CHAPTER - II

REVIEW OF RELATED LITERATURE
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LITERATURE SURVEY

Literature survey has served as a guideline to identify the different training programmes designed for peak performance in sports and games. This chapter is divided into six pertinent headings: comparison of dominant vs. non-dominant arm on performance, effects of imagery training, kinematic analysis and transfer of dominant versus non-dominant arm on throwing skill performance, influence of psychomotor training and performance, psychomotor training on coordination and resistance training, plyometrics, speed training on throwing performance and its adaptations which forms the background for the present study.

2.1 Comparison of dominant versus non-dominant arm on performance

Shabbot and Sainburg (2008) designed a study to differentiate between two models of motor lateralization: "feedback corrections" and dynamic dominance. Whereas the feedback correction hypothesis suggests that handedness reflects a dominant hemisphere advantage for visual-mediated correction processes, dynamic dominance proposes that each hemisphere has become specialized for distinct aspects of control. This model suggests that the dominant hemisphere is specialized for controlling task dynamics, as required for coordinating efficient trajectories, and the non-dominant hemisphere is specialized for controlling limb impedance, as required for maintaining stable postures. To differentiate between these two models, they examined whether visuomotor corrections are mediated differently for the non-dominant and dominant arms. Participants performed targeted reaches in a virtual reality environment in which visuomotor rotations occurred in two directions that
elicited corrections with different coordination requirements. The feedback correction model predicts a dominant arm advantage for the timing and accuracy of corrections in both directions. Dynamic dominance predicts that correction timing and accuracy will be similar for both arms, but that inter limb differences in the quality of corrections will depend on the coordination requirements, and thus, direction of corrections. The results indicated that correction time and accuracy did not depend on arm. However, correction quality, as reflected by trajectory curvature, depended on both arm and rotation direction. Non dominant trajectories were systematically more curvilinear than dominant trajectories for corrections with the highest coordination requirement. These results support the dynamic dominance hypothesis.

It has long been known that practicing a task with one limb can result in performance improvements with the opposite, untrained limb. Hypotheses to account for cross-limb transfer of performance state that the effect is mediated either by neural adaptations in higher order control centers that are accessible to both limbs, or that there is a "spillover" of neural drive to the opposite hemisphere that results in bilateral adaptation. Carroll et al., (2008) examined these hypotheses by assessing performance and corticospinal excitability in both hands after unilateral practice of a ballistic finger movement. Participants (n = 9) completed 300 practice trials of a ballistic task with the right hand, the aim of which was to maximize the peak abduction acceleration of the index finger. Practice caused a 140% improvement in right-hand performance and an 82% improvement for the untrained left hand. There were bilateral increases in the amplitude of responses to transcranial magnetic stimulation, but increased corticospinal excitability was not correlated with improved performance. There were no significant changes in corticospinal excitability or task performance for a control group that did not train (n = 9), indicating that performance testing for the left hand alone did not induce performance or corticospinal
effects. Although the data do not provide conclusive evidence whether increased corticospinal excitability in the untrained hand is causally related to the cross-transfer of ballistic performance, the finding that ballistic practice can induce bilateral corticospinal adaptations may have important clinical implications for movement rehabilitation.

Jorg et al. (2007) wanted to test the negative perceptual frequency effect, left handed athletes who are still rare in interactive sports might have an advantage as their competitors are unfamiliar with the way a left-hander acts in a game. At least two interacting advantages might be differentiated: 1) tactics (eg left hand serve in tennis) or (2) techniques (e.g different spin bowling in cricket). The aim of these two experiments is to determine the role of perceptual pre-experience on performance in throwing prediction. In experiment 1, n = 13 skilled goalkeepers and n = 30 novices were asked to respond as quickly and accurately as possible to handball penalty throws to one of the four corners of a goal. Overall, 196 video scenes from two left and two right handers were presented in three different temporal occlusion conditions. Half of the sequences were mirrored along the horizontal axis, so that left-handers were presented as right handers. In experiment 2, n = 31 German novices participated. They accomplished a shorter handball task and an additional cricket task (unknown sport in Germany) both with 24 video sequences. For both tasks mirrored sequences were administered as well as normal ones. For experiment 1, significant differences between skilled goalkeepers and novices were found (F(1,41) = 9.62 p<0.01, Eta 2 = .19) as well as differences between temporal occlusion conditions (F(2,82) =5.89, p<0.01 Eta = .13) for reaction time. For reaction accuracy differences were observed for laterality of presented throwers (f(1,41)=6.01, p = 0.02 Eta2 =.13, temporal occlusion conditions (F(2,82)=27.37, P <0.01. Eta2 =.40) and interaction of expertise and temporal occlusion conditions (F(2,82) = 26.65 p
<0.01, $\eta_2 = 0.30$). In experiment 2, descriptive differences concerning handedness of thrower were higher for handball than for cricket. Throw directions of right-handed athletes were better anticipated than those of left-handed throwers. Only the differences for handball reached significance ($F(1,30)=3.77, p<.05, \eta_2 = 0.11$). Overall, the results of the two presented experiments support the negative frequency hypothesis. Therefore, enhancing the level of perceptual familiarity with left-handed opponents might reduce their strategic advantage in interactive sports.

Lange et al., (2006) investigated the Coordinate processing during the left-to-right hand transfer. Information about visuomotor tasks is coded in extrinsic, object-centered and intrinsic, body-related coordinates. For the reproduction of a trained task in mirror orientation with the opposite untrained hand, acquired extrinsic coordinates must be transformed. In contrast, intrinsic coordinates have to be modified during the execution of the originally oriented task. Processes of coordinate transformations during the right-to-left hand transfer are associated with movement preparation and occur preferentially in the left hemisphere. Here, movement-related potentials, EEG power, and EEG coherence were recorded during the repetition of a drawing task previously trained by the nondominant left hand (Learned-task) and its execution in original and mirror orientation by the right hand (Normal- and Mirror-task). To identify EEG correlates of coordinate processing during intermanual transfer rather than effects due to the use of the right versus left hand, only those EEG data were analyzed which differed between the Normal- and Mirror-tasks. Whereas the Normal-task did not differ from the Learned-task in any of these predefined EEG parameters, beta coherence increased in the Mirror-task in the period ranging from 1 to 2 s after movement onset. These increases were especially prominent between hemispheres but were also observed symmetrically in the parieto-frontal electrode pairs of both hemispheres.
Behavioral data revealed that the performance in the Learned- and both transfer tasks improved after left-hand training. Results of the present study indicate that coordinate transformation during the left-to-right hand transfer occurs in the phase of movement execution and affects predominantly extrinsic coordinates. Intrinsic coordinates are presumably mainly used in their original form. The modification of extrinsic coordinates is accompanied by increased information flow between both hemispheres; thereby inter-hemispheric connections as mediated via the corpus callosum seem to play a central role.

Kumar and Mandal (2005) attempted to study Bilateral transfer of skill as a function of speed and accuracy in self-classified left-handed (n = 20) and right-handed (n = 40) subjects. Two transfer conditions (non-preferred to preferred hand, preferred to non-preferred hand) were manipulated in a mirror-drawing task and data were treated with Groups (left, right hander) × Transfer type (speed, accuracy) × Side (non-preferred to preferred hand, preferred to non-preferred hand) mixed factorial ANOVA with repeated measure in Transfer and Side factors. Percentage of bilateral transfer (First 5 trials-Last 5 trials/First 5 trials × 100) was the dependent measure. Left and right-handers did not differ in the magnitude of bilateral transfer. Bilateral transfer was greater (a) from non-preferred to preferred side as compared to the reverse, and (b) was greater with respect to speed but not with accuracy.

Cross-education has been defined as the performance improvement in the untrained limb after a period of unilateral exercise training. It has been accepted that cross-education can include the transfer of muscular strength to the untrained homologous muscle after a period of unilateral training and the transfer of motor skill learning to the untrained muscle. Cross-education of strength may be dependent on the direction of the effect or training of muscle on either the dominant or non-dominant side. Most studies of cross-education have tried to control for the effect of dominance by training muscle groups on
the same side of the body across subjects, regardless of handedness. The effect of the direction of transfer on cross-education in right-handed persons was determined. Farthing et al. (2005) attempted to find out the effect of the direction of transfer on cross-education in right-handed persons. Thirty-nine strongly right-handed women were randomly assigned to a left-hand training, right-hand training, or non-training control group. The training groups participated in 6 weeks of strength training, which consisted of maximal isometric ulnar deviation 4 times per week. Peak torque, muscle thickness, and electromyographic (EMG) activity were assessed before and after training in both limbs. There was a greater change in strength in the untrained limb in the right-hand training group (39.2%). No significant changes in strength in the untrained limb were observed in the left-hand group (9.3%) or for either limb in the control group (10.4% and 12.2%). Strength training also increased trained limb strength in both the left-hand and right-hand training groups (41.9% and 25.9%, respectively). The training groups increased trained limb muscle thickness compared with the control group. There were no changes in muscle thickness of untrained limbs compared with the control group. Agonist EMG activation in the trained limb increased with training, with no change for the antagonist. Changes in untrained limb EMG were not different compared with the control group. Cross-education with hand strength training occurred only in the right-to-left direction of transfer in right-handed persons. Cross-education of arm muscular strength is most pronounced to the non-dominant arm. The quality of the movement will depend upon such factors as the precision of the act required, the performer’s past experience with similar skills, the speed of the movement, the force of the motor act, and the body part or parts to be moved.

Mechanisms underlying interlimb transfer of adaptation to visuomotor rotations have recently been explored in depth. However, little data are
available regarding inter-limb transfer of adaptation to novel inertial dynamics. Wang and Sainburg (2004) investigated inter-limb transfer of dynamics by examining the effect of initial training with one arm on subsequent performance with the other in adaptation to a 1.5-kg mass attached eccentrically to the forearm. Using inverse dynamic analysis, we examined the changes in torque strategies associated with adaptation to the extra mass, and with inter-limb transfer of that adaptation. Following initial training with the dominant arm, non-dominant arm performance improved substantially in terms of linearity and initial direction control as compared with naive performance. However, initial training with the nondominant arm had no effect on subsequent performance with the dominant arm. Inverse dynamic analysis revealed that improvements in kinematics were implemented by increasing flexor muscle torques at the elbow to counter load-induced increases in extensor interaction torques as well as increasing flexor muscle torques at the shoulder to counter the extensor actions of elbow muscle torque. Following opposite arm adaptation, the nondominant arm adopted this dynamic strategy early in adaptation. These findings suggest that dominant arm adaptation to novel inertial dynamics leads to information that can be accessed and utilized by the opposite arm controller, but not vice versa. When compared with our previous findings on interlimb transfer of visuomotor rotations, our current findings suggest that adaptations to visuomotor and dynamic transformations are mediated by distinct neural mechanisms.

Leia and Sainburg (2002) Recent findings from the laboratory of Leia and Sainburg (2002) suggest that a major factor distinguishing dominant from non-dominant arm performance is the ability by which the effects of intersegmental dynamics are controlled by the CNS. These studies indicated that the dominant arm reliably used more torque-efficient patterns for movements made with similar speeds and accuracy than non-dominant arm movements.
Whereas, non-dominant hand-path curvatures systematically varied with the amplitude of the interaction torques transferred between the segments of the moving limb, dominant hand-path curvatures did not. However, our previous studies did not distinguish whether dominant arm coordination advantages emerged from more effective control of dynamic factors or were simply a secondary effect of planning different kinematics. The purpose of this study was to further investigate inter limb differences in coordination through analysis of inverse dynamics and electromyography recorded during the performance of reaching movements. By controlling the amplitude of intersegmental dynamics in the current study, we were able to assess whether systematic differences in torque-efficiency exist, even when differences in hand-path shape were minimal. Subject's arms were supported in the horizontal plane by a frictionless air-jet system and were constrained to movements about the shoulder and elbow joints. Two targets were designed, such that the interaction torques elicited at the elbow were either large or small. Our results showed that the former produced large differences in hand-path curvature, whereas the latter did not. Additionally, the movements with small differences in hand-path kinematics showed substantial differences in torque patterns and corresponding EMG profiles which implied a more torque-efficient strategy for the dominant arm. In view of these findings we propose that distinct neural control mechanisms are employed for dominant and non-dominant arm movements.

Augusto (2002) attempted to study Bilateral transfer of perceptual and motor components in movement control was investigated through two experiments. In Experiment 1 a simple anticipatory timing task was practiced with either the preferred or the nonpreferred hand. After a short resting interval an additional set of trials was performed with the contralateral hand. In Experiment 2, the same experimental design was used to investigate bilateral
transfer of fine force control in a wrist-flexion movement. Analysis of the results showed that bilateral transfer of learning took place for both anticipatory timing and force control, with more noticeable transfer of training for the former. Asymmetry in transfer was found for force control, with significant transfer only in the preferred-to-non preferred direction. Transfer of anticipatory timing occurred similarly in both directions. These results indicated anticipatory timing as a powerful component for bilateral transfer, while force control showed to be more dependent on practice with the specific muscular system.

Panayiotou et al. (2007) attempted to find out whether hand preferences affected inter limb motor skill transfer. They also tested whether hand preference led to a reduction of the surface electromyography. Twenty participants were randomly assigned into one of the two groups including practice with dominant hand and transfer test with non dominant hand or reverse. In the experiment, the participants were asked to sit at a table to quickly squeeze a hand dynamometer in order to reproduce a force curve with 200 N as its peak and 140ms as its period. The acquisition session consisted of six blocks of 10 trials following by an immediate transfer test. A delayed retention and transfer test was conducted 48 hour after the practice session. The force production and the surface EMG on the brachioradialis were collected by a biopac system. The ANOVA on acquisition indicated no group effect on the root mean squared error of force production, F(1,18)=1.21, p >0.05. The analysis revealed that the participants reliably improved their production performance with practice, F(5,100)=44.4, p <0.01. The further analysis on transfer tests demonstrated there was no difference between the last block of acquisition and the test for immediate transfer. That is, learning a force production curve using dominant hand can successfully transferred to the non dominant hand and vice versa. The present results suggested inter limb
transfer of a simple force production task was independent of hand preference. In addition, the analysis failed to detect any difference on practice or hand preference in terms of the total EMG.

Transfer of learning involves the influence of previous experiences on the performance or learning of new skills. It is defined as a gain (or loss) in the capability for performance on one task as a result of practice on another. Weigeit et al. (2000) attempted to examine the degree of transfer between various association football skills. Twenty intermediate male players participated in the study. During pre- and post-training tests, participants juggled a football as many times as possible within 30s using feet or knees. Further tests required participants to control an approaching football inside a restricted area using the preferred and non-preferred kicking leg. Following performance on the pretest, two matched skill groups were obtained. One group participated in a 4-week training period in which feet-only ball juggling was practiced for 10 min daily, while the remaining group acted as a control. Trained participants exhibited superior post-test performance on knee juggling and ball control with preferred and non-preferred leg tasks relative to the control group (p < 0.05). Findings indicate positive transfer of learning from juggling practice with the feet to juggling with the knees and a football control task. Implications for theory and practice are highlighted.

2.2 Effects of Imagery training and performance

Malouin et al. (2009) attempted to find out the vividness of motor imagery in dancers and in persons with late blindness, with amputation or an immobilization of one lower limb the effects of prosthesis use on motor imagery; and the temporal characteristics of motor imagery. Eleven dancers, 10 persons with late blindness, 14 with amputation, 6 with immobilization, and 2 groups of age matched healthy individuals (27 in control group A; 35 in control group B) participated. The kinesthetic and Visual Imagery questionnaire served
to assess motor imagery vividness. Temporal characteristics were assessed with mental chronometry. Late blindness group and dance group displayed higher imagery scores than respective control groups. In the amputation and immobilization groups, imagery scores were lower on the affected side than the intact side and specifically for imagined foot movements. Imagery scores of the affected limb positively correlated with the time since walking with prosthesis. Movement times during imagination and execution were longer on the affected side than the intact side, but the temporal congruence between real and imagined movement times was similar to that in the control group. The mental representation of actions is highly modulated by imagery and motor activities. The ability to generate vivid images of movements can be specifically weakened by limb loss or disuse, but lack of movement does not affect the temporal characteristics of motor imagery.

Wright et al. (2009) compared the effects of PETTLEP-based and more traditional imagery on muscle strength. PETTLEP is a set of guidelines for producing functionally equivalent imagery. Fifty participants were assigned to one of five groups: PETTLEP, "traditional" imagery, physical practice, PETTLEP/physical practice (combination), and control. Pre- and post-tests consisted of 1 R.M. tests on a bicep curl machine. PETTLEP participants imaged two sets of curls while sitting at the machine watching an internal perspective video. "Traditional" participants imaged while relaxing in a quiet room. Physical participants performed two sets of curls. Combination participants performed one set and imaged another. Interventions were completed twice per week for six weeks. PETTLEP, combination, and physical groups improved, whereas traditional and control groups did not. There were no differences between improvements shown by the PETTLEP and physical groups. These findings support the use of PETTLEP with strength tasks, especially when combined with physical practice.
Nelson et al. (2008) examined the effects of a three-week imagery and video imagery intervention program on the throwing accuracy of individual baseball pitchers. A secondary purpose of this study was to investigate whether differences in accuracy response characterize both low- and high-ability imagers. A sample of pitchers (n=30) were asked to take the Movement Imagery Questionnaire-Revised; study participants were randomly selected from the highest and lowest 20% of the group. The participants were obtained from high school and college teams within southeastern Georgia (n= 6). Following the first week of baseline measurements, 2 high-ability and 2 low-ability imagers took part in a three-week video imagery and imagery intervention program. One participant from each group together constituted a control group, which was asked only to try their best when throwing for the study’s accuracy measurements. Results showed that 2 participants demonstrated an increase in performance, while all participants expressed a desire to continue to use imagery for its various effects. Suggestions for future research and further insight are discussed.

Smith et al. (2007) attempted to examine the effects of PETTLEPP based imagery compared to traditional imagery interventions. PETTLEPP imagery aims to produce a realistic and more functionally equivalent imagery experience than traditional imagery methods through factors such as wearing the correct clothing or imaging in the correct environment. 48 varsity hockey players were divided into four groups: “Sport-specific” imagery, “clothing imagery,” “traditional” imagery and control imagery participants imaged 10 penalty flicks daily for six weeks, and controls spent an equivalent time reading hockey literature. In the post-test, the sport-specific group scored significantly higher than the clothing group, who scored significantly higher
than the traditional imagery group. In study 2, 40 junior gymnasts attempted a turning jump on the beam. They were split into four groups: A Physical practice group, a PETTLEP imagery group, a stimulus only imagery group, and a control (stretching) group. Each group performed their task three times per week for six weeks. Both physical practice and PETTLEP groups improved significantly from pre-test to post-test, with no significant difference between them, but the stimulus and control groups did not improve significantly. Taken together the results from study 1 and 2 provide support for the efficacy of PETTLEP – based imagery over more traditional imagery interventions.

Lacourse et al. (2005) attempted to find out functional magnetic resonance imaging to compare functional neuroanatomy associated with executed and imagined hand movements in novel and skilled learning phases. It was hypothesized that 1 week of intensive physical practice would strengthen the motor representation of a hand motor sequence and increase the similarity of functional neuroanatomy associated with executed and imagined hand movements. During functional magnetic resonance imaging scanning, a right-hand self-paced button press sequence was executed and imagined before (NOVEL) and after skilled 1 wk of intensive physical practice n = 54 right-hand dominant. The mean execution rate was significantly faster in the SKILLED (3.8 Hz) than the NOVEL condition (2.5Hz) (P <0.001), but there was no difference in execution errors. Activation foci associated with execution and imagery was congruent in both the NOVEL and SKILLED conditions, though activation features were more similar in the SKILLED versus NOVEL phase. In the NOVEL Phase, activations were more extensive during execution than imagery in primary and secondary cortical motor volumes and the cerebellum, while during imagery activations were greater in the striatum. In the SKILLED phase, activation features within these same volumes became increasingly similar for execution and imagery, though
imagery more heavily activated pre motor areas, inferior parietal lobe, and medial temporal lobe, while execution more heavily activated the precentral/postcentral gyri, striatum, and cerebellum. This experiment demonstrated congruent activation of the cortical and sub cortical motor system during both novel and skilled learning phases, supporting the effectiveness of motor imagery-based mental practice techniques for both the acquisition of new skills and the rehearsal of skilled movements.

Deborah and Feltz (1998) examined the effectiveness of mental practice techniques for improving figure skating performance, self-efficacy and self-confidence for competition. Two interventions, paper freestyle drawing (PFD) and walk through on floor (WTF), were compared to a stretching control group. Participants (n=27), ages 10 to 18 years, were members of the United states figure skating association and were randomly assigned to one of the three groups. The study included procedural reliability checks such as pre and post manipulation check; structured seminars; and homework workbooks. Results indicated that the two mental practice groups significantly improved their performance ratings in jumps and spins, and their competition confidence compared to the stretching control group. Results also indicated that the walk through on floor mental practice group increased their spinning self-efficacy beliefs compared to the paper freestyle drawing practice treatment and the stretching control group.

Joans and Gershon (1996) conducted two studies to examine the effect of imagery on eye-hand coordination task throwing a basketball in a basket. In the first study 75 high school students were divided into 3 treatment conditions and one control. The experimental conditions were comprised of watching a short video clip of either 15 successful basketball foul shots or of recreational skiing. Then the subjects were taught how to experience and feel movement through relaxation and imagery. In the second study, similar procedures were
applied to 20 subjects who were students in a coaching academy. In study 1, the four shooting trials were performed at one week intervals; in study 2, they were performed twice a week. In study 1, results indicated that while imagery vividness remained high and unchanged across four trials in all groups, performance improved with time as a result of acquaintance with the task. However, in study 2, external imagery orientation increased while performance remained unchanged. It was concluded that imagery can continue to performance only when subjects efficiently master the task. Accordingly, novice subjects should first practice the task and only later integrate imagery into their practical programs. The findings of the present study suggest that practicing imagery of a motor skill which is not yet mastered by the subjects may result in two possible outcomes: study 1 indicates that while imagery vividness is sustained following a once a week practice by all the groups, physical performance which requires eye-hand coordination may increase as a result of improved acquaintance with the task. However, study 2 indicates that while imagery vividness increased at a high level following twice-a-week practice of imagery, physical performance was sustained at the same level throughout the four trials. This indicates an improved acquaintance with imagery but not with the eye-hand coordination task.

Sandy et al. (1994) attempted to find out the effectiveness of an internal versus, external imagery training program on performance of cricket bowlers. Subjects N=64 were high school students involved in a cricket studies curriculum. Based on baseline assessments of bowling performance, subjects were matched and then randomly assigned to one of three conditions, (a) internal imagery training, (b) external imagery training, (c) control. Both internal and external imagery training groups received 10 minutes of training specific to their condition prior to each of six physical practice sessions over a three week period. After practicing their use of internal and external imagery
during physical practice, each subject was instructed to use his specific imagery orientation prior to the performance of 12 pitches at the end of each of the six practice sessions. Control subjects simply viewed instructional videos for 10 minutes prior to each practice with no mention of imagery. Results from a 3x6x3 revealed that although all groups improved over time, there were no significant performance differences between the imagery groups. Results from the post experimental questionnaire indicated that although subjects did practice and utilize their specific imagery orientation, approximately 50% found themselves switching between internal and external imagery. Results of the present investigation did not demonstrate the superiority of internal imagery over external imagery as suggested by previous research. However, the unstable nature of image orientation subjects’ ability level and the propensity for all subjects to use internal imagery may have contributed to these results. Thus it appears that image orientation may not be as critical to performance effectiveness. From an applied perspective, at this point it would seem more important to teach athletes to follow the principles of imagery training and let them image in whatever perspective seems more comfortable to them since their tendency appears to be to switch perspectives anyway.

2.3 Kinematic analysis and transfer of dominant versus non-dominant arm on throwing skill performance

Sachlikidis and Salter (2007) attempted to determine the kinematic differences between dominant and non-dominant arm throwing techniques for speed and accuracy conditions in under 17, and under 19 high performance cricketers, participants (n=7) performed ten throws for each arm dominant and non-dominant and condition speed / accuracy at a target positioned 10m in front of them. Kinematic variables were measured three dimensionally using a Vicon motion analysis system. Digital footage was used to calculate stride
data, ball speed and record target accuracy. Data were analyzed using repeated measures ANOVA and chi-squared tests. Statistical significance was set up at P=0.05. The non-dominant hand throws were found to have significantly shorter stride length, lower maximum lead knee lift, did not extend the lead knee in the arm acceleration phase, had significantly less elbow flexion prior to extension, had significantly less shoulder external rotation at the commencement of the arm acceleration phase, did not have a delay between the initiation of pelvic and upper torso internal rotation, and displayed a less than optimal co-ordination pattern. A sped-accuracy trade off was found to exist for the dominant arm throws; however no trade-off was identified for the nondominant arm throws. The suggestions to the athlete when learning to throw with the non-dominant hand are: a) point at the target with the lead arm; b) lift the leading knee higher when stepping; c) Keep the back foot on the ground; d) cock the elbow more before throwing; e) train the rotation flexibility of the shoulder; f) delay external rotation of the shoulder until after planting the front foot; g) release the ball in front of and wider than the shoulder; and h) follow through across the body.

Hirashima et al. (2008) investigated how the human CNS organizes complex three-dimensional (3D) ball-throwing movements that require both speed and accuracy. Skilled baseball players threw a baseball to a target at three different speeds. Kinematic analysis revealed that the fingertip speed at ball release was mainly produced by trunk leftward rotation, shoulder internal rotation, elbow extension, and wrist flexion in all speed conditions. The study participants adjusted the angular velocities of these four motions to throw the balls at three different speeds. We also analyzed the dynamics of the 3D multi joint movements using a recently developed method called "non orthogonal torque decomposition" that can clarify how angular acceleration about a joint coordinate axis (e.g., shoulder internal rotation) is generated by the muscle,
gravity, and interaction torques. We found that the study participants utilized the interaction torque to generate larger angular velocities of the shoulder internal rotation, elbow extension, and wrist flexion. To increase the interaction torque acting at these joints, the ball throwers increased muscle torque at the shoulder and trunk but not at the elbow and wrist. These results indicate that skilled ball throwers adopted a hierarchical control in which the proximal muscle torques created a dynamic foundation for the entire limb motion and beneficial interaction torques for distal joint rotations.

Bower (2005) examined whether previous kinematic results examining dominant versus non-dominant and expert versus novice throwing tasks apply to a realistic cricket fielding scenario. Eight male cricketers were filmed by two high-speed cameras whilst gathering and throwing a cricket ball with both their dominant and non-dominant arm. Upper body linear and angular data was obtained for comparison between dominant and non-dominant arm throws during approach, gather and throw of the cricket ball towards a target. A temporal analysis was also conducted on maximal linear velocities of joints in the upper body during the execution and release. The results indicated that dominant arm throws possessed a higher release velocity, lower release angle and lower release height than those of the non-dominant arm (p <0.001). These release parameters are associated with a more successful execution of the overarm throw. It was concluded that the dominant arm results could be attributed to the more efficient application of the summation of speed principle, an increased use of the non-throwing arm, a later occurrence of maximal linear velocity of the wrist, and a rapid elbow extension in the throwing arm prior to ball release.

John and Craig (2005) attempted to examine the nature and persistence of bilateral transfer of a throwing skill for a large sample of male and female children. One hundred and sixty children ages, 6, 8, 10 and 12 years were
randomly assigned to either an experimental or control group with an equal number of boys and girls in each group. The experiment lasted 2 days and consisted of a pretest, each participant performed 10 trials of a novel one-hand throwing task. Following the pretest, participants in the experimental group practiced the skill with the hand opposite the one used during the pretest until they had successfully reached a designated criterion for their age. Participants in the control group performed a balancing activity. Following the practice phase, all participants performed immediate (10 min later) and delayed (24 hour later) transfer tests under the same conditions as the pretest. The results revealed no group differences on the pretest but significantly higher throwing accuracy for the experimental group than the control group on both transfer tests. In addition, boy's throwing accuracy was significantly superior to the girls. It was concluded that bilateral transfer of throwing accuracy can be both a temporary and relatively persistent phenomenon for children and the superior throwing accuracy for boys is consistent with similar gender differences in throwing distance and throwing velocity.

Haaland and Hoff (2003) examined bilateral motor performance effects from training the non-dominant leg of competitive soccer players. The subjects were 39 soccer players, 15-20 years of age, performance-matched and randomly divided into a training group (n = 18) and a control group (n = 21) both belonging to the same team. Both groups were tested by using two standardized foot-tapping tests and three soccer-specific tests. The training intervention consisted of the experimental group participating in all parts of their soccer training except full play, using the non-dominant leg for 8 weeks. Statistical analyses for the soccer-specific tests revealed that the experimental group improved significantly as compared to the control group from the pretest to the post-test period in their use of the trained non-dominant leg. Somewhat unexpectedly, the experimental group also improved significantly in
the tests, which made use of the dominant side. The standardized foot-tapping
tests revealed similar results. The results might be explained by improved
generalized motor programmes, or from a Dynamic Systems Approach,
indicating that the actual training relates to the handling of all the information
available to the subject in the situation, and that the body self-organizes the
motor performance.

Katrin and Shumakov (2000) attempted to find out the functional
interhemispheric asymmetry during dynamics of bimanual activity at children
7-11 years old during mastering of basic origami techniques. It was also
intended to find out the functional interhemispheric asymmetry and
psychomotor, intellectual and creative parameters at children 7-11 years old.
Children in the age group of 7-11 were divided into 4 age groups 7-8 yeas 8-9
years, 9-10 years and 10-11 years. In total 137 children participated in the
research, from which there are 67 boys an 70 girls. None of them had origami
skills prior to the beginning of the research. The research was carried out in
four stages: first, third and fourth were psycho-diagnostic testing, second was
forming experiment consisting in intensive training of children to origami
skills. The average interaction with one child was lasted about 30 hours. In
research were applied the hardware techniques (study skin-galvanic reaction of
the right and left hand, gaploscopia), test techniques ( test on definition of an
individual structure of functional interhemispheirc asymmetry, tapping – test of
E.P.IIlyayn, test of E.P Torrance Choice of the side, Raven progressive
matrixes. Interpretation of pictures test by J.Guilford, Addition of figure test by
Barron, test for definition of ability to judge by eye and expert estimation of
development of origami program and level of display of creative abilities in
origami, made by the teacher and independent expert origami teacher. The
reliability of the received results was provided with a variety of diagnostic
procedures, amount of children, the processing of the received data was carried
out by standard mathematical methods. Findings of this study allow recommending the origami training for practical using for development of motor, intellectual and creative abilities of children, and also for practical using at realization of psycho-therapeutic and psycho-correctional works with the young school boys. Successful mastering of origami as the indicator of good bimanual coordination can be one of the attributes of good interhemispheric interaction. The origami-test revealing ability of the child to repeat step by step folding of simple model can be used by the psychologist as a component in an estimation of interhemispheric interaction. Dynamics of activity of hemispheres was investigated at bimanual activity during origami learning. For the first time was experimentally proved that the origami training based on asymmetrical bimanual activity creates conditions of intensive interaction of hemispheres and allows effectively to develop motor abilities of both hands, intellectual and creative abilities at children 7-11 years.

Bagesteiro and Sainburg (2002) stated that recent findings from their laboratory suggest that a major factor distinguishing dominant from non-dominant arm performance is the ability by which the effects of intersegmental dynamics are controlled by the CNS. These studies indicated that the dominant arm reliably used more torque-efficient patterns for movements made with similar speeds and accuracy than non dominant arm movements. Whereas, non-dominant hand-path curvatures systematically varied with the amplitude of the interaction torques transferred between the segments of the moving limb, dominant hand-path curvatures did not. However, our previous studies did not distinguish whether dominant arm coordination advantages emerged from more effective control of dynamic factors or were simply a secondary effect of planning different kinematics. The purpose of this study was to further investigate interlimb differences in coordination through analysis of inverse dynamics and electromyography recorded during the
performance of reaching movements. By controlling the amplitude of intersegmental dynamics in the current study, we were able to assess whether systematic differences in torque-efficiency exist, even when differences in hand-path shape were minimal. Subject's arms were supported in the horizontal plane by a frictionless air-jet system and were constrained to movements about the shoulder and elbow joints. Two targets were designed, such that the interaction torques elicited at the elbow were either large or small. Our results showed that the former produced large differences in hand-path curvature, whereas the latter did not. Additionally, the movements with small differences in hand-path kinematics showed substantial differences in torque patterns and corresponding EMG profiles which implied a more torque-efficient strategy for the dominant arm. In view of these findings we propose that distinct neural control mechanisms are employed for dominant and non-dominant arm movements.

Lateral asymmetries of manual, pedal and ocular preference, and motor asymmetry in the performance of the forceful overarm throw were analyzed in 71 children aged 4 to 10 years old by Augusto and Rafaella (2002). Performance with each side of the body was assessed on the basis of qualitative analysis, as proposed by M.A. Roberton and I.Halverson for identification of developmental stages by components of the task. Lateral preference was indicated by the frequency the children used the right or the left side of their body to carry out different manual, pedal and ocular task. The overarm throw movement pattern was developed with both sides of the body but at different levels. Development of the non dominant side lagged behind that of the dominant side at all ages; a significant asymmetry in performance detected in the 4-year olds was stable up to the age of 10 years. Indices of asymmetry for lateral preference and performance were found to be specific because no consistent correlations were observed among them throughout the
age periods studied. Those results who the multidimensional character of human laterality and imply a property of motor development that prevents asymmetry of performance from increasing because of unilateral practice.

Mavromatis and Gourgoulis (1998) attempted to find out the kinematic, dynamic and myoelectrical characteristics in one foot vertical jumps with the dominant and the non-dominant leg, in order to determine the biomechanical features of the performance dominance in lower limbs. Seventy-nine volunteers age: 21.3 ± 1.7 years performed one foot vertical jumps after a preliminary step with arms akimbo. Each subject performed five vertical jumps with right leg and five additional jumps with the left leg on piezoelectric force place, which recorded the ground reaction force with a sampling frequency of 1000Hz. At the same time the event was recorded by two S-VHS cameras at 60 field/sec for the three dimensional analysis of the movement. In order to determine the kinematic characteristics of the movement, selected points on the body were digitized using the Ariel Performance Analysis System. The spatial coordinates of the selected points were calculated using the DLT procedure. For the calibration of the movement space a calibration rectangular cube was used with 23 control points. The results revealed that high performance scores were the output of common movement patterns for both the dominant and the non-dominant leg. The backward rotation of the upper body starts earlier than the extension of the thigh, while the latter begins earlier than the extension of the shank. So the body segments contribute in a fixed sequence from proximal to distal to the velocity of the projected body, as in vertical jumps with two legs. This movement pattern was the output of a specific pattern of muscle activation. This pattern of muscle activation has been found to be responsible for the optimal transition of the mechanical power from the proximal limbs of the body to the distal limbs and finally to the ground. It seems that the improved performance in the vertical jump with the dominant leg was the
result of more effective activation of the leg's muscles, which might have been produced because of the more frequent execution of vertical jumps with the dominant leg during daily activities. Thus training may improve the neuromuscular coordination of the non-dominant leg, producing greater numbers of soccer players or jumpers who can perform well with both legs.

Hore et al. (1996) attempted to study the errors in the joint rotations associated with inaccuracy, and thereby to gain insight into the neural mechanisms that contribute to skill in overarm throwing. Overarm throws from both left and right arms were recorded on different occasions as six right-handed subjects sat with a fixed trunk and threw 150 tennis balls at about the same speed at a 6 cm square on a target grid 3 m away. Joint rotations at the shoulder, elbow, wrist, and finger, and arm translations, were computed from recordings of arm segment orientations made with the magnetic field search-coil technique. All subjects threw less accurately in this task with the left (non-dominant) arm. For throws made with the left arm, the height of ball impact on the target grid was related to hand trajectory length and to hand orientation in space at ball release, but not to hand trajectory height. Two hypotheses were proposed to explain the decreased ball accuracy in the high-low direction during throwing with the non-dominant arm: that it was caused by increased variability in the velocity or timing of onset of rotations at proximal joints (which determine the path of the hand through space) or increased variability in the velocity or timing of onset of finger extension (which determine the moment of ball release). A prediction of the first hypothesis was that proximal joint rotations should be more variable in throws with the left arm. This was the case for the majority of proximal joint rotations in the six subjects when variability was examined in joint space. However, some proximal joint rotations were more variable in the right arm. The first hypothesis was directly tested by determining whether hand angular position in space (which
represents the sum of all proximal joint rotations) was related to ball impact height on the target grid at a fixed translational position in the throw. No relation was found between these variables for throws with the left arm in four subjects, whereas a weak relation was found for two subjects. It was concluded that, considering all subjects, the first hypothesis could not explain the results. In contrast, in agreement with the second hypothesis, a strong relation ($P < 0.001$) was found in all subjects between ball impact height on the target grid and time of ball release for throws with the left arm, and with time of onset of finger extension. Across all six subjects the timing precision (windows) for 95% of the throws was (for ball release) right arm, 9.3 ms; left arm, 22.5 ms; (for onset of finger extension) right arm, 13.7 ms ;left arm, 26.7 ms. Timing of onset of finger extension was no less accurate than timing of onset of other joint rotations for both left and right arms. However, simulations of throws showed that, for the same error in timing, finger extension had twice as large an effect on ball direction as any other joint rotation. Timing errors at the fingers have a greater effect than errors at other joints because finger errors are scaled by the higher angular velocity of the hand in space rather than by the smaller angular velocities of the individual joints. It is concluded that although rotations were in general mode variable at both proximal and distal joints of the non-dominant (left) arm, the major cause of its decreased throwing accuracy was increased variability at the distal joints, i.e., in the timing of onset of finger extension. This may be due to a lack of precision in the commands from the right hemisphere to the left fingers in right-handed throwers.

2.4 Psychomotor training and performance.

To determine if a glenohumeral joint internal rotation range of motion difference (IRD) and external rotation difference (ERD) exists between dominant and non-dominant shoulders of cricketers as demonstrated in other
overhead sports, and, if present, to establish if differences exist between cricketers with and without a history of gradual onset non-specific shoulder pain was studied by Giles and Musa (2008).

One hundred and nine elite male and female cricketers (11–35 years), representing 97% of the England and Wales national and West of England regional Under 13 teams, consented. The final number included for data analysis was 133. Data relating to playing position, cricket exposure, shoulder pain and demographic details collected using a questionnaire. Passive isolated glenohumeral rotation measured in 90° shoulder abduction using an inclinometer. Cricketers who regularly bowl or throw overarm had significantly less internal (−7.9°, p<0.001) and greater external (8.6°, p<0.001) dominant to non-dominant glenohumeral rotation. Wicket-keepers had tendencies for smaller differences that were still statistically significant [mean IRD −5.9° (p<0.001); ERD 5.0° (p=0.002)]. Cricketers who experienced shoulder pain demonstrated a significantly greater IRD [mean 3.2° (p=0.032)] than those who did not. The results of this study support measurement of passive glenohumeral joint rotation during musculoskeletal profiling and indicate that a possible link between increased IRD and non-specific shoulder pain warrants further investigation.

Makam et al., (2004) attempted to examine the performance of experienced surgeons and compared to the performance of residents. The purpose of the study is to validate the BEST-IRIS training simulator. The different kinds of surgeries performed by Gastro Intestinal surgeons, gynecologists, urologists, pediatric and endocrine surgeons were recorded and the various actions performed during the surgeries were analyzed. The basic actions performed were noted and exercises were designed to mimic these basic actions. Any surgery would be a permutation and combination of these basic exercises. Thirty eight residents and thirteen experienced surgeons
(n=51) participated in this study. Each subject completed all seven tasks thrice a day for a week. The data was analyzed to evaluate the individual subject’s performance by the scoring system in the simulator. The subjects were also evaluated by using a standard test procedure (paper-cutting test) on a pelvi trainer in the beginning and at the end of the session. The scores obtained by surgeons and residents were compared. The surgeons were found to perform significantly better. There was a clear demarcation in the scores noted between the experienced surgeons and residents. This was proved by a statistical analysis (p=0.05). This was also in agreement with the paper-cutting test results. Thirty six out of thirty eight residents improved with practice. With an objective that 90% of residents would improve their skills by practicing on this system, statistical analysis has shown to be significant at a p value of <0.05.

Gupta et al. (2003) examined their preliminary experience with planned intensive in vitro training program focused on the non-dominant hand and reducing physical fatigue. Apart from this, they attempted to calculate how much training is required for a novice urologist to master laparoscopic freehand suturing with the dominant and non-dominant hands. One trainee worked on a pelvi-trainer, first with the dominant hand and then with the left hand, practicing intracorporeal suturing and cutting and improving physical endurance by gradually increasing the duration of each training session. Along with the pelvi trainer, he worked on left-handed writing to improve wrist movements. Before starting this training, he did not have any laparoscopic experience as assistant or primary surgeon. The progress was stored in the computer prospectively to compare the results with those obtained at the end of the training. For the dominant hand, 30 hours over 2 months was required to master laparoscopic suturing skills. After training of the right hand, the nondominant hand required 40 hours of pelvi trainer work and 20 hours of handwriting during 2 months. Physical endurance for suturing in the pelvi
trainer increased from 15 minutes to 150 minutes over 3 months. The main improvement was in the degree of pain over the right shoulder because of the abducted position and backache.

VanHedel et al. (2002) attempted to find out whether a newly acquired locomotor skill can be transferred to the mirror condition. Twenty healthy subjects (mean age 29.9, range 24-37 years, eight males and four females; 165 to 180 cm in height) participated in the study that conformed to standards set by the declaration of Helsinki. Subjects were trained to step over an obstacle on a treadmill, the appearance of which was signaled by an acoustic stimulus, while visual information was prevented. Feedback information about foot clearance was provided by acoustic signals. During two successive runs the same leg was leading. In the following third run, the leading and trailing legs were changed. During each of the three successive runs the adaptational changes were analyzed by recording leg muscle electromyographic activity, joint angle trajectories and foot clearance over the obstacle. The training effect gained between the first and second runs and the transfer to the mirror condition were evaluated. Adaptation changes of all measures, except ankle joint trajectory, could to a significant extent be transferred to the mirror condition. No side-specific differences in the amount of transfer were found, neither from the right to the left side, nor vice-versa. These observations are at variance with adaptation changes observed split-belt walking or one-legged hopping on a treadmill, where no transfer to the mirror condition occurred. It is assumed that this might be due to the specific requirements of the tasks and the leg muscles involved. While in the split-belt and hopping experiments leg extensor muscles are mainly involved, leg flexors predominate in the performance of the present task. The observation that during stepping over an obstacle a considerable transfer of skill to the mirror condition occurs might have consequences for training strategies in sports and rehabilitation.
2.5 Psychomotor training on coordination

Cup stacking is a sport in which participants stack and un-stack specially designed plastic cups in predetermined sequences. Preliminary research, although limited, has found some support for claims made by the manufacturer that the activity improved coordination by improving ambidexterity, developing hand-eye accuracy, and promoting upper extremity quickness. Emily et al. (2007) attempted to test two separate techniques of practice on cup stacking performance. Thirty volunteer participants ranging between 19-27 years old, all of whom had no prior training or experience in cup stacking, were randomly assigned to the massed (n=10), distributed (n=10), and control (n=10) practice sessions. The massed group practiced a series of stacking sequences for 60 consecutive minutes. The distributed group practiced for three 20 minute sessions. The control group did not practice cup stacking. All groups were pre and post tested on reaction time (RT), using the same yardstick test as RT data were analyzed using a 3 (group) x 2 (TEST), mixed analysis of variance. There was a significant interaction (Group X Test), F (2,27) = 8.910 p<0.05. LSD post hoc analyses revealed that only the massed and distributed groups had improved their reaction times following the 1 hour cup stacking practice. Cup stacking performance between these two groups was compared by examination of stacking time for three sequences (6,3-6-3 and 6-6) with the latter sequence serving as a transfer test. A 2 (group) x 3 (sequence) mixed analysis of variance was used. There was a significant Group main effect, F (1, 18) = 9.318, p<.05 with faster stacking times exhibited for the distributed group. There was no significant Group X sequence interaction, F (2, 36) = .33, P>.05. It was concluded that practicing cup stacking in distributed fashion will lead to better performance; however reaction time gains can be elicited with either practice schedule after only 1 hour of practice.
Toit et al. (2006) attempted to study whether a transfer effect of eye-hand co-ordination performance and consequently motor learning, can occur in rugby players after practicing diverse eye-hand co-ordination skills with the left hand. An experimental quantitative design was adopted to determine a transfer effect of motor learning and eye-hand coordination skills by assessing eye-hand co-ordination performance before and after practice. A total of 55 subjects (14-17 years of age) participated in the study. The participants were rugby players from secondary schools in Pretoria, Gauteng, South Africa. They were randomly selected from a group of 74 players who were interested in taking part in the study. They were randomly divided into an experimental (31 subjects) and a control group (24 subjects), but during the study six players in the experimental group were injured. Any player who was right hand dominant, aged between 14 to 17 years of age plays rugby was the criteria to participate in the study. Rotator pegboard, strobespecs and Accuvision1000-test apparatus were used to test the different components of eye-hand coordination. Forty-nine of the 55 participants completed the five-week program and were re-evaluated. At the beginning of the experiment there were no significant differences between the test results of the experimental and control group in all the tests. The results show a significant increase in the performance of the different parameters of eye-hand coordination skills after the five-week practice period. The p values for the different tests clearly indicate that the control group achieved no improvement in performance of the different skills. The hypothesis is therefore accepted that a transfer effect of eye-hand co-ordination skills from the right to the left cerebral hemisphere does exist. The existence of a transfer effect from the right to the left cerebral hemispheres may contribute to the optimization of eye-hand co-ordination skills in athletes with injury to the right upper limb.
Whitacre et al. (2002) examined the effects of parameter variability on the generalized motor programs and movement parameterization. N=20 participate in the experiment for course credit. Participants had no prior experience with the experimental task and were not aware of the specific purposes of the study. Participants attempted to exert a force pattern that resembled in force and time a waveform displayed on a computer monitor. The analysis suggested that relative timing a measure of the generalized motor programs performance remained remarkably stable across retention and transfer tests, whereby the structure of the movement remained intact, although the parameter or muscle group changed during transfer. The result also indicated that variable parameter practice did not enhance generalized motor program learning but did degrade the learning parameter that was not varied (force). In addition, parameter specification was substantially less stable than the generalized motor program, with time and force parameter performance deteriorating from the retention to transfer tests. These findings suggest that parameter specification, and not the generalized motor program, is the primary cause of poorer performance in parameter and effect of transfer.

Rintalaa et al. (1998) compared the effectiveness of two approaches to movement intervention for children with a combination of language and movement difficulties – a specialist approach labelled psychomotor training and regular PE lessons from trained PE teachers. From a sample of 76 children formally classified as suffering from developmental language disorder, 54 (71%) fell below the 15th percentile on a test of motor competence. These 54 children were then divided into two groups, one of whom received a 10 week psychomotor training programme and the other regular PE lessons. Although all children, regardless of the type of intervention, made progress, the differences between these two approaches were small. However, the children in the psychomotor training programme did improve more than those who
followed the regular physical education curriculum, particularly on the object control task of the Test of Gross Motor Development. Our results are discussed in terms of the contribution movement intervention can make to the overall development of children with developmental language disorders.

Tan (1993) attempted to study the speed and accuracy in hand speed in relation to sex-related differences in left-handed normal subjects. Hand skill was assessed by a peg moving task. Hand speed increased linearly with successive trials. Left hand speed exhibited a higher learning capacity than right-hand speed. Right hand speed and right hand learning were equivalent in males and females. Left-hand speed was higher in females than males; left-hand learning was equivalent in males and females. Left minus right hand speed decreased linearly with right-hand speed; left hand speed did not influence L-R hand speed. Learning curves were constructed for each subject. Standard error of a learning curve was considered as accuracy of hand skill. In females, accuracy of hand movement decreased as hand speed increased. In males, only accuracy of right-hand speed decreased as right-hand speed increased; left hand accuracy did not depend on left hand speed. It was concluded that right brain controlling left hand in left handers has a higher capacity than left brain for motor learning; L-R hand speed was largely determined by left brain; accuracy in hand skill depends on both brains in females, and on only left brain in males; the female brain is more bilaterally organized than male brain in fine motor control.

In an experiment conducted by Dunham (1977), subjects practiced a pursuit rotor task (20 rpm for 20 seconds) according to either a sequence order of right and left hand practice, or a serial order of practice to the sequence order, subjects practiced with preferred hand until a score of 70% on target (14 seconds out of 20) for two consecutive trials was achieved. When this criterion was reached, the subjects transferred to the opposite hand and practiced until
they achieved the same 70% criterion with that hand. The serial order group alternated hands until each 70% criterion was achieved by each hand. The results show that sequential order group achieved criterion performance with both hands in fewer trials than the serial order group. These results indicate that bilateral transfer occurs faster when one limb is practiced to a reasonable degree of proficiency before practice is begun with the opposite limb.

2.6 Resistance training, plyometrics and speed training on throwing performance.

Koley et al. (2009) attempted to study the association of left and right hand grip strength with eight anthropometric traits, viz. height, weight, body mass index, hand length, hand breadth, upper arm length, forearm length and total arm length in 100 male cricketers aged 17 – 21 years (mean age 18.29 ± 2.21 years) of Amritsar, Punjab, India. A total of 100 controls were also taken for comparisons. The findings of the present study indicate a strong association of right hand grip strength with height (r =0.383), weight (r=0.498), body mass index (r=0.401), hand length (r=0.444), hand breadth (r=0.326) and forearm length (r=0.215). Whereas left hand grip strength was reported to be closely associated with height (r=0.355), weight (r=0.472), body mass index (r=0.374), hand length (r=0.320) and hand breadth (r=0.330).

To determine normative values for isometric flexion/extension, abduction/adduction, and external/internal and external rotation strengths were measured (1) with the arm abducted 15° and neutral external/internal rotation and (2) with the arm abducted 90° and externally rotated 30° above the transverse plane. No statistically significant differences in agonist/antagonist strength ratios were found between dominant and non-dominant sides or between genders. Age was associated with changes in strength ratios for
measurements taken with the arm flexed or abducted 90°. Posture was found to affect strength ratios. Internal and external rotation strengths were measured (1) with the arm abducted 15° and neutral external/internal rotation and (2) with the arm abducted 90° and externally rotated 30° above the transverse plane. No statistically significant differences in agonist/antagonist strength ratios were found between dominant and non-dominant sides or between genders. Age was associated with changes in strength ratios for measurements taken with the arm flexed or abducted 90°. Posture was found to affect strength ratios.

Petersen et al. (2009) attempted to quantify the positional movements of cricketers in Twenty 20 cricket matches. The time-motion characteristics of five cricket positions (Batsmen, Fast bowlers, Fielders, Spin bowlers, Wicketkeepers) were quantified during four State Twenty20 (T20) cricket matches. A total of 18 different players were monitored over 30 innings. Several time motion characteristics were quantified using portable 5Hz global positioning system (GPS) units. Descriptive statistics (mean ± SD) were used to describe the data while the effect size statistic was used to determine the magnitude of difference in patterns of movement between positions. T20 cricketers covered between 6.4 - 8.5 km, with 0.1 - 0.7 km of this distance spent sprinting during an 80 min fielding innings. Fast Bowlers covered 8.5 ± 1.5 km; sprinted 42 ± 8 times, mean sprint distance was 17 ± 2 m and total sprinting distance was 0.7 ± 0.2 km. Wicketkeepers covered 6.4 ± 0.7 km; sprinted 5 ± 2 times, mean sprint distance was 10 ± 3 m and total sprinting distance was 62 ± 44 m. While batting (30 min) players covered ~2.5 km; sprinted 12 ± 5 times, mean sprint distance was 14 ± 3m and total sprinting distance was 160 ± 80 m. Fast bowlers and fielders have substantially greater physical demands than spin bowlers and wicketkeepers in T20 cricket.
Freeston and Rooney (2008) attempted to assess the efficacy of progressive velocity throwing training on throwing velocity and accuracy, in a cricket-specific test. Eighteen sub-elite male cricket players were assessed for maximal throwing velocity and at four different throwing velocities relative to maximal throwing velocity. The participants were randomly assigned to either an intervention (n=9) or control (n=9) group. Both groups performed usual pre-season activities for 8 weeks, during which the intervention group performed two additional specific throwing training sessions per wk. Maximal throwing velocity was re-assessed at 4 weeks and the progressive velocity throwing programme was adjusted accordingly. The 8 week progressive velocity throwing training significantly increased peak and mean maximal throwing velocity (p = 0.01). Absolute changes in peak and mean maximal throwing velocity were negatively and significantly correlated with initial maximal throwing velocity at 4 weeks (r =0.805, p = 0.01 and r = 0.806, p = 0.01 respectively) but not at 8 weeks. No significant difference was observed in accuracy for either group at any time. This is the first published study to describe the effectiveness of a progressive velocity throwing training programme on throwing performance in a group of sub-elite cricket players. The addition of two specific throwing training sessions per week can increase maximal throwing velocity without detriment to throwing accuracy.

Nimphius et al. (2005) investigated to determine whether performing high force or explosive force movements prior to sprinting would improve running speed. Fifteen NCAA Division III football players performed a heavy-load squat, loaded counter movement jump or control warm up condition in a counter balanced randomized order over the course of three weeks. The heavy-load squat protocol consisted of one set of three repetitions at 90% of the subject’s one repetition maximum. The loaded countermovement jump protocol was one set of three repetitions at 30% of the subject’s one repetition
maximum. At four minutes post-warm-up, subjects completed a timed 40 meters dash with time measured at 10, 30, and 40 meters. The results of the study indicated that no significant differences were observed in the 10 meters or 30 meters split times between the three conditions. The data from this study suggest that an acute bout of low volume heavy lifting with the lower body may improve 40 meters sprint times, but that loaded countermovement jumps appear to have no significant effect.

Sixty four novice tennis players (21.1 +/- 1.3 years) were equally (n=16) assigned to a control, plyometric training, tennis-specific drills training and combined training. Training was performed three times per week for nine weeks. Testing was conducted before and after training for the evaluation of reaction time (single lateral step), four meter lateral and forward sprints, twelve meter forward sprints with and without turn, reactive ability, power, and strength. It was concluded plyometric training improved fitness characteristics that rely more on reactive strength and powerful push-off of legs such as, lateral reaction time, four meter lateral and forward sprints, drop jump and maximal force. Tennis specific drills training improved all four meter and twelve meter sprint performances, whereas combined training appeared to incorporate the advantage of both programs and showed improvement in most of the test items.

Pyne et al. (2006) characterized the relationships between anthropometric and isoinertial strength characteristics and bowling speed in junior and senior cricket fast bowlers. Subjects were first-class senior (n=24; mean ± SD age=23.9 ± 4.8 years, height =187.4 ± 4.8 cms, mass =87.8±8.4 kg) and junior representative (n=48 ±SD age = 14.8 ±1.3 years, height =175.7 ±9.8 cm, mass =65.8 ±12.9 kg) male fast bowlers. A full anthropometric profile, upper and lower body isoinertial strength tests, and peak bowling speed (V peak) were assessed on the same day. The senior bowlers had a substantially
faster Vpeak (126.7 km.h-1) than the juniors (99.6 km.h-1) a larger estimated muscle mass (seniors 40.0 ± 3.9 kg, juniors 28.3±5.6 kg), and greater bench press throw and deltoid throw (all p<0.001). The best multiple predictors of Vpeak for the junior bowlers were the static jump, bench throw, body mass percentage muscle mass, and height (multiple – correlation r = 0.86). For the senior bowlers, static jump and arm length correlated positively with Vpeak (multiple – correlation r = 0.74). The 1-legged countermovement jump was negatively correlated with V peak in both groups. It was concluded that differences in Vpeak between junior and senior bowlers relate primarily to body mass and upper-body strength. However, lower body strength is a more important contributor to Vpeak in senior bowlers.

Peterson et al. (2004) attempted to study the effects of training with overweight and underweight cricket balls on fast-bowling speed and accuracy were investigated in senior club cricket bowlers randomly assigned to either a traditional (n=9) or modified-implement training (n=7) group. Both groups performed bowling training three times a week for 10 weeks. The traditional training group bowled only regulation cricket balls (156 g), whereas the modified-implement training group bowled a combination of overweight (161-181 g), underweight (151 -131 g) and regulation cricket balls. A radar gun measured the speed of 18 consecutive deliveries for each bowler before, during and after the training period. Video recordings of the deliveries were also analyzed to determine bowling accuracy in terms of first-bounce distance from the stumps. Bowling speed, which was initially 108 ± 5 km h -1 and in the traditional training group by 1.3km h-1 (difference, 2.7 km h-1; 90% confidence limits, 1.2 to 4.2 kmh-1). For a minimum worthwhile change of 5kmph-1, the chances that the true effect on bowling speed was practically beneficial/trivial/harmful/ were 1.0/99/<0.1%. For bowling accuracy, the
chances were 1/48/51%. This modified-implement training programme is not a useful training strategy for club cricketers.

Bat velocity is considered to be an important factor for successful hitting. The relationship between grip strength and bat velocity has not been conclusively established. Hughes et al. (2004) attempted to study relationship of grip strength to bat velocity and to ascertain whether the performance of resistance training exercises designed to specifically target the forearms and grip would significantly alter bat velocity. The subjects for this study were 23 male members (mean ± SD, age = 19.7 ± 1.3 years, height = 182.5 ± 5.9 cm, weight = 85.4 ± 15.5 kg, experience = 14.4 ± 1.7 years) of a varsity baseball team at a National Collegiate Athletic Association Division II school. The Jamar hand dynamometer was used to test grip strength, and the SETPRO Rookie was used to measure instantaneous bat velocity at the point of contact with the ball. Subjects were randomly divided into an experimental group and a control group. For 6 weeks, both groups participated in their usual baseball practice sessions, but the experimental group also performed extra forearm and grip strengthening exercises, whereas the control group did not. Pretest and posttest correlations between grip strength and bat velocity revealed no significant relationship between grip strength and bat velocity (pretest $r = 0.054$, $p = 0.807$; posttest $r = 0.315$, $p = 0.145$). A dependent $t$-test performed on all subjects revealed that a significant ($p = 0.001$) increase in bat velocity did occur over the course of the study. A covariate analysis, employing pretest bat velocity as the covariate, revealed no significant difference ($p = 0.795$) in posttest bat velocity scores between the experimental and control groups. Thus, increases in bat velocity occurred, but the differences were similar for both the experimental and control groups. The findings of this study suggest that grip strength and bat velocity are not significantly related, and that the allocation of
time and energy for added training of the forearms in order to improve grip strength for the purpose of increasing bat velocity may not be warranted.

Treiber et al. (1998) attempted to determine a combination of 4-week isotonic resistance training program using Theraband elastic tubing and lightweight dumbbells on velocity of serve and concentric shoulder rotator strength in a group of elite-level tennis players. Twenty two male and female varsity college Tennis players were randomly assigned to control or 4-week training groups. Subjects were pre and post tested in concentric internal and external rotation torque using an isokinetic dynamometer. Functional performance was assessed before and after training by recording the peak and average velocities of eight maximal serves. The experimental group exhibited significant gains in internal rotation torque at both slow (120 deg/sec) and fast speeds (300 deg/sec) for total work and in peak torque to body weight ratio and torque acceleration energy at the fast speed. This group also exhibited significant gains in external rotation torque for the same parameters at fast speed. Regarding speed of serve, the experimental group exhibited significantly greater increase in peak speed (+6.0% compared with -1.8%) and average speed(+7.9% compared with 2.3%) compared with the control group. Men exhibited greater internal and eternal rotation torque on all parameters and in a peak and mean speed of serve on both evaluations. Men also exhibited greater imbalance in external to internal rotation torque ratios. In conclusion, resistance training using theraband tubing and lightweight dumbbells may have beneficial effects on strength and functional performance in college-level tennis players.

Eliasz (1995) attempted to find the relationships between the ball velocity during different types of throws in handball and basic motor ability parameters (muscle strength, arm speed) of players, in order to improve the efficiency of training. Twelve high-performance handball players took part in
the experiment. The average values of basic parameters of physical characteristics of the subjects were: 89.07.8 kg (body mass), 1.880.05 m (body height) and 23.32.5 years of age. The Shapiro-Wilk test, Pearson's correlation matrix and multiple regression analysis were used \( (a=0.05) \). In order to assess the overarm throwing performance, a standard handball was used (mass 480 g, circumference 58 cm). The subjects were instructed to throw the ball as fast as possible at a target (50 x 50 cm) placed at a distance of about 6 meters. Each subject performed trials until three registered throws (i.e. when the ball hit the target) were achieved. The average linear ball velocity was measured over a 2 meter distance using a special photocells system. Handballers performed three of the most popular types of throws: on the spot, with a cross-over step and with an upward jump. Each session was preceded by 10-minute standard warm-up. Each subject executed three kinds of tests: maximal speed diagnostic (MSD), isokinetic exercises (IKE) at angular velocities 100, 300 and 500 deg/s, isotonic exercises (ITE) at external torques 10, 30 and 50 Nm. The following parameters were chosen to further the analysis: maximal angular velocity of the bar measured during MSD, maximal and average mechanical power during IKE and ITE, maximal and average torque developed in IKE, maximal and average angular velocity measured in ITE.