure (DBP and SBP) were evaluated by means of a manual sphygmomanometer immediately before and during the last two repetitions (last set) of each technique. A two-way ANOVA test (time and technique) was performed to investigate the PNF effect on blood pressure. No time (preexercise to postexercise) (p=0.33 for DBP; p=0.06 for SBP) or PNF technique (p=0.75; p=0.81) effect were observed. In conclusion, they stated that the execution of PNF techniques was safe for the cardiovascular system of healthy elderly women, because no blood pressure increases were found.

Franco NR et.al. (2012) determined the effect of a 6-week sprinter-specific proprioceptive training program on core stability and gravity centre control in sprinters. Thirty-three athletes (21.82 ± 4.84 years, 1.76 ± 0.07 m, 67.82 ± 08.04 kg, 21.89 ± 2.37 kg/m2) from sprint disciplines were divided into a control (n=17) and experimental (n=16) groups. A 30 minutes proprioceptive training program was included in the experimental group training sessions, and it was performed for six weeks, three times each week. The program included 5 exercises with BOSU and Swiss ball as unstable training tools that were designed to reproduce different moments of the technique of a sprint race. Stability with eyes open and eyes closed, postural stability and gravity centre control were assessed before and after the training program. Analyzes of covariance ($\alpha = 0.05$) revealed significant differences on stability in medial-lateral plane with eyes open, gravity centre control in the right direction and gravity centre control in back direction after the exercise intervention in the experimental athletes. No other significant differences were demonstrated. The sprinter-specific proprioceptive training program provided postural stability with eyes open and gravity centre control measures improvements, although it was not clear if the effect of training would transfer to the general population.

Rammelt S et.al. (2011) found that injuries to the lateral ankle ligaments are the most common sports injuries. Determination of their severity and exclusion of relevant accompanying injuries requires a subtle clinical and a focused radiological assessment. Treatment is non-operative and functional in the majority of cases. Consequent application of orthoses limiting supination and proprioceptive training are essential to avoid chronic instability.

Janssen KW et.al. (2011) documented that ankle sprains are the most common sports and physical activity related injury. There is extensive evidence that there is a twofold increased risk for injury recurrence for at least one year post injury. In up to 50% of all cases recurrences result in disability and lead to chronic pain or instability, requiring prolonged medical care. Therefore ankle sprain recurrence prevention in athletes is essential. This RCT evaluated the effect of the combined use of braces and neuromuscular training (e.g. proprioceptive training/sensorimotor training/ balance training) against the individual use of either braces or neuromuscular training alone on ankle sprain recurrences, when applied to individual athletes after usual care. The study was designed as three-way randomized controlled trial with one year follow-up. Healthy individuals between 12 and 70 years of age, who were actively participating in sports and who had sustained a lateral ankle sprain in the two months prior to inclusion, were eligible for inclusion. After subjects had finished ankle sprain treatment by means of usual care, they were randomised to any of the three study groups. Subjects in group 1 received an eight week neuromuscular training program, subjects in group 2 received a sports brace to be worn during all sports activities for the duration of one year, and group 3 received a combination of the neuromuscular training program and a sports brace to be worn during all sports activities for the duration of eight weeks. Outcomes were assessed at baseline and every month for 12 months thereafter. The primary outcome measure was incidence of ankle sprain recurrences. Secondary outcome measures included the direct and indirect costs of recurrent injury, the severity of recurrent injury, and the residual complaints during and after the intervention. This study, yet to be completed, expected to identify the most effective and cost-efficient secondary preventive measure for ankle sprains. The authors claim it to be the first randomized controlled trial to directly compare the secondary preventive effect of the combined use of braces and neuromuscular training, against the use of either braces or neuromuscular training as separate secondary preventive measures.

Salsabili H et.al. (2011) designed evaluations and balance training with a 3-week baseline with evaluation after 3 weeks, followed by training over 3 weeks with reevaluation. They acquired control scores for standing balance from the Biodex stability system and fluctuations of the center of pressure. They performed repeated measure analysis of variance to test mean differences in three sessions of assessments. In addition, they compared mean differences of each pair of sessions with the least significant difference test. They used the paired t-test to compare the pure effects of trainings. Their investigation showed that the results of Biodex stability scores and force platform medial-lateral sway measurements improved statistically. Significant higher open-eyes median and mean frequency values of postural sway in the medial-lateral direction indicated that balance training allowed patients to develop control over the degree of freedom at the hip joint. In conclusion, training that compensates for disordered balance indicated by subclinical constraints with respect to the guidance effect of external visual feedback improves standing postural control in patients with type 2 DN.

Salomonczyk D et.al. (2011) explored the relationship between changes in sensory and motor systems by examining these processes following (1) prolonged reach training and (2) training with increasing visuomotor distortions. To examine proprioceptive recalibration, they determined the position at which subjects felt their hand was aligned with a reference marker after completing three blocks of reach training trials with a cursor that was rotated 30° clockwise (CW) for all blocks, or with a visuomotor distortion that was increased incrementally across the training blocks up to 70°CW relative to actual hand motion. On average, subjects adapted their reaches by 16° and recalibrated their sense of felt hand position by 7° leftwards following the first block of reach training trials in which they reached with a cursor that was rotated 30°CW relative to the hand, compared to baseline values. There was no change in these values for the 30° training group across subsequent training blocks. However, subjects training with increasing levels of visuomotor distortion showed increased reach adaptation (up to 34° leftward movement aftereffects) and sensory recalibration (up to 15° leftwards). Analysis of motor and sensory changes following each training block did not reveal any significant correlations, suggesting that the processes underlying motor adaptation and proprioceptive recalibration occur simultaneously yet independently of each other.

Cappellino F et.al. (2012) tested a neurocognitive rehabilitative approach based on proprioceptive exercises and proper motor strategy choices, compared with conventional rehabilitation, assessing baropodometric, gait and clinical changes. Fourteen subjects (27.9±5.2 years) underwent to a surgical reconstruction of ACL were divided into the two groups. The subjects were randomly assigned into a group who received a specific neurocognitive and perceptive rehabilitation treatment (TG), and into a control group who received the common physical therapy (CG). The following outcome measures were assessed pre-intervention, one, three and six months later: static and dynamic baropodometry, Visual Analog Scale for pain, Short Form SF-36, Range of Motion, trophism of thigh region, edema, Manual Muscle Test, magneto-resonance imaging assessment. Lower impairment was observed in TG in respect of CG in terms of load asymmetry during static baropodometry (from 7% to 3% vs. from 10% to 7%, interaction time per treatment: P=0.037), less wide steps during gait (effect size=1.05 vs. 0.38 for CG), swelling (treatment effect: P=0.012). A significantly higher improvement (from 35% to 100%) in terms of SF-36 was recorded only in TG for physical activity (P=0.027). CG showed a quite higher walking speed (treatment effect: P=0.049). Even if further studies are needed on larger samples, the obtained results showed that a neurocognitive rehabilitative approach could be an effective treatment after ACL-reconstruction: in TG they observed a more rapid load symmetrization, the reduction of step width and a more rapid resolution of edema.

Cressman EK and Henriques DY (2011) assessed proprioceptive recalibration by comparing subjects' estimates of the position at which they felt their hand was aligned with a reference marker (visual or proprioceptive) before and after aiming with a misaligned cursor that was typically rotated 30° clockwise (CW) with respect to the hand. In general, results indicated that subjects recalibrated proprioception such that their estimates of felt hand position were shifted in the same direction that they adapted their reaches. Moreover, proprioception was recalibrated to a similar extent of motor adaptation (30%), regardless of how the hand was positioned during the estimate trials (active or passive placement), the location or modality of the reference marker (visual or proprioceptive), the hand used during reach training (right or left), how the distortion was introduced (gradual or abrupt), and age (young or older subjects) and the magnitude of the visuomotor distortion introduced (30° or 50° or 70°). Their results suggest that in addition to recalibrating the sensorimotor transformations underlying reaching movements, visuomotor adaptation results in partial proprioceptive recalibration.

Mörl F et.al. (2011) evaluated the effect of different training methods in physiotherapy on pain relief and change in proprioception and kinesthesia of the shoulder. Further, the connections between pain relief and change in motor function of the shoulder were investigated with two groups of unspecific shoulder pain patients (group1 n = 12, group2 n = 10) and one group (n = 8) of non-symptomatic subjects. The first shoulder-pain group was trained using flexible foil, whilst flexible bands were used to train the patients in the second group. Training period was 12 weeks. Pain of the shoulder was evaluated through functional pain assessment (Constant-Murley score) before, halfway through and after intervention. Proprioceptive and kinaesthetic ability was measured by an active-active angle-replication test for the shoulder before and after intervention. The data of the shoulder patients was compared to the group of non-symptomatic subjects. Pain was reduced significantly in both groups ($p < .05$) whereas no changes were measured for the ability to replicate angles of the shoulder. This suggests that pain relief in the shoulder is not associated with enhancement of the investigated parameters in motor function.

Gomes TM et.al. (2011) assessed the acute effects of the static and proprioceptive neuromuscular facilitation (PNF) stretching methods on local muscular endurance performance at intensities between 40 and 80% of 1 repetition maximum (1RM) for the knee extension (KE) and bench press (BP) exercises. Fifteen male volunteers (23.9 ± 4.3 years; 174.5 ± 8.5 cm; and 77.8 ±

7.6 kg), who were non-athletes but had previous experience in resistance training, volunteered for the study. Participants were assigned to 9 randomly ordered experimental conditions, in which all subjects performed endurance tests at 40, 60, and 80% of 1RM, preceded by static stretching (SS), PNF, and no stretching (NS) in the KE and BP exercises. One-way repeated-measures analysis of variance (NS × SS × PNF) revealed an influence of stretching for all intensities only when the PNF treatment was used. Significant differences ($p < 0.05$) were found in the KE exercise, with reductions in the number of repetitions when comparing PNF40 (23.7 ± 2.7) to NS40 (27.5 ± 3.6); PNF60 (12.6 ± 2.8) to SS60 (16.5 ± 4.1) and NS60 (17.3 ± 3.2); and PNF80 (6.3 ± 1.7) to SS80 (9.9 ± 2.5) and NS80 (9.8 ± 2.3) conditions. Significant differences ($p < 0.05$) were also found for the BP exercise with decreases in the number of repetitions when comparing PNF60 (13.7 ± 2.8) to NS60 (17.0 ± 3.0) and PNF80 (6.2 ± 2.2) to NS80 (8.7 ± 2.3) conditions. Their findings suggested that for the intensities studied (40, 60, and 80% 1RM), only the PNF method decreased muscle endurance. Strength and conditioning professionals may want to consider avoiding PNF stretching before activities requiring local muscular endurance performance.

Shimura (2002) attempted to better understand the mechanisms behind proprioceptive neuromuscular facilitation (PNF), an important method in motor rehabilitation, and investigated the effects of assuming a PNF posture relative to a neutral posture on the initiation of voluntary movement (Experiment 1) and the excitability of the motor cortex (Experiment 2) using a wrist extension task. The initiation of voluntary wrist movement was operationalized in terms of the electromyographic reaction time (EMG-RT), and the excitability of the motor cortex in terms of motor evoked potentials (MEPs). Compared to the neutral position, they found that (1) the facilitation position changed the muscle discharge order enhancing the movement efficiency of the joint, (2) the facilitation position led to a reduction in EMG-RT, the magnitude of which depended on the proximity of the muscle to the movement joint, and (3) MEP amplitude increased and MEP latency decreased in the facilitation position as a function of the proximity of the muscle to the joint. The findings corroborate the presumed effects of PNF and provide insights into the neurophysiological mechanisms underlying the PNF method.

Caplan et. al., (2009) studied the effect of proprioceptive neuromuscular facilitation and static stretch training on running mechanics. There is a long-standing belief that increased range of movement (RoM) at the hip or knee will improve running mechanics; however, few studies have examined the effect of such an increase in RoM. The aim of their study was to determine the influence of 2 methods of stretch training (static and proprioceptive neuromuscular facilitation [PNF]) on high-velocity running. Eighteen rugby league players were assessed for maximum sprinting velocity. They were randomly allocated into 2 stretch training groups: PNF or static. Each group trained their hamstrings 4 d x w(-1) for 5 weeks. Pre- and posttraining subjects were videoed while running at 80% of maximum velocity. The video was digitized to identify biomechanical changes in hip flexion (HF), knee extension (KE), stride length (SL), stride rate (SR), and contact time (tc). Stretch training resulted in gains ($p < 0.05$) in HF for the static stretch (SS) (4.9%) and PNF (7.6%) groups. There were reductions in KE ($p < 0.05$) for SS (1.0%) and PNF (1.6%) groups. Stride mechanics were also altered after training. There were increases in SL ($p < 0.05$) for SS (7.1%) and PNF (9.1%) and a concomitant reduction in SR ($p < 0.05$) for SS (1.9%) and PNF (4.3%). No changes were observed in tc in either group. In conclusion, both SS and PNF training improved HF RoM and running mechanics during high-velocity running. Their findings suggest that stretch training undertaken at the end of regular training is effective in changing running mechanics.

Osternig et.al. (1987) reported that proprioceptive neuromuscular facilitation (PNF) techniques are often used to induce muscle relaxation and increase joint range of motion (ROM). However, the relationship between muscle activation and ROM with PNF is not well understood. The purpose of their study was to investigate the effect of three common PNF stretching techniques on hamstring muscle activation and knee extension. Three PNF techniques: stretch-relax (SR), contract-relax (CR) and agonist contract-relax (ACR) were applied to ten male and female subjects aged 23-36 years who were stabilized to isolate knee extension measurements. Knee joint position and EMG activity from quadriceps and hamstring muscles were computer processed throughout technique application. The results revealed mean hamstring EMG activity increased 8-43% within a given trial of ACR and CR respectively, and did not diminish across trials. SR produced a 11% decrease in mean hamstring EMG activity. ACR produced 3-6% greater knee extension values than CR and SR respectively, in spite of 71-155% greater hamstring EMG activity during ACR. The data suggest that CR and ACR do not evoke sufficient relaxation in muscles opposing knee extension to overcome tension facilitation generated by stretch. Thus, increases in ROM are achieved while the hamstrings are under considerable tension. Such tension increases muscle vulnerability to soreness and strain if stretching continues. The degree of knee extension produced via SR, although 3-6% less than CR and ACR, was achieved during simultaneous reduction in hamstring activity and may be the safer stretching technique.

Rowlands (2003) conducted a study to assess the effect of two isometic contraction durations during propiceptive neuromuscular facilitation stretching on gains inflexion at the hip. Forty-three women (M age = 20.0 years, SD = 1.3) were assigned to one of three groups: 5-s isometric contraction (5-IC), 10-IC, and control. Flexibility was assessed at baseline and Weeks 3 and 6. Analysis of covariance, controlling for pretest differences, showed a significant interaction, $F(2, 33) = 44.1$, $p < .001$. Flexibility was significant lower in the control group relative to the 5-IC and 10-IC groups and in the 5-IC group relative to the 10-IC group at 3 and 6 weeks (3 weeks = 101.2 +/- 1.4 degrees, 114.3 +/- 1.5 degrees, 120.5 +/- 1.3 degrees; 6 weeks = 103.0 +/- 1.4 degrees, 126.1 +/- 1.6 degrees, 133.3 +/- 1.4 degrees for control, 5-IC and 10-IC groups, respectively). A longer contraction time led to greater increases in flexibility.

Lucas (1984) conducted a study wherein 63 college women served as subjects in a 7-wk. study examining the effects of static, dynamic, and proprioceptive neuromuscular facilitating stretching techniques on the flexibility of the hamstring-gastrocnemius muscles. Subjects were assigned to one of the 3 treatment groups and received treatment 3 days a week. A pretest, a midtest (after 11 treatment days), and a posttest (after 21 treatment days) were administered. Analysis of group and test effects was accomplished by using a 3 X 3 factorial design with the group factor nested and the test factor crossed. Post hoc analysis indicated that all scores significantly improved from pretest to posttest. The findings indicated all 3 methods of flexibility training produced significant improvements when pretest and posttest mean scores were compared.

Bradley (2007) did a research to compare the acute effects of different modes of stretching on vertical jump performance. Eighteen male university students (age, 24.3 +/- 3.2 years; height, 181.5 +/- 11.4 cm; body mass, 78.1 +/- 6.4 kg; mean +/- SD) completed 4 different conditions in a randomized order, on different days, interspersed by a minimum of 72 hours of rest. Each session consisted of a standard 5-minute cycle warm-up, accompanied by one of the subsequent conditions: (a) control, (b) 10-minute static stretching, (c) 10-minute ballistic stretching, or (d) 10-minute proprioceptive neuromuscular facilitation (PNF) stretching. The subjects performed 3 trials of static and countermovement jumps prior to stretching and post stretching at 5, 15, 30, 45, and 60 minutes. Vertical jump height decreased after static and PNF stretching (4.0% and 5.1%, $p < 0.05$) and there was a smaller decrease after ballistic stretching (2.7%, $p > 0.05$). However, jumping performance had fully recovered 15 minutes after all stretching conditions. In conclusion, vertical jump performance is diminished for 15 minutes if performed after static or PNF stretching, whereas ballistic stretching has little effect on jumping performance. Consequently they suggested that PNF or static stretching should not be performed immediately prior to an explosive athletic movement.

2.3 SUMMARY OF RELATED STUDIES

This chapter detailed a number of studies made on neuromotor task training including proprioceptive neuromuscular facilitation (PNF) training and its effects on the performance of different population. The review showed the training effects of neural and physiological effects among different population and proved further scope for research in finding out these training effects on determinants of athletic performance among young adults.

Based on the experience gained through review of related studies, the investigator formed suitable methodology to be adopted for this study, which is described in chapter III.