Roget's Pocket Thesaurus (1946) defines the noun sport as an "Activity engaged in for relaxation and amusement". It is especially an outdoor activity, having immense physical and psychological benefits. Sports and exercise psychologists identify principles and guidelines that professionals can use to help adults and children participate in and benefit from sports and exercise activities. Variety of terms has got frequently used in physical activity research: physical fitness, physical activity, and exercise (Barenberg et al. 2011). Physical fitness is a set of attributes describing an individual’s ability to perform physical activity, including physiological (blood sugar levels), health-related (oxygen supply) and skill-related (coordination of motor responses) parameters (Bouchard, Shephard & Stephens, 1994; Corbin, Pangrazi & Franks, 2000).

Physical activity refers to any muscular movement requiring substantial energy expenditure and has various subcategories (leisure activities or exercise). Of these, exercise is exclusively characterized by the intention to develop physical fitness (Bouchard et al., 1994). Physical activity and exercise are regarded as process variables indicating behavior capable of influencing product variables, such as attributes of physical fitness or health (Corbin et al., 2000). Physical activity and exercise are frequently applied as interventions, with physical fitness as an outcome measure. The manipulation of physical activity can vary in terms of format, intensity, and duration. The format can vary from simple cycling or walking interventions to more complex aerobic training programs. The level of intensity is generally defined as a certain percentage of the individual maximum workload, as measured by assessments of oxygen uptake, heart rate or lactate level. In terms of duration, two types of physical activity interventions can be distinguished,

1. Short-term interventions - consisting of a single bout of physical activity.
2. Long-term interventions - involving several weeks of exercise.

Over the past decades, physical activity research has also begun to address the product variables of cognitive functions in general (Etnier et al., 1997) and, more recently, executive functions in particular (Colcombe & Kramer, 2003).

In this research, an attempt is made to study Emotional Intelligence, Executive Function and Explanatory Style as a function of participation in competitive Mallakhamb.
3.1 Emotional Intelligence

Emotional intelligence is the set of skills that underlie the accurate assessment, evaluation, expression and regulation of emotions (Salovey & Mayer, 1990). Since this definition omitted a very important reciprocal interaction between emotion and cognition, a revised definition of emotional intelligence as ‘Emotional intelligence involves the ability to perceive accurately, the appraisal and expression of emotions; the ability to access and/or generate feelings when they facilitate thought, the ability to understand emotion and emotional knowledge; and the ability to regulate emotions to promote emotional and intellectual growth’ was presented. According to it, emotional intelligence has four aspects: (1) the ability to perceive emotions in oneself and in others, (2) the ability to use emotions to facilitate thought, (3) the ability to understand emotional information and its impact, and (4) the ability to manage emotions, both one’s own and those of others. According to psychologist Daniel Goleman (1995), emotional intelligence underlies the ability to get along well with others. It provides with an understanding of what other people are feeling and experiencing and permits to respond appropriately to the others needs. He also included various personality attributes into his definition of emotional intelligence like zeal, persistence and motivation. Emotional intelligence is the basis of empathy for others, self awareness and social skills. Abilities in emotional intelligence may help explain why people with only moderate scores on traditional intelligence tests, may be quite successful, despite their lack of traditional intelligence. Bar-On (2000) defines emotional intelligence in terms of an array of emotional and social knowledge and abilities that influence our ‘overall ability to effectively relate with environmental demands’. This array includes: (1) the ability to be aware of, to understand and to express oneself; (2) the ability to be aware of, to understand and to relate to others; (3) the ability to deal with strong emotions and control one’s impulses; and (4) the ability to adapt to change and to solve problems of a personal or a social nature. The five main domains in his model are intrapersonal skills, interpersonal skills, adaptability, stress management and general mood.

Numbers of studies have been conducted to look into the nature of Emotional intelligence and its relation to sport performance. It was found that emotionally intelligent people use psychological skills such as imagery, goal setting and positive self talk more often than their less emotionally intelligent counterparts. It was also found that emotionally intelligent people are mentally tough and they also find exercise enjoyable (Lane, 2006); emotional intelligence can assist in the regulation of psychological states that facilitate performance (Lane, et al., 2005). A case study was conducted to investigate the relationship
between emotional intelligence and self-talk in performance of rugby goal kicking in five volunteer male rugby goal kickers (Low, Lane & Devonport, 2007). Effects of the self-talk conditions on performance in relation to emotional intelligence were examined. Performance was assessed using a rugby-specific kicking task. It appeared that self-talk and emotional intelligence did not positively impact on physical performance but on the mental state of participants for rugby goal kicking early on in performance.

Downs and Ashton (2011) hypothesized that students who were continuously active across high school and college or are currently active would report lower negative affect and stress, higher positive affect, self-esteem, and subjective well-being than their less active peers. The participants included 395 undergraduate college students, with the age range from 17 to 38. Consistent with hypothesis, the continuously active participants reported significantly higher self-esteem, higher positive affect, and lower perceived stress. They also reported engaging in a significantly higher frequency of general wellness behaviours, reported eating significantly more healthy foods, and spending less time using electronics than their non-continuously active peers. Contrary to hypothesis, the two groups did not differ on subjective well-being, negative affect, consumption of unhealthy foods or binge drinking. Specifically, it was found that individuals who were adequately active in every year of high school and college reported experiencing significantly more positive affect, higher self-esteem and less stress than those who were not always active. When 64.3% of participants who were currently active were compared to the 35.7% who were not currently active, a similar pattern was found, with the active students reporting more positive affect, higher self-esteem and less stress than their insufficiently active counterparts.

Lane et al. (2010) investigated relationships between self-report measures of emotional intelligence and memories of pre-competitive emotions before optimal and dysfunctional athletic performance. Participant-athletes (n = 284) completed a self-report measure of emotional intelligence and two measures of pre-competitive emotions; a) emotions experienced before an optimal performance, and b) emotions experienced before a dysfunctional performance. Results demonstrated pleasant emotions associated with optimal performance and unpleasant emotions associated with dysfunctional performance. Emotional intelligence correlated with pleasant emotions in both performances, with individuals reporting low scores on the self-report emotional intelligence scale appearing to experience intense unpleasant emotions before dysfunctional performance. It was seen that optimal performance was associated significantly with higher scores on the vigor, happiness and calmness scales coupled with lower anger, confusion, depression, fatigue and tension.
scores. The study also investigated the extent to which emotional intelligence was related to variations in pre-competition emotion. It was found that, emotional intelligence correlated with pleasant emotional states before optimal and dysfunctional performance. Hence, emotional intelligence appeared to correlate with emotions such as vigour, happiness, calmness even when participants’ performance is below personal standards.

Lane, Devonport and Stevens (2010) investigated relationships between trait emotional intelligence, pre-race emotions and post-race emotions among a sample of 93 competitive 10-mile runners. Participants completed emotional intelligence and pre-race emotion scales approximately one hour before starting a 10-mile race, repeating completion of the emotion scales within one hour of finishing. Results indicated emotional intelligence correlated significantly with higher pleasant emotion and lower unpleasant emotion before and after racing. Path analysis results revealed emotional intelligence predicted both pre and post-race emotion. Results lend support to the notion that emotional intelligence is associated with emotional well-being. It was suggested that future research should investigate emotional intelligence and its relationship with strategies used by athletes to regulate emotion before, during, and after competition. Lane, Galloway and Devonport (2006) studied relationships between emotional intelligence and mood states associated with successful performance in sport and academic settings. It was hypothesized that emotional intelligence will be associated with mood states in competition and examination settings. Anger, confusion, depression, fatigue, tension, vigour, calmness and happiness were assessed. A 33-item measure of emotional intelligence was used (Schutte, et al., 1998). A significant interaction was found for differences in mood between successful and unsuccessful performance in academic and sport conditions, with significant main effect for sport and academic performance. Findings here lend support to the notion that mood states are associated with successful performance (Beedie, Terry & Lane, 2000).

Emotionally intelligent athletes have been found to use psychological skills more frequently. In a study on volunteer student athletes (Lane et al., 2005) it was found that high emotional intelligence was associated with significantly higher vigor scores and successful performance. Emotional intelligence appears to be linked with reducing the tendency to experience depressed mood (Lane & Terry, 2000). The ability to regulate mood states has been shown under the rubric of emotional intelligence in general psychology. Emotional intelligence scores were found to be significantly related with self talk in practice, self talk used in competitions, goal setting used in competitions and imagery used in competitions.
In the study by Lane and Lowther (2005) it was hypothesized that emotional intelligence would be associated with more frequent use of psychological strategies during practice and competition. With emotional intelligence, eight psychological strategies used in competition (activation, automaticity, emotional control, goal-setting, imagery, negative thinking, relaxation and self-talk,) and eight used in practice (the same strategies except negative thinking is replaced by attentional control) were assessed. Correlation results indicated emotional intelligence scores significantly related with self-talk used in practice; self-talk used in competition, goal setting used in competition and imagery used in competition. Findings lend some support to the notion that emotional control and psychological skills are related. Emotionally intelligent athletes reported using self-talk consistently in competition and training. It was suggested that future research is needed to explore relationships between emotional control and psychological skills.

Zizzi, Deaner and Hirschhorn (2003) explored the relationships between emotional intelligence and global measures of baseball performance in a sample of college baseball players. The study provided only modest support for the link between emotional skills (emotional awareness, control and utilization) and athletic performance. The data suggested that components of emotional intelligence appear to be moderately related to pitching performance, but not related to hitting performance. This may be because, pitchers maintain more control over the pace of play than hitters and are presented with regular, structured opportunities (between pitches or batters) to recognize and regulate their own emotional states during performance. While pitchers have the ability to dictate the pace of play, batters must react. Hitting is a high-level sport skill that requires a combination of vision, hand-eye coordination, timing, technique and power to be demonstrated in a split second. The context under which typical at-bats occur would provide hitters with less time for emotional intelligence skills to be utilized. In addition to the skill of accurately delivering the ball to the catcher’s mitt, pitchers are required to communicate with teammates (catcher and other position players) and be aware of runners on base. The pitching process, therefore, frequently requires recognition of other’s emotional states and effective communication (verbal and nonverbal) with teammates. This explanation supports Abraham’s (1999) position, which links EQ with cohesion and work-group performance. In sum, it appears that EQ may be salient for pitchers due to the additional time provided to internally regulate oneself and the need to externally interact and communicate with others during performance. As the competitive level of sport increases, the disparity in physical skills between competitors diminishes thereby increasing the potential importance of mental skills in determining
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performance outcomes. Thus, although the relationship between EQ and pitching performance is modest at best, these emotional skills may have the potential to impact performance at high levels of competition.

Exercise is also found to improve positive affect and few studies have shown increase in emotional intelligence as a function of participation in exercise and also impact of exercise on development of life skills and improvement in prosocial behaviour and work quality. Thøgersen-Ntoumani, Fox and Ntoumanis (2005) conducted a study to find out the relationships between exercise and three components of mental well-being (physical self, work-related and global) in corporate 312 employees from an information technology company. Structural equation modelling was used to examine links between exercise participation and the three well-being components within a hierarchical framework, featuring global well-being constructs at the apex and specific elements of well-being at lower levels. Support was found for the a priori model. There were direct paths from exercise to physical self and enthusiasm at work. Also, there were indirect paths between exercise and global well-being components through measures of the physical self and enthusiasm at work. The results of an alternative model using physical activity as opposed to exercise were generally similar. It was concluded that exercise is associated directly and indirectly with high well-being in various facets of employees' lives. The results pertaining to physical activity also suggest that workplace exercise promotion programmes should incorporate and promote lifestyle physical activity. Reed and Ones (2006) conducted a meta-analysis on the effect of acute aerobic exercise on self-reported positive activated affect (PAA). Samples from 158 studies from 1979 to 2005 were included yielding 450 independent effect sizes and a sample size of 13,101. Effects were consistently positive for immediately post-exercise, when pre-exercise PAA was lower than average, for low intensity exercise, for durations up to 35 min and for low to moderate exercise doses. The effects of aerobic exercise on PAA appeared to last for at least 30 min after exercise before returning to baseline. It was concluded that the typical acute bout of aerobic exercise produces increases in self-reported PAA, whereas the typical control condition produces decreases. However, additional variables, possibly related to individual differences, further moderate the effects of exercise on PAA.

An exploratory study was conducted to test the relationship between Yoga and emotional intelligence (Kumar, et al., 2005) using an experimental design. The participants in the experimental group underwent a 7 day yoga training during which they were exposed to a rigorous yogic way of life, and the participants in the control group did not undergo yoga training and did not practice the yogic way of life. Both the groups were tested using the adult
version of Bar-On (1997) EQi before and after the 7 day yoga camp. Significant differences in scores before and after the camp were observed for the experimental group in assertiveness, interpersonal relationship, stress tolerance, impulse control, happiness, interpersonal EQ, stress management and general mood.

Research in developmental and general psychology has focused on the experiences youth have and the benefits they derive from taking part in organized out of school activities. In a study by Larson, Hansen and Moneta (2006) over 2000 high school students completed the Youth Experiences Survey-2 (YES-2), a measure of the development gains young people can derive from extracurricular activity participation, and an activity participation survey. Findings revealed that when compared to other activities, youth involved in sports and arts scored higher on initiative (reported more experiences related to sustaining effort and setting goals), emotional regulation and teamwork. Sports participants, however, also reported higher levels of one negative experience: stress. In a follow-up manuscript using the same sample, Hansen and Larson (2007) identified variables that they hypothesized “amplified” or moderated the relationship between activity participation and developmental experiences in youth activities. In addition to completing the YES-2, activity dosage or amount, motivations for taking part, lead roles experienced and the ratio of the number of adults to youth were assessed for each participant. It was found that the more the young person is motivated by enjoyment and future goals, the more he experienced a greater program dosage, held a lead role, and took part in programs characterized by higher adult-to-youth ratios, the more he or she reported a higher frequency of positive developmental experiences.

Gould, Flett and Lauer (2012) conducted a study to assess what developmental outcomes underserved youth report from their sports participation, identify these youth’s perceptions of the sports climate their coaches create, and measure the relationships between participants reported gains and perceptions of the psychosocial sports climate. It was expected that there would be a significant relationship between mastery motivational climate and positive developmental gains in young athletes. It was also expected that greater developmental gains would be associated with greater perceptions of a caring coaching climate. Participants were 239 urban youth sports participants from an underserved community who completed the YES-2, Sport Motivational Climate Scale, Caring Climate Scale and measures of the importance their coaches placed on life skills. It was seen that these youth most often perceived teamwork and social skills, physical skills development and initiative as the benefits they felt they most often derived from their sports experience. Stress was the negative experience most often experienced. The strongest influence on youth
experiences came from ego-oriented climates, suggesting that avoiding an ego-oriented climate is especially important in fostering positive psychosocial development.

3.2 Executive Functions

A regular programme of exercise is thought to have positive cognitive and affective consequences for both normal and clinical populations. In one study, Barry, Steinmetz, Page and Rodhal (1966) found improved performance on imagining and colour discrimination tasks after a 3 month program of aerobic exercise. However, performance on variety of working memory and discrimination tasks was unaffected by exercise.

The pioneering research in the study of the fitness on mental function dates back to 1970s, with the studies by Spirduso and her colleagues. In a classic study, Spirduso and Clifford (1978) compared the performance of young and old racquet sportsman, runners and sedentary adults on simple, choice and movement time tasks. In general, these studies found that older athletes outperformed older sedentary adults on simple, choice and disjunctive reaction time tasks, as well as on movement tasks. Indeed, older athletes tended to perform these tasks as well as young sedentary adults, who often performed slightly poorly than young athletes. The superior performance obtained by older athletes in these cross sectional fitness studies was confirmed and extended by subsequent research that has found that older, high fit individuals outperform older low-fit adults on a variety of perceptual, cognitive and motor tasks including reasoning, working memory, stroop, trails-B, symbol digits, vigilance monitoring and fluid intelligence tests (Abourezk & Toole, 1995; Bunce, Barrowclough & Morris, 1996; Clarkson-Smith & Hartley, 1990; Cook et al., 1995; Del Rey, 1982; Dustman et al., 1990; Dustman, Emmerson & Shearer, 1994; Emery & Gatz, 1990; Powell & Pohndooof, 1971; Shay & Roth, 1992; Stones & Kozma, 1989).

Elsayed, Ismail and Young (1980) found an improvement in fluid but not crystallized intelligence scores after a 4 month program of jogging and calisthenics. The failure to include a non-exercise control group made it impossible to determine whether performance improvements were due to the exercise intervention or due to the effects of practice.

Folkins & Sime (1981) reviewed the available literature on the relationship between exercise and cognitive functioning and concluded that while success has been achieved with geriatric mental patients, picture was much less clear with normal children and adults.

Tomporowski and Ellis (1986) reviewed several dozen studies and generally arrived at the same conclusion as Folkins and Sime (1981). Tomporowski and Ellis (1986) have categorized the available studies in one of the four ways and analyzed them.
very brief, high intensity anaerobic exercise – moderate levels of anaerobic exercise facilitate cognitive performance as measured by digit span test, perception of geometric figures and paired associate learning. High and low levels of tension did not facilitate cognitive functioning.

2. Short duration, high intensity anaerobic exercise – results here are most inconclusive. 6 of 11 studies surveyed showed no effects, others showed facilitation of cognitive functioning up to 10 or 15 minutes of exercise, at which time impaired performance became dominant. One additional study showed cognitive impairment at all the points. Bicycle pedaling, step up tasks or treadmill running was paired with discrimination or arithmetic tasks in these various studies.

3. Short duration, moderate intensity anaerobic exercise – Calisthenics, step up tasks, bicycle pedaling, treadmill running and run jog walk were employed in this group of studies. Studies in which moderate levels of exercises were used tended to report improved cognitive functioning with increase in arousal. Also, highly fit participants performed better than less physically fit people on cognitive tasks that were administered in the, moderate intensity exercise condition.

4. Long duration, aerobic exercise – Only 3 studies were evaluated in this category. A marathon race, a 5-mile march carrying a 40 pound pack and a treadmill task to fatigue were used as long duration aerobic events, with signal detection, perceptual organization and a free recall memory test serving as cognitive measures. Facilitation was found in 2 studies (Gliner, Matsen-Twisdale, Horvath & Maron, 1979, Lybrand, Andrews & Ross, 1954) and no effect was found in the third.

Research studies have shown mixed results concerning exercise and cognitive functioning due to variety of problems. Little of what has been done has been tied to theory and methodological flaws are numerous. Selection bias is found in many studies. Folkins and Sime (1981) sum up selection bias problem as follows; ‘Self selected, motivated volunteers may demonstrate improvement in psychological functioning simply because they are motivated for overall self improvement. It is therefore necessary to arrange for control groups that have time exposure equal to that of trainees, as well as equal and justified expectation for benefit’. Proposals for improving future research on fitness were suggested by them. One suggestion was to pay more attention to the measurement of physical effects brought about by
exercise, for example lactic acid production, precision of measurement of cardiovascular functioning, assessment of pre-intervention levels of fitness. The second suggestion was to systematically analyze the intensity and duration of the exercise and the placement of the measures of cognitive functioning during or after the exercise (Flory & Holmes, 1991).

Dustman et al. (1984) found improvements in the performance of a number of tasks, including critical flicker fusion, the digit symbol test of the WAIS (Weschler, 1955), a single reaction time task, and a stroop task (Stroop, 1935), following a 4 month exercise program. These improvements were largest for the aerobic exercise group. Participants in a strength and flexibility training program showed a significant improvement, but it was smaller than the aerobic group. Participants in the non exercise control group did not show any significant improvement in performance across test administrations. However, consistent with previous longitudinal studies, there were also a variety of tasks in which aerobic exercise failed to have beneficial effect. These tasks included choice reaction time, culture fair IQ and digit span. Together, the results of these longitudinal studies were supportive of selective improvements in a number of mental processes with short term programs of aerobic exercise.

In an early study of chronic exercise and cognition, Tuckman and Hinkle (1986) compared the effects of a 12-week aerobic running program to a standard physical education class in 4th, 5th and 6th grade children. The various running exercises became increasingly more physiologically-demanding over the course of the program. Comparisons of post-test cognitive functioning revealed that the aerobic running program did not influence perceptual-motor skills or visual-motor coordination but did improve children’s creativity as assessed by the Alternate Uses Test. In a subsequent study, Hinkle, Tuckman and Sampson (1993) examined the effects of a similar aerobic running program in 8th grade children. In comparison to the control group, children assigned to aerobic running performed better on the Torrance Test of Creative Thinking. Although not pure measures of EF, creativity tasks are believed to tap EF (Delis et al., 2007), and therefore, these results support the notion that EF is sensitive to the effects of chronic aerobic exercise (Tomporowski, et al., 2008).

Van Boxtel et al. (1997) studied the aerobic capacity and cognitive performance in a cross-sectional aging study. It was hypothesized that cognitively demanding tasks would be sensitive to aerobic capacity. Healthy participants between 24 and 76 year of age took part in a submaximal bicycle ergometer protocol and an extensive neurocognitive examination, including tests of intelligence, verbal memory and simple and complex cognitive speed. No group differences were found in the basic anthropometric characteristics height, weight and BMI. Two of four subtasks that reflect complex cognitive speed (Stroop color/word
interference and Concept Shifting Test) showed main and interaction effects with age of aerobic capacity in a hierarchical regression analysis, accounting for up to 5% of variance in parameter score after correction for age, sex, and intelligence main effects. These findings fit well within a moderator model of aerobic fitness in cognitive aging. They add to the notion that aerobic fitness may selectively and age-dependently act on cognitive processes, in particular those that require relatively large attentional resources.

It has been assumed that aerobic fitness would translate into increased blood flow in the brain, which in turn would support more efficient brain function – particularly in older adults, for whom such function is often compromised. Research using animal models provided reasonable grounds to expect aerobic exercises to have a positive impact on human cognitive function through a variety of cellular and molecular mechanisms. Increases in capillary density in the Cerebellum was found, when rats exercised on running wheel (Black, Isaacs, Anderson, Alcantara & Greenough, 1990). Aerobic fitness also resulted in the enhancement of cortical high-affinity choline uptake and increased dopamine-receptor density in the brain of old rats (Fordyce & Farrar, 1991), increases in brain derived neurotrophin factor (BNDF) gene expression in rats (Neeper, Gomez-Pinilla, Choi & Cottman, 1995) and increased number of new cells in the hippocampus of mice (van Praag, Kepermann & Gage, 1999). It speculated that these cellular, molecular and neurochemical changes observed in rats and mice in response to exercise interventions may underlie the improvements in perceptual, cognitive and motor processes in adult humans. Cotman and Engesser-Cesar (2002) showed that exercise enhances and protects brain function. Physical activity, in the form of voluntary wheel running was found to induce gene expression changes in the brain. Animals that exercise show an increase in brain-derived neurotrophic factor, a molecule that increases neuronal survival, enhances learning, and protects against cognitive decline. Microarray analysis of gene expression provided further support that exercise enhances and supports brain function.

Michael and Stephen (2005) reviewed salient basic research regarding physical exercise as a major protective factor against hippocampal degradation and to emphasize its relevance to humans. The method used was literature search and theoretical discussion of recent mammalian and human research. Results indicated that the cascade of cellular damages from oxidative stress, nitrosative stress and glucocorticoid effects are cumulative and age related. Exercise training reduces oxidative stress, nitro-sative stress and improves neuroendocrine autoregulation which counteracts damages from stress and age related neuronal degeneration, brain ischemia and traumatic brain injury. Conversely, lack of
exercise and motility restrictions are associated with increased vulnerability from oxidative stress, nitrosative stress and glucocorticoid excess, all of which precede amyloid deposition and are fundamental in the cascade of events resulting in neuronal degradation, especially in the hippocampi. It was concluded that despite the paucity of human research, basic animal models and clinical data overwhelmingly support the notion that exercise treatment is a major protective factor against neurodegeneration of varied etiologies. The final common pathway of degradation is clearly related to oxidative stress, nitrosative stress, glucocorticoid dysregulation, inflammation and amyloid deposition. People prone to chronic distress, brain ischemia, brain trauma and the aged are at increased risk for neurodegenerative diseases such as Alzheimer's. Exercise training may be a major protective factor but without clinical guidelines, its prescription and success with treatment adherence remain elusive.

Neuroscientists have focused on the mechanisms by which exercise may have an impact on cognitive functioning. Some researchers suggested that exercise may provide cognitive benefits because it increased cerebral blood flow, which brings important nutrients such as glucose and oxygen to the brain (Chodzko-Zajko, 1991; Madden, Blumenthal, Allen & Emery, 1989). Studies with human models have supported the hypothesis that exercise has an effect on cognitive functions in humans (Etnier, et al., 1997), an analysis that included a total 134 studies of acute and chronic exercise. Much of the research focused on older adults, a population that is of particular interest to researchers because older adults are more susceptible to cognitive decline due to age related deterioration in brain function (Kramer et al., 2000). Several researchers have suggested that in older adults, aerobic fitness has a larger impact on the tasks that require effortful processing than tasks that are executed using automatic processing (Chodzko-Zajko, 1991; Chodzko-Zajko & Moore, 1994). However there is inconsistent support for this hypothesis. For example, one study reported a stronger relationship between fitness and performance on effortful Stroop interference conditions than performance on tasks that are more automatic, such as simple colour and word naming (Schuler, Chodzko-Zajko & Tomporowski, 1993). This finding has not been consistently reported as other researchers have failed to find this differential effect in older adults using different cognitive measures (Hill, Storanet & Malley, 1993, Blumenthal et al., 1991).

To explain this discrepancy Kramer et al (1999; 2000) suggested that in older adults, aerobic fitness would be related to selective improvements in executive control processes, such as coordination, planning and working memory. This hypothesis was based on the literature that showed the part of the brain responsible for this type of brain activity tends to decline earlier in aging process (West, 1996). To test this hypothesis, researchers had
sédentaire des adultes âgés participent à un programme d'entraînement cardiovasculaire ou un groupe contrôle anaérobie (Kramer, et al., 1999). Il a été trouvé que les adultes du groupe de marche ont exécuté mieux que les adultes du groupe contrôle sur une variété de tâches de contrôle exécutif. Les augmentations de la volume de la matière blanche antérieure et de plusieurs régions de la matière grise (i.e. antérieur cingulé, gyrus frontal moyen et lobe temporal supérieur) ont été observées dans le groupe d'entraînement cardiovasculaire mais non dans le groupe contrôle non cardiovasculaire. Le suivi suivant a utilisé des techniques d'imagerie cérébrale et a montré que les adultes âgés entraînés de manière cardiovasculaire avaient une plus grande activité dans les régions du cerveau qui sont supposées supporter les fonctions de contrôle exécutif (Colcombe et al., 2004). Kramer et al. (1999) ont étudié la relation entre l'âge, la condition physique et la fonction neurocognitive. L'objectif était de voir si une plus grande condition physique aérobie des adultes serait capable d'engendrer des améliorations sélectives en matière de processus de contrôle exécutif, tels que le planification, l'organisation, l'inhibition et la mémoire de travail. Au cours de six mois, 124 adultes sédentaires âgés de 60 à 75 ans, qui ont été assignés au hasard au groupe d'entraînement cardiovasculaire (marche) ou à un groupe contrôle anaérobie (stretched and toning) ont été étudiés. Chaque participant a bénéficié d'un test cardiorespiratoire, la consommation d'oxygène a été mesurée, et une variété de tâches cognitives, y compris la sélection de tâches, la compatibilité de la réponse, la compatibilité des fonctions et le stop étaient utilisés. Les trois mesures étaient dépendantes des processus de contrôle exécutif et la perméabilité du cortex préfrontal et frontal était sensible à l'intervention d'entraînement. Les outils utilisés étaient les fonctions motrices, le Test de Tapping des doigts (Reitan, 1970) et le Test de Tapping de la coordination des mains (Luria, 1966). Le groupe d'entraînement cardiovasculaire a montré des améliorations substantielles en performance sur les tâches exigeant un contrôle exécutif comparées au groupe entraîné anaérobie. Cependant, l'effet bénéfique de l'exercice cardiovasculaire n'a pas affecté les performances sur les autres mesures ou les tâches qui n'étaient pas liées aux fonctions exécutives frontales. Stanley et Arthur (2003) ont conduit une étude méta-analytique pour examiner l'hypothèse que l'entraînement cardiovasculaire améliore la vitalité cognitive des adultes sédentaires âgés. Dix-huit études d'exploration publiées entre 1966 et 2001 ont été intégrées dans l'analyse. Plusieurs résultats théoriquement et pratiquement importants ont été obtenus. Le plus important, l'entraînement cardiovasculaire a été trouvé d'avoir des effets bénéfiques robustes et sélectifs pour la cognition, avec les plus grands bénéfices d'entraînement cardiovasculaire se produisant pour les processus de contrôle exécutif. L'entraînement physique ait eu un effet positif sur la fonction cognitive des adultes âgés. Deuxièmement, bien que les effets d'entraînement aient été observés sur une grande variété de tâches et de processus cognitifs, l'effet était le plus important pour les tâches impliquant des processus de contrôle exécutif (i.e. planification, organisation, mémoire de travail, contrôle de l'interférence, coordination des tâches). L'entraînement physique
programs also had a larger impact on cognition if the study samples included more than 50% females. Additionally, participants in the mid-old category seemed to benefit most from the exercise. Both clinical and non clinical population showed similar improvements with exercise, suggesting that exercise intervention can be equally efficacious for clinical and non clinical population. Meta analysis revealed that several other moderator variables influenced the relationships between exercise training and cognition. For example, aerobic exercise training combined with strength and flexibility regimens had a greater positive effect on cognition than aerobic exercise components alone. The magnitude of fitness effects on cognition was also moderated by a number of programmatic and methodological factors, including the length of the fitness-training intervention, the type of the intervention, the duration of training sessions, and the gender of the study participants. The results discussed in terms of recent neuroscientific and psychological data indicated that cognitive and neural plasticity gets maintained throughout the life span.

Yaffe, Barnes, Nevitt, Lui and Covinsky (2001) reported a study of 5925 high functioning community dwelling women (above 65 yrs of age) who were characterized in terms of number of blocks that they walked per week. Women with greater physical activity levels at baseline were less likely to experience cognitive decline as assessed with the mini mental status exam during 6-8 yrs follow up. This effect remained even after adjusting for age, education, health status, depression, stroke, diabetes, hypertension, smoking and estrogen use. A study by Barnes, Yaffe, Satariano and Tager (2003) with 349 participants of 55 yrs of age and older, also found that fitness level at baseline predicted higher levels of cognitive performance 6 years later. This study was noteworthy as it used both the measures of aerobic fitness and self report measures of 22 different physical activities and also assessed a wide variety of cognitive processes. Higher levels of aerobic fitness at baseline predicted better performance on a number of different measures of attention and executive function. Richards, Hardy and Wadsworth (2003) found that self reported physical activity level at 36 years of age was predictive of higher levels of verbal memory, in a sample of 1919 participants, from 43 to 53 years of age. Spare time activities such as game playing, attending religious services or playing a musical instrument were not predictive of memory performance.

Hillman and Buck (2004) conducted study to determine the influence of physical activity participation on the underlying electrocortical processes involved in executive control during older adulthood. The low, moderate and high physically active older adults were compared with a younger adult control group on Ericson Flankers task, which required
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Participants to focus and respond to a centrally located target stimulus while ignoring flanking distracters. This component of executive control represents the ability to successfully cope with interference from task irrelevant information. The P3 component of an ERP was measured along with reaction time and response accuracy to better understand the relationship between underlying electrocortical activity and performance based on age and physical activity history. Compared to younger adults, high and moderate active older adults’ exhibited increased ERP component P3 amplitude for the incompatible condition at the frontal electrode site. Results suggested that physical activity may improve executive control function in older adults by affecting the distribution of P3 amplitude, which has been related to memory and attentional processing and by decreasing P3 latency, which relates to the speed of cognitive processing.

Unfortunately, there have been far fewer studies involving young people and studies involving children is a recent phenomena. However, one study (Kubota et al., 2001), reported at the 2001 Society for Neuroscience conference, found that, following a 12 week regimen of jogging for 30 minutes two to three times a week, young adults significantly improved their performance on a number of cognitive tests. The scores fell again if participants stopped their running routine. In this particular case, it does not seem that level of fitness is the primary cause - otherwise, one would expect test performance not to be so quickly affected by the cessation of physical activity. The researchers suggested that increased oxygen flow to the brain might have been behind the improvement in mental sharpness. Oxygen intake did rise with the joggers’ test scores. Supplemental oxygen administration has been found to significantly improve memory formation in healthy young adults, as well as improving reaction time (Scholey, Moss, Neave & Wesnes, 1999).

Hillman, Castelli and Buck (2005) investigated the relationship between age, aerobic fitness and cognitive function by comparing high- and low-fit preadolescent children and adults. Twenty-four children (mean age = 9.6 yrs) and 27 adults (mean age = 19.3 yrs) were grouped according to their fitness (high, low) such that four approximately equal groups were compared. Fitness was assessed using the Fitnessgram test, and cognitive function was measured by neuroelectric and behavioral responses to a stimulus discrimination task. The findings suggested that fitness was positively associated with neuroelectric indices of attention and working memory, and response speed in children. Fitness was also associated with cognitive processing speed, but these findings were not age-specific. These data indicate that fitness may be related to better cognitive functioning in preadolescents and have
implications for increasing cognitive health in children and adults. A study was conducted to examine whether a relationship exists between physical activity and working memory in young adults (Lambourne, 2006). The physical fitness level of 42 male and female participants was assessed. The participants also completed a task from Daneman and Carpenter’s (1980) reading span task. The task required the participants to read a series of sentences and then recall the last word of each sentence. This task, designed to assess the reading span, is widely used as a measure of working memory capacity (Daneman & Merikle, 1996). The finding supported the hypothesis that exercise is related to an effortful processing task that measure working memory capacity in younger adults. The working memory capacity of individuals who fit recommended exercise requirements differed from those who did not. Working memory capacity did not differ with regard to gender or academic department from which the participants were recruited.

Although number of studies have been conducted on effects of fitness on mental function, unfortunately the results have been somewhat mixed. Some researchers have found improvements in various aspects of perception, cognition and motor processes, with improvements in aerobic fitness (Dustman et al., 1984, Hawkins, Kramer & Capaldi, 1992., Rikli & Edwards, 1991). Others have failed to find any improvement in cognition with improvements in aerobic fitness (Bluementhal et al., 1991, Hill, Storandt & Malley, 1993).

A study by Colcombe et al (2006) examined whether aerobic fitness training of older humans can increase brain volume in regions associated with age-related decline in both brain structure and cognition. Fifty-nine healthy but sedentary community-dwelling volunteers, aged 60–79 years, participated in the 6-month randomized clinical trial. Half of the older adults served in the aerobic training group, the other half of the older adults participated in the toning and stretching control group. Twenty young adults served as controls for the magnetic resonance imaging (MRI), and did not participate in the exercise intervention. High spatial resolution estimates of gray and white matter volume, derived from 3D spoiled gradient recalled acquisition MRI images, were collected before and after the 6-month fitness intervention. Estimates of maximal oxygen uptake (VO2) were also obtained. Results showed significant increases in brain volume, in both gray and white matter regions, as a function of fitness training for the older adults who participated in the aerobic fitness training but not for the older adults who participated in the stretching and toning (nonaerobic) control group. As predicted, no significant changes in either gray or white matter volume were detected for our younger participants. These results suggested that cardiovascular fitness is associated with the sparing of brain tissue in aging humans. Furthermore, these results also
suggest a strong biological basis for the role of aerobic fitness in maintaining and enhancing central nervous system health and cognitive functioning in older adults.

Preliminary results from a series of studies undertaken with elementary school children do indicate a strong relationship between academic achievement and fitness scores. One study found that physically fit children identified visual stimuli faster. Brain activation patterns provided evidence that the fit children allocated more cognitive resources towards the task, as well as processing information faster. A meta-analysis by Sibley and Etnier (2003) determined a positive relation between physical activity and cognitive performance in school-age children (aged 4–18 years) in eight measurement categories (perceptual skills, intelligence quotient, achievement, verbal tests, arithmetic tests, memory, developmental level/academic readiness and other). A beneficial relationship was found for all categories, with the exception of memory, which was unrelated to physical activity behaviour, and for all age groups (although it was stronger for children in the age ranges of 4–7 and 11–13 years, compared with the age ranges of 8–10 and 14–18 years). The effect size (ES) observed in their meta-analysis was similar to that which was observed in a meta-analysis of the effects of physical activity on cognition across the lifespan (6–90 years) (Etnier et al., 1997). These findings suggest that although physical activity might be beneficial at all stages of life, early intervention might be important for the improvement and/or maintenance of cognitive health and function throughout the adult lifespan.

A more recent study by Davis et al. (2007) provides further evidence that EF is sensitive to aerobic training. Overweight children (P 85th percentile BMI, aged 7–11) completed an aerobic exercise intervention involving group aerobic games (running games, modified basketball and soccer). Children were randomly assigned to one of three treatment conditions: no exercise control, 20-min exercise dose or 40-min exercise dose. Children in the 20-min and 40-min groups spent an equivalent time in the research facilities and received equal attention. Cognitive functioning was assessed via the Cognitive Assessment System (CAS; Naglieri & Das, 1997). As predicted, the aerobic training only had an effect on tasks requiring EF. Moreover, the aerobic training had a marginal positive effect on mathematics achievement. These cognitive gains were complemented by increased PFC activation, but decreased parietal activation, in a sub-sample of the children using an fMRI anti-saccade paradigm (Davis et al., in press). For both the behavioral and fMRI data, comparisons were made to control children who received no attention or intervention of any kind. Thus, these findings indicate that participation in aerobic training influences EF and the underlying neural networks, but it does not rule out that other forms of exercise also may influence EF.
One interesting experimental design, more often used in acute exercise studies, is to examine differences in cognitive functioning upon completing different types of exercise. In one such study (Budde et al., 2008); adolescents (aged 13–16) were randomly assigned to either a 10-min bout of a challenging bimanual coordinative exercise or to a 10-min bout of non-coordinative exercise. Heart rate monitoring ensured that both exercise conditions were of moderate aerobic intensity; however, the challenging exercise involved a series of skilled bimanual coordination tasks whereas the simpler exercise involved only repetitive motor movement. Both task accuracy and completion time on a selective attention task (selectively attend to the letter “d” while actively ignoring the orthographically similar letter “p”) were better for adolescents assigned to the challenging exercise than for adolescents assigned to the simpler exercise. According to the authors, the complex coordination exercise likely required “frontal-dependent cognitive processes” (EF), which enhanced prefrontal neural functioning. The simpler, repetitive exercise ostensibly did not rely on frontal circuitry. A second study (Pesce et al., 2009) also compared two forms of aerobic exercise of equivalent aerobic intensity: During one session preadolescent children (aged 11–12) completed 1 hour of individual circuit training and during another session completed 1 hour of aerobic group games. Unlike other studies, the children’s motor activity was categorized in order to provide information about the social and cognitive interactions for each form of exercise, circuit training contained more opportunities to learn motor skills, and group games provided more opportunities to apply those motor skills in a competitive and strategic manner. Also, the circuit training consisted solely of individual activity, and the group games consisted roughly of equal parts individual activity and group activity. After each session, children completed a list-learning procedure to assess both immediate and delayed word recall. Important to the current focus on EF, the conscious recollection of items, as is required in a word recall task, is thought to rely on PFC-mediated cognitive processes, such as strategic and effortful searches (Della Rocchetta & Milner, 1993; Moscovitch & Winocur, 2002). For immediate word recall, only the acute bout of group aerobic games enhanced memory relative to baseline memory performance. For delayed recall, both forms of exercise benefited memory performance. The group games condition induced a more specific cognitive activation that further enhanced immediate recall. Together, these two findings raise the possibility that the degree to which the exercise requires complex, controlled, and adaptive cognition and movement may determine its impact on EF. Coordinative exercises require substantial top-down cognitive control and the ability to override automatic behavior (Diamond, 2000, 2009); aerobic group games (Pesce et al. 2009) require cooperation with other children,
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strategic behavior, coordination of complex bodily movements, and adaptation to continually changing task demands. Repetitive aerobic exercises, on the other hand, require less cognitive engagement, particularly of EF, since there is little need to guide cognition to accomplish a challenging goal or coordinate the body to execute complex movements. These differences in EF demands may lead complex exercise to have a stronger effect on EF than simpler exercise. Other recent experimental research has compared simple repetitive aerobic exercise (e.g., treadmill walking) to periods of rest. If complex forms of aerobic exercise facilitate EF more so than simpler forms, then differences in EF performance following simple exercise and periods of rest should be smaller. Tomporowski, Davis, Lambourne, Gregoski & Tkacz, (2008) provide evidence consistent with this idea by showing that acute treadmill walking had no effect on shifting, a core EF component, in overweight children (aged 7–11). Using a within-subjects design, children completed the shifting task after a 23-min, moderate intensity treadmill walk and after watching a video of equivalent length. No improvements were found in shifting performance after walking relative to performance after watching the video. Similarly, Stroth et al. (2009) found that 20 min of stationary bicycling at moderate intensity, relative to watching a video for an equivalent time period, did not facilitate adolescents’ (aged 13–15) performance on a modified go/no-go version of the flanker task that taps several aspects of EF, including selective attention, inhibition of certain responses, and the maintenance of rules in working memory. On the other hand, Hillman et al. (2009) found that acute treadmill walking did have an effect on children’s EF. Also using a within-subjects design, children (mean age = 9.6) completed an inhibition task both after 20 min of treadmill walking at moderate intensity and after 20 min of resting with no intervening activity. The Eriksen flanker task (Eriksen & Eriksen, 1974) assessed inhibition. Importantly, acute walking only facilitated response accuracy on incongruent trials, which require inhibition, suggesting a selective effect on inhibitory processes and not a more global effect on perceptual or response processes. The acute walking also had a beneficial effect on children’s reading comprehension skills. These behavioral findings were corroborated by neuroelectric data via EEG assessment. Specifically, increases in P3 amplitude located in fronto-central, central, and parietal regions were observed following exercise, indicating greater allocation of attentional resources to the stimulus. Furthermore, Ellemberg and Louis-Deschênes (2010) found that stationary cycling for 40 min at a moderate intensity while watching an age-appropriate television show enhanced response time, but not accuracy, on simple and choice reaction time tasks. The researchers used a tightly controlled between-subjects design, comparing healthy 7- and 10-year-old boys, exercised children to children
who sat motionless on the stationary bike while watching the same television show. Although reaction time was significantly faster following exercise on both tasks, the enhancement was greater for the choice reaction time task. According to the researchers, the choice reaction time task taps EF processes such as flexibility and inhibition, and the results support EF’s sensitivity to acute aerobic exercise. Thus, aerobic exercise appears to enhance EF, and it may be that exercises requiring greater cognitive engagement have a stronger effect on EF than simpler exercises, requiring limited cognitive engagement. Comparisons across studies are difficult, may also explain the inconsistent findings. It may be likely that, EF may be more sensitive to aerobic exercise at one developmental time point than at another, and one EF component may be more sensitive to acute aerobic exercise than another. During late childhood, inhibition (Hillman et al., 2009) may be more sensitive than shifting (Tomporowski et al., 2008) to the effects of acute exercise, but during adolescence, it may no longer be as sensitive to those effects (Stroth et al., 2009). To date, few studies have taken the developmental approach of considering moderation by age. A study conducted by Caterino and Polak (1999), found that an acute bout of stretching and aerobic walking, relative to a grade-appropriate classroom activity, facilitated selective attention, in 4th graders but not in 2nd or 3rd graders. It is possible that variations in hormone levels could moderate the influence of aerobic exercise on cognition. It is important to remember that, there are several differences among these studies, some are conducted applied studies, in which children were tested in groups in a school setting, others are clinical studies, in which children were tested individually in a tightly-controlled laboratory setting. Also, there are numerous confounds that exist in applied studies (e.g., social interaction, time of testing, variation in the precise activity of each child) that are minimized in laboratory-based, clinical studies, which require researchers to be cautious in comparing clinical and applied studies. That being stated, even slight differences in both the exercise and control conditions among the clinical studies may account for differences in the results. For example, by having children watch an age-appropriate video while exercising; Ellemberg and Louis-Deschênes (2010) may have provided a more cognitively-engaging exercise condition than the other studies, which in turn, may have influenced the results. With regard to the control condition, Tomporowski et al. (2008) and Stroth et al. (2009) had children watch a video while resting whereas Hillman et al. (2009) did not provide any sort of activity during the rest period. Although these procedural differences may seem trivial, they may actually be important. Whether exercise was determined to have a positive effect on EF or not was relative to the impact of the control condition on EF, rather than on some absolute change in EF performance. It is
possible that a video would engage children more so than the no-activity rest condition, and this engagement could facilitate EF performance and reduce the relative impact of walking on EF. Thus, what the exercise condition is compared to needs to be carefully considered. The study by Ellemberg and Louis-Deschênes (2010) provides an example of how to control for subtle differences that often exist between exercise and control conditions. In summary, these experimental studies suggest that single bouts of aerobic exercise may transiently facilitate children’s EF and also that chronic participation in aerobic exercise may induce more enduring improvements to EF. Additionally, the amount of EF engagement during the exercise appears to be an important factor, at least for acute aerobic exercise. Whether this engagement is an important factor for chronic exercise remains to be tested. To date, most experimental studies have used acute exercise bouts, likely due to the greater cost and participant attrition associated with long-term interventions.

Several lines of research outline the potential role of movement in cognitive development starting in infancy. Robertson and Johnson (2009) examined the second-by-second coupling of movement and visual attention engagement and disengagement in young infants. This research suggests that physical activity may aid in unlocking infant’s sustained attention, allowing for attention to shift to another stimulus. The integration of movement and attention that occurs over the first few months of life may be significant to later attention and cognitive development. In a longitudinal study, Friedman, Watamura and Robertson (2005) found that variation in movement–attention coupling in early infancy significantly correlated with parent reports of hyperactivity and inattention 8 years later. Given that childhood inattention problems (i.e., ADHD) have been linked to executive dysfunction (Barkley, 1997) and that individual differences in attention during infancy predict later EF abilities (Sethi, Mischel, Aber, Shoda & Rodriguez, 2000), early movement–attention coupling such that motor activity is suppressed during sustained attention likely is a critical foundation to later EF development.

Motor activity continues to be important to higher-order cognitive development during the preschool years. Campbell, Eaton and McKeen (2002) examined whether variation in motor activity in preschool children (aged 4–6) predicted variation in behavioral control. It was found that higher levels of movement predicted higher inhibition performance but not non-inhibition performance i.e., control trial performance. High activity in preschoolers represents functional, exploratory activity rather than a lack of behavioral control. Similar to the arguments of Adolph (2006, 2008), movement may require constant shifts in attention
and motor response (i.e., cognitive flexibility) that “may stimulate prefrontal lobe functioning and enhance young children’s inhibitory ability”.

Angevaren et al. (2007) investigated the association between the time spent on physical activity as well as the average intensity of these activities and cognitive function. 1927 healthy men and women aged 45-70 years in the Netherlands, were examined from 1995 until 2000. Physical activity was assessed with an extensive questionnaire and cognitive function by a neuropsychological test battery. Results showed that intensity of weekly physical activities was significantly positively associated with processing speed, memory, mental flexibility and overall cognitive function. No significant associations were observed between the time spent weekly on physical activities and the various cognitive domains. At the same time, variation in activities was significantly positively associated with speed, memory, mental flexibility and overall cognitive function.

Research suggests that acute exercise positively impacts some of the same mechanisms that have been implicated in Attention Deficit Hyperactivity Disorder (ADHD), a leading childhood psychiatric disorder, suggesting that exercise might serve as an effective adjuvant therapy (Gapin & Etnier, 2008). One common mechanism is brain derived neurotrophic factor (BDNF). Stimulant medications increase BDNF and there are significant correlation between genetic variations in BDNF and vulnerability to ADHD. In animals, exercise is linked to increased BDNF and is associated with improved performance on cognitive tasks. Recent human studies show significant increase in BDNF following acute bouts of exercise. A second common is catecholamines. ADHD is associated with decreased levels of catecholamines, specifically dopamine, that impact working memory, arousal and attention. Exercise is widely known to stimulate the noradrenergic system, which influences catecholamine function. Evidence from animal models shows that acute exercise benefits dopamine release and turnover. An additional commonality is related to executive function. ADHD is characterized by deficits in executive function as compared to control participants. Research with older adults and children without ADHD shows that exercise selectively improves performance on executive function tasks, thus exercise can be a simple, widely available and well tolerated intervention for ADHD.

A randomized controlled trial testing the effects of a single bout of aerobic exercise on executive function was conducted on ADHD children by Labban, Gapin and Etnier (2009). Cognitive measures, taken before and after the treatment, were WISC-IV Digit Span (DS) was used to measure working memory, Tower of London (TOL) for planning and organization, and Children’s Color Trail Test (CCTT) 1 and 2 for processing speed. The
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exercise group completed 20 minutes of moderate exercise, whereas the control group watched a DVD for 20 minutes. Results for DS showed a positive effect for exercisers over controls, exercisers performed better on the CCTT 2 and completed TOL in fewer moves than controls. The results were promising and initial analysis suggested that moderate bout of aerobic exercise improves executive function in ADHD children.

Smith et al. (2009) conducted a study to determine whether physical activity intervention improves ADHD symptoms in 17 young children. These children belonged to diverse, low SES community and they were provided 8 week, 26 mins of continuous moderate to vigorous physical activity in small group setting before each school day. Both, pre and post program measures of motor, social and behavioural functioning, weekly ecological measures of response inhibition and daily coding of negative behaviour was done. Significant or marginally significant effects were obtained on half of the measures, with response inhibition effects most consistent. The post program ratings provided by parents, teachers and program staff indicated that 69%, 64% and 71% of children respectively, showed overall improvement. Although preliminary, the finds were found to be promising.

Chang and Etnier (2008) conducted a randomized controlled design to examine the effect of an acute bout of localized resistance exercise on cognitive performance in healthy middle aged adults. 41 adults were randomly assigned to either resistance exercise or control condition. The Stroop Test and the Trail Making Test (TMT) were completed at baseline, immediately followed by performance of the treatment. Results indicated that resistance exercise significantly benefited speed of processing (Stroop Word and Stroop Color) and that there is a trend toward resistance exercise benefiting performance on an executive function task (Stroop Color-Word) that requires shifting of habitual response. The results for TMT were not significant, which demonstrated that acute inhibition has limited effect on inhibition. Thus, the findings extend the literature by indicating that an acute bout of resistance exercise has a positive impact on automatic cognitive processes and on particular type of executive function in middle aged adults.

Etnier, Chang, Gappin and Labban (2008) conducted a meta-analysis of the literature to estimate the magnitude of the effect size (ES) of acute exercise on cognitive performance and to allow for an exploration of potential moderators of the effect. Studies were coded and ES’s (corrected for sample size) were calculated for 209 effects from 23 studies randomly selected from literature. The overall average ES suggested that acute exercise has a significant small positive effect on cognitive performance. ES’s differed significantly as a function of the type of cognitive performance task with moderate effects observed for
term intervention studies provided evidence for the effectiveness of physical activity on executive functioning. The majority of long and short term interventions improved executive functioning. However, long-term interventions seemed to have effects on all types of executive functions while the effects of short-term interventions differed across the executive functions.

Liu-Ambrose, Nagamatsu, Hsu and Bolandzadeh (2012) found that exercise prescription is an effective intervention strategy for preventing falls. It is widely believed that exercise reduce falls due to improved physiological function. But, according to the authors improved cognitive function, specifically, executive functions and associated functional plasticity may be an important yet underappreciated mechanism by which the exercise reduces falls in older adults. A systematic review of the physical and cognitive effects of physically based interactive computer games (ICGs) in older adults (>65 years) was conducted by Bleakley et al. (2013). Physical or cognitive outcomes of effects of ICGs with a physical component (aerobic, strength, balance, flexibility) and secondary outcomes including adverse effects, compliance and enjoyment were determined. Preliminary evidence indicated that ICG is a safe and effective exercise intervention for older adults. This result has to be seen with caution, as there is dearth of high-quality research in this area. No major adverse effects were reported. It is possible to improve ICG further by tailoring interventions for older adults; with the aim to optimize safety, motivation, and enjoyment for this population.

Ross and Thomas (2010) reviewed studies that compared the effects of yoga, a mind–body-based exercise, considered to be way of life, which included the practice of specific postures, regulated breathing, meditation and aerobic exercise. It was concluded that yoga may be as effective, or better than, aerobic exercise at improving a variety of health-related outcome measures, in both healthy and diseased populations. Yoga involves an active attentional or mindfulness component but its potential benefits have not been thoroughly explored. There has been tremendous increase in interest related to the health benefits of practice of yoga, but the research focusing on the relationship between yoga practice and cognition is limited. In a study conducted by Sarang and Telles (2007) performance on a 6-letter cancellation task in males (age 18–48 years) immediately before and after 2 yoga-based relaxation techniques and a control session of equal duration was evaluated. The relaxation methods were cyclic meditation and supine rest and it was found that the net scores of the participants practicing these methods were significantly higher after both practices. Telles, Raghuraj, Arankalle & Naveen (2008) also used a 6-letter cancellation task. They also
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Executive function and crystallized intelligence, small effects for information processing and negligible effects for reaction time. ES’s also differed significantly as a function of the exercise intensity level, with larger ESs evident for light, moderated and hard exercise and negligible ESs for very light and maximal exercise. Time of test administration also impacted ES, with smaller ESs found during exercise than immediately post exercise.

Labban and Etnier (2008) examined the effect of moderate bout of acute aerobic exercise on Long Term Memory and to determine if the effect is influenced by the order in which the exercise is introduced relative to the consolidation phase of the memory task. 48 adults were randomly assigned to one of the three conditions: exercise-rest, rest exercise and rest-rest. Long Term Memory was assessed using the Standard New York University Paragraphs. Results indicated that there were significant differences in delayed recall performance between groups, F (2,45) = 4.37, p< .05. Post hoc analyses indicated that the exercise-rest group performed significantly better than either the control group or the rest-exercise group which were not significantly different from one another. Thus, the results indicated that Long Term Memory may be positively influenced by bout of acute aerobic exercise and may be moderated by the order in which the exercise is introduced.

Smiley-Oyen, Panteleimon and Kristin (2008) studied the exercise, fitness and neurocognitive function in older adults. They used randomized clinical trial to investigate the hypotheses that (a) the effects of exercise training on the performance of neurocognitive tasks in older adults is selective, influencing mainly tasks with a substantial executive control component, and (b) that performance in neurocognitive tasks is related to cardiorespiratory fitness. 57 older adults participated in aerobic or strength-and-flexibility exercise training for 10 months. Neurocognitive tasks were selected to reflect a range from little (e.g. simple reaction time) to substantial (i.e., Stroop Word-Color conflict) executive control. Results indicated that tasks requiring little executive control was unaffected by participating in aerobic exercise. Improvements in Stroop Word-Color task performance were found only for aerobic exercise group. Cardiorespiratory fitness and changes in fitness were generally unrelated to neurocognitive functions. Thus, it was concluded that aerobic exercise in older adults can have beneficial effect on the performance of speeded tasks that rely heavily on executive control. Improvements in aerobic fitness do not appear to be a prerequisite for this beneficial effect.

Voelcker-Rehage, Godde and Staudinger (2008) analysed the relationship between older adults’ motor status and their cognitive performance using behavioural tests and functional MRI. Results revealed a significant correlation between motor and cognitive
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performance. Participants with higher motor index showed better performance in flanker task. Motor balance, fine coordination and speed showed the highest association with flanker performance. Motor tasks involving visual system, eye hand coordination and speed were related to flanker performance, whereas motor tasks involving strength and flexibility were not. For fMRI data analysis, the group was split into participants with low and high motor index respectively. During the flanker task, low fit participants with rather good cognitive performance showed wide spread activation patterns indicating compensation processes, whereas high fit older adults had more focused activations, suggesting that a higher motor status might also lead to improved cognitive performance, decision and inhibition processes seem to be more active.

The short term effects of acute exercise on two aspects of cognitive functions in healthy adults were studied by Blum, Bruce and Garner (2008). Twenty participants were given the Color-Word Interference (CWI) and Verbal Fluency (VF) scales of the Delin-Kaplin Executive Function System before and after twenty minutes of walking (exercise group) or reading (control group). Three significant univariate interactions (VF category, CWI Naming, Color-Word reading) favoured exercisers.

Across last 15 years, a new, strength-based conception of adolescent development has emerged to counter the traditional deficit conception of adolescence as a period of universal and biologically inevitable storm and stress (Lerner, 2009). Derived from developmental systems, this model emphasizes the plasticity of changes possible across the life span. Through mutually beneficial relations between individuals and their contexts, plasticity may be capitalized on to enhance thriving among youth. Development promoting resources (developmental assets) in the ecology of youth and the strengths (individual developmental assets) aligned positive youth development and youth contributions to and context occur. A 4-H study of positive youth development- a large national longitudinal study in the U.S. is documenting the role of variety of factors, including sports programs in the positive youth development. Researchers wanted to look at how positive influences in the lives of youth help protect them from getting involved in "problem behaviors", such as substance abuse, unsafe sex, school underachievement and failure, and delinquency and violence. The purpose of the research was to identify characteristics that are related to positive youth development. Among other factors, role of sports programs was found to be important in promoting thriving among diverse youths.

Gapin and Etnier (2009) studied whether physical activity participation predicted development of executive function in 18 boys, diagnosed of ADHD. The children were tested
on 4 measures of EF: planning (Tower of London); working memory (Digit Span); processing speed (Color Trails Tests 1 and 2) and inhibition (Corner’s Continuous Performance Test). Physical activity was measured with the help of an accelerometer, which recorded moderate to vigorous physical activity (MVPA). A linear regression revealed that MVPA was a significant predictor of performance on Tower of London. Additionally, although non significant, correlations for 5 of other 6 EF measures with physical activity showed higher physical activity predictive of better physical performance. Marzolini, Oh, McIlroy and Brooks (2012) studied the effects of an aerobic and resistance exercise training program on cognition following stroke, hypothesizing that aerobic and resistance training would confer benefit for post stroke recovery. They studied effects of a 6-month exercise program on cognition in patients with motor impairments. There were significant improvements in overall cognitive assessment scores as well as in the subdomains of attention/concentration and visuospatial/executive function.

The effects of acute exercise on cognitive performance were examined using meta-analytic techniques by Lambourne and Tomporowski (2010). They focused exclusively on acute-exercise studies in which young adults' cognition was measured during or after single bouts of exercise using a within-subjects, repeated-measures design. The dual-task conditions of research protocols used to measure cognition during exercise (e.g., concurrent running and cognitive testing) differ theoretically from single-task protocols used to measure cognition following exercise (e.g., cognitive test only). Given these fundamental differences in attentional demands, studies that measured cognitive function during exercise were analyzed separately from those that measured cognitive function following exercise. Selection of potentially moderating variables was guided by previous narrative and quantitative reviews and by contemporary cognitive theories. First, the relation between acute exercise and cognition was expected to be dependent on the exercise intensity and duration requirements placed on participants. As described previously, researchers have employed exercise protocols designed with a priori assumptions that interventions would either facilitate or degrade cognitive test performance. Second, the time at which cognitive tests were administered was expected to influence effect size, with larger effects expected during exercise as the length of the exercise bout increased and the effects dissipating gradually following termination of exercise. The third hypothesis focused on exercise mode. Ergometer cycling and treadmill running exercise protocols have been used most frequently but relatively little distinction has been made between the two modalities. However, the attentional demands required to maintain a desired treadmill running pace might be greater
than the demands when seated on a cycle ergometer. As such, fewer attentional resources would be available to runners to perform cognitive tasks than cyclists under dual-task conditions. Effect sizes were predicted to be smaller during exercise in studies that utilized running protocols when compared to effect sizes obtained from studies utilizing ergometer cycling protocols. The fourth hypothesis tested the supposition that acute exercise has selective effects on cognitive test performance. Effect sizes were predicted to be larger for tasks that emphasize processing speed, decision making, and executive processing and smaller for tasks that involve memory encoding and retrieval processes. The final hypothesis addressed study-design factors. Studies with greater experimental rigor typically result in smaller effect sizes than studies with fewer controls. Thus, studies in which a resting control condition was included in the design were hypothesized to exhibit smaller effect sizes than studies that employed a pre- and post-exercise measurement design.

Analysis of studies that examined the impact of exercise on cognition during physical activity revealed several significant moderator variables. First, different results were yielded based on the point in time that participants performed cognitive tests. Averaging the effect sizes according to the time interval between exercise onset and cognitive test performance revealed that participants’ performance declined during the initial 10 min of exercise and subsequent 10 min interval. However, performance was facilitated when cognitive testing occurred after 20 min of exercise or longer. Exercise physiologists have evaluated how specific areas of the brain are involved in the initiation of physical activity and how feedback from the body determines the point at which physical activity is reduced or stopped. Participants in exercise studies were asked to pedal or run voluntarily for specified durations. It was observed that a multitude of changes begin to occur within the body as neurological signals to begin exercise were sent from the motor cortex of the brain. Within seconds, metabolic energy pathways were made available to provide peripheral and central systems with the resources required to meet the physical demand. During the initial phase of exercise, sensory feedback from numerous peripheral systems was routed through the thalamus and other diencephalon structures to striatal and prefrontal lobe circuits, which then provide top down regulation of motor commands. Many of the neural processes that adjust motor commands were found to occur without any awareness; however, other adjustments such as physical interactions with cycle ergometers or motorized treadmills; orientation with equipment used for cognitive testing; instructions or feedback from laboratory personnel, were found to require participants’ attention. The changes that occur in the brain during the initiation and maintenance of exercise have been linked to shifts in cognitive performance.
Classic and contemporary theories of attention assume that attention has a limited capacity, which can compromise cognitive performance when there is a competition for resources. Dual-task interference may provide a viable explanation for the negative effects sizes observed during the first few minutes of acute exercise. Researchers (Audiffren, 2009; Pesce, 2009) have discussed the role of dual task demands on attentional allocation during acute exercise. According to the hypofrontality hypothesis proposed by Dietrich (2003), the neural circuitry involved in the initiation, control, and maintenance of motor movements requires considerable metabolic resources. As a consequence, available resources are drawn from cortical networks that control less immediately critical behaviors, such as pre-frontal lobe networks. This neurological model proposed by Dietrich (2003) predicts declines in complex mental processing during periods of physical activity.

Some exercise protocols employed in the studies reviewed involved a relatively brief “warm up” period of 3 to 5 min, which was followed by increases in exercise demand. Participants exercised until they reached a designated level to ensure that an aerobic steady-state exercise bout could be maintained. In other studies, the physical demand increased incrementally or gradually throughout the exercise session and was maintained at levels that required participants to draw upon anaerobic energy sources. Moderator analysis revealed that participants' cognitive performance improved over pre-exercise levels when tested after 20 min of exercise. However, exercise type interacted with the type of cognitive task performed. Performance on information-processing tasks (e.g., simple, choice, and discriminant response time) improved during steady-state aerobic-type exercise but was negatively impacted during physically challenging and primarily anaerobic exercise. Improvements in information processing during steady state, dynamic whole-body exercise have been predicted by investigators (Tomporowski, 2003), who suggest that these improvements are driven by alterations in brain neurotransmitter systems. McMorris (2009) proposed a neuroendocrinological model to predict exercise conditions that would either facilitate or hinder cognitive function. With the onset of physical activity, the hypothalamus triggers the synthesis of catecholamines in the sympathetic-adrenal-system axis. As exercise increases in intensity, adrenaline and noradrenaline are released from the adrenal medulla, signaling the release of catecholamines in the brain. Norepinephrine and dopamine, in particular, are thought to influence the brain networks responsible for information processing. Moderate increases in the level of these two neuromodulators could influence pre-frontal lobe attentional systems by altering background neural noise relative to target saliency. An enhanced signal-to-noise ratio may improve stimulus encoding, decisional processes, and
response mobilization, and explain the reductions in exercisers' response times during steady-state aerobic exercise. McMorris' (2009) model also provides a viable explanation for the negative effect sizes observed when cognitive performance was measured during protocols designed to test the inverted-U hypothesis. While acute exercise leads to the increased peripheral levels of adrenaline and noradrenaline, there are also neuroendocrine responses initiated by the hypothalamic-pituitary system axis. The release of cortisol is thought to modulate arousal by limiting the synthesis of corticotrophin releasing hormone (CRH) and adrenocorticotrophin hormone (ACTH). As exercise increases in intensity or duration, cortisol production is unable to inhibit CRH and ACTH and arousal levels increase to the point that cognitive performance is compromised. Alternatively, alterations in exercise demands and the behavioral adjustments required of participants may have resulted in dual-task conditions during which exercisers' attention was allocated to the control of running or cycling rather than the performance of cognitive tasks. Partial support for the dual-task attentional allocation explanation is provided by the second significant moderating variable, exercise mode.

Pesce (2009) expresses the need to be aware of the skill level and sport experience of participants in acute exercise studies. Laboratory motorized treadmill protocols are well suited to obtain physiological data; however, they constitute rather novel experiences for even highly trained athletes. Compared to cycle ergometer riding, treadmill running requires considerably more balance and upper and lower-body coordination. While not studied directly, failure to maintain a sufficient running pace on a treadmill is probably more disruptive to runners' attention because losing balance increases the risk of falling. In contrast, cyclists can simply modify their cycling rhythm and perform the task easily. Future research may help clarify the acute exercise–cognition relation by examining the role of exercise modality and skill level of the participants.

The third significant moderator variable indicated that acute exercise influenced participants' performance on some cognitive tests more than others. As described above, performance on tests that stressed information-processing speed and response speed was dependent on exercise demand. In addition, the weighted mean of the effects for tasks that measured inspection-time speed (e.g., visual search) was positive and differed significantly from the mean of the effects for tasks that required participants to make choice responses on the basis near-threshold perceptual discrimination (e.g., line matching) and response time tasks. Neurophysiological arousal during exercise may have its greatest impact on basic
bottom-up processes and automatic processing, and have minimal or no effect on higher-level, top-down processes.

Regardless of the type of physical activity performed, participants' cognitive performance improved when tested after exercise. The findings regarding steady-state exercise confirm predictions made by several researchers that metabolic recovery occurs gradually and the heightened level of arousal during this period facilitates cognitive function (Tomporowski, 2003). Interestingly, participants' cognitive performance also improved following exercise protocols designed to induce physical fatigue. The anecdotal evidence for the debilitating effects of acute fatigue on attention and cognition and resultant decrease in performance is overwhelming; however, this phenomenon has been elusive in laboratory studies. Results from the studies that have focused on the relation between acute physical fatigue and operational performance have been inconsistent. These inconsistencies have been explained in terms of individual differences in participants' physical fitness, the intensity and/or duration of exercise, the nature of the psychological task, and the time at which the task is administered. The duration of exercise may be particularly important given that the few studies that report decrements in cognitive function have required participants to exercise for 2 hours or more and have also manipulated hydration levels. This pattern of results suggests that typical laboratory-based exercise protocols that are presumed to produce fatigue may be insufficient to simulate the physiological demands encountered in naturalistic sport and extreme human performance environments. Alternatively, several of the studies that have reported decrements in cognitive function did not meet the inclusion criteria for this analysis and their findings did not contribute to the results. It was also the case that a significant positive effect size was obtained from studies designed to test the inverted “U” hypothesis. In the majority of these studies, participants' cognitive performance was evaluated several times during a session. In a study, Bender and McGlynn (1976) varied exercise intensity in stages that placed various levels of aerobic or anaerobic cardiorespiratory demands on participants. Cognitive tests were administered following each stage of exercise with the expectation that performance would be facilitated by low-to-moderate levels of aerobic exercise and debilitated by intense aerobic exercise. Together, the results of studies conducted to assess fatigue and studies designed to assess the inverted-U hypothesis suggest that young adults may be able to maintain cognitive efficiency following relatively brief periods of physically demanding exercise. Despite researchers' longstanding interest in understanding the construct of mental fatigue a laboratory model that reliably links physical fatigue to cognitive performance has yet to be developed. Several moderators were found to be independently
related to the size of the overall effect. Exercise mode was a significant moderator, with larger effect sizes associated with ergometer cycling than with running protocols. While cycling and running are aerobic activities that utilize large muscle groups, differences in muscle recruitment patterns between these two activities invoke different aerobic and anaerobic contributions to exercise energy expenditure. Cycling requires less metabolic energy compared to running because the vertical excursion of the body's center of mass is reduced by maintaining a seated position. The cycling position allows muscles to contract in a more efficient range of movement than does running. It is thus possible that after running, sensory afferents continue to influence the integration of cortical activation and lower the signal-to-noise ratio, which results in less efficient information processing, discrimination, and detection. Support for a neural interference interpretation comes from three studies in which event-related potentials were measured to assess P3 waveforms following moderate or heavy exercise. The amplitude of the P3 wave increased and latency decreased after moderate exercise, which was indicative of improved decision-making processes. However, no changes in P3 indices were observed following heavier exercise and decreases in P3 amplitude as well as longer latencies were detected following cycling to exhaustion. Additional study of the short-term after effects of exercise on the brain will be required to determine if and why cognitive performance is affected differentially by exercise mode. Little is known, for example, of the effects of circuit- and resistance-training exercise protocols on cognitive function. The type of cognitive task performed following exercise also moderated the exercise–cognition relation. The weighted mean of effects from studies that employed tests of memory was significantly larger than the weighted mean of effects from studies that measured executive function or information-processing time. These results differ from predictions made in previous narrative reviews, which hypothesized that acute exercise would minimally affect memory encoding and retrieval processes (Tomporowski, 2003). The results of several recently conducted studies contribute to a better understanding of the exercise–cognition relation (Coles and Tomporowski, 2008; Tomporowski and Ganio, 2006). The link between acute exercise and memory storage and retrieval processes has important practical and theoretical ramifications. Traditionally, exercise-induced arousal has been viewed as a factor that temporarily influences performance. Similar to the effects of stimulant drugs, once exercise-induce changes in the central nervous system dissipate, behavior is thought to return to baseline levels. Given that acute exercise can alter memory processes, it may also impact learning, which is a relatively permanent change in behavior. The link between acute exercise and memory processes may help explain why chronic exercise interventions, which are
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composed of a series of acute exercise bouts, favorably impact executive function and memory processes in older adults (Colcombe and Kramer, 2003) and children (Davis et al., 2007; Hillman et al., 2005). Experiences acquired over repeated bouts of physical activity may alter the manner in which individuals adapt to novel conditions that require goal directed planned behaviors (Pesce, 2009). This review revealed that the study design was a significant moderator in the regression analysis of studies that measured cognition following exercise. Similar to Etnier et al.'s meta-analysis (1997), smaller effects were observed in studies that included a control condition. Single-group designs with pre- and post- intervention measures are one of the weakest experimental designs because they do not control for extraneous factors such as practice effects and the passage of time (Campbell and Stanley, 1963). It requires extra time and resources to include a resting control condition; nevertheless, it is necessary to prevent overestimation of the effects of acute exercise on cognitive task performance. On the basis of arousal theory, it was predicted that the effect of an exercise bout on cognitive performance would decline with the lengthening of the interval between the termination of exercise and measurement of cognitive performance. The moderator analysis did not provide support for this hypothesis.

Very few researchers have designed studies that systematically investigated how cognitive performance changes either during and/or following the termination exercise. The results from the studies that have closely examined time-related changes in cognitive performance suggest that the effects of exercise may be subtle and influenced by a variety of factors. In the analyses of studies that measured cognition during exercise and studies that assessed cognitive performance following exercise, visual inspection of the effect sizes associated with different levels of descriptive variables revealed that effect sizes were similar across levels. No differences were noted among the weighted mean effects from studies using male-only samples, female-only samples, and mixed samples. However, it should be noted that females are underrepresented in this literature, particularly in studies with measures of cognition during exercise. Similarly, there were no visible differences in weighted mean effects for fitness levels that could be coded based on VO2max scores. Tests of VO2max were administered and reported in only 38% of the studies assessing cognition during exercise and 41% of the studies measuring cognition following exercise. The failure to include indices of cardiorespiratory fitness may be particularly problematic for studies designed to assess fatigue effects. A high exercise workload may not produce the same pattern of fatigue in highly cardiovascular fit individuals as compared to those with lower levels of aerobic fitness. Exercise studies that include a test of maximal aerobic capacity and
utilize an exercise intensity that is relative to each participant's maximum may help resolve the inconsistencies found within the literature. The studies selected in the present analysis were restricted to those that evaluated healthy adults between the ages of 18 and 30 and, as such, generalizations to other age groups and individuals with physical impairment or disease state are limited. The restricted criterion for selection was driven partly by the paucity of well-controlled studies conducted with middle-aged adults, and older adults. More research is needed to assess how acute exercise affects the cognitive function of middle-age and older adults who are experiencing age-related changes in physical function. Also excluded from these analyses were the small number of studies that assessed the effects of acute bouts of exercise on children’s’ and adolescents' cognitive function.

Similar to observations made by Etnier and her colleagues (Etnier et al., 1997; Chang et al., 2009; Etnier et al., 2006), this review of the literature revealed that a wide number of cognitive tests have been used to assess the acute exercise– cognition relation. The tests also vary considerably in their psychometric properties and reliability. As a result, it has been challenging for researchers to categorize tests according to the mental processes they purportedly measure. In summary, this quantitative synthesis of the literature supports earlier reviews, which concluded that acute bouts of exercise have an influence on cognitive function. The separate analysis of studies that measured cognitive performance during exercise and those which assessed cognition following exercise review added to the literature in this area. The picture that has emerged from recent narrative and quantitative reviews of acute exercise indicates that the exercise–cognition relation is complex. Cognitive performance may be enhanced or impaired depending on when it is measured, the type of cognitive task selected, and the type of exercise performed. During exercise, arousal appears to impact basic bottom-up mental processes and enhance performance on tasks that involve rapid decisions and automatized behaviors. Following exercise, arousal continues to facilitate speeded mental process and also enhances memory storage and retrieval. Thus, under specific conditions exercise may prime individuals to perform simple tasks rapidly and efficiently and then retain information concerning the results of those actions. This speculation must be tempered, however, as only a few exercise studies have focused on memory processes. It is particularly important that more well-designed experiments are conducted that measure encoding and retrieval processes.

The finding that learning is facilitated by individual bouts of exercise may be very helpful for researchers who strive to explain how repeated individual bouts of exercise (i.e. chronic exercise programs) alter specific cognitive processes.
A meta-analysis was conducted by Lot Verburgh, Königs, Scherder and Oosterlaan (2013) on the effect of physical exercise and executive functions in preadolescent children, adolescents and young adults. The purpose of this study was to group together available empirical studies on the effects of physical exercise on executive functions in preadolescent children (age group 6–12 years), adolescents (age group 13–17 years) and young adults (age group 18–35 years). The electronic databases PubMed, EMBASE and SPORTDiscus were searched for relevant studies, giving information about the effects of physical exercise on executive functions. In all, nineteen studies were selected. Results showed that there was a significant overall effect of acute physical exercise on executive functions. There were no significant differences between the three age groups. It was observed that acute physical exercise enhances executive functioning. The studies on chronic physical exercise are limited and it needs to be investigated whether chronic physical exercise shows effects on executive functions comparable to acute physical exercise. This meta-analytic study is highly relevant in preadolescent children and adolescents, given the importance of well-developed executive functions for daily life functioning and the current increase in sedentary lifestyle in these age groups.

It is generally found that hippocampus shrinks in late adulthood, leading to impaired memory and increased risk for dementia. Higher-fit adults show larger hippocampal and medial temporal lobe volumes and it is also observed that, physical activity training increases hippocampal perfusion, but the extent to which aerobic exercise training can modify hippocampal volume in late adulthood needs to be studied. In a randomized controlled trial conducted by Erickson et.al (2011), with 120 older adults, it was seen that aerobic exercise training increased the size of the anterior hippocampus, leading to improvements in spatial memory. The hippocampal volume was increased by 2% after exercise training, effectively reversing age-related loss in volume by 1 to 2 yrs. It was also demonstrated that increased hippocampal volume is associated with greater serum levels of BDNF, a mediator of neurogenesis in the dentate gyrus. In the control group, hippocampal volume declined, but higher pre-intervention fitness partially attenuated the decline, suggesting that fitness protects against volume loss. Caudate nucleus and thalamus volumes were unaffected by the intervention. These theoretically important findings, thus, indicates that training in aerobic exercise is effective in reversing hippocampal volume loss in late adulthood, which in turn, is accompanied by improved memory function.

In an extensive meta analysis by Barenberg, Berse and Dutke (2011), psychological, medical, and sports science databases for relevant publications: PsycInfo, MedLine,
SportDiscus, Academic Search Premier were searched and using variety of criteria, finally 23 articles based on data obtained from a total of 1045 participants aged 7–88 years were considered. All nine of the 23 studies involving long-term interventions reported significant intervention effects on behavioral measures of executive functions, except for one study finding only neuroelectrical effects (Kamijo et al., 2007). Thus, eight of the nine studies provided empirical support for the effectiveness of long-term interventions on behavioral executive measures, although the designs of the studies were quite heterogeneous. In all, 548 persons (7–88 years) participated in the nine studies. The smallest sample comprised 14 subjects (Harada, Okagawa & Kubota, 2004); the largest, 126 (Kramer et al., 2001). The studies examined overweight children (Davis et al., 2007); healthy adults (Harada, Okagawa & Kubota, 2004; Masley, Roetzheim & Gualtieri, 2009); older adults, including two pathological samples (Khatri et al., 2001; Tanaka et al., 2009). Intervention effects were found for all target populations. Thus, although older adults evidently remain a main focus of physical activity research, three studies began to broaden the data basis by studying children and healthy adults. The studies employed walking or walking/cycling programs (Khatri et al., 2001), some kind of multicomponent exercise program (Masley, Roetzheim & Gualtieri 2009), and an aquatic training program (Hawkins, Kramer & Capaldi, 1992). The intensity, in terms of frequency, varied from two to more than five training sessions per week and the duration of intervention programs ranged from 10 to 40 weeks. However, within two studies, a high-dosed intervention group outperformed a low-dosed group (Davis et al., 2007; Masley et al., 2009). Another aspect of interest was the variation in the assessment of executive functions. Some studies applied only one measure of executive functioning (Tanaka et al., 2009), whereas others applied several measures (Kramer et al., 2001); including reaction time (Stroop), correctness of responses or complex scores (Wisconsin Card Sorting Test), shifting tasks, inhibition tasks, and dual task coordination. Intervention effects were found for all types of executive function. In conclusion, there is accumulating support from empirical data for the effectiveness of long-term physical activity interventions on executive functions, and first studies have begun to broaden the data basis beyond older adults. As these studies showed higher executive performance after more intense activity, it may be speculated that a certain intensity level is needed to alter executive functioning. No specific pattern of influence was found with regard to task requirements. However, the mixed results for tasks with complex requirements indicated that the more complex the executive measure, the more difficult it was to find an effect of physical activity.
There were 14 studies involving short-term interventions. Here too, many studies revealed significant intervention effects on measures of executive functions (Kubesch et al., 2003), some did not (Coles & Tomporowski, 2008). This could be because sample sizes and populations varied substantially. In total, 497 persons (7–64 years) participated in the 14 studies, with the smallest sample of ten subjects (Tomporowski et al., 2005); the largest, 76 (Sibley, Etnier & Le Masurier, 2006). The studies examined depressive adults (Kubesch et al., 2003); children (Hillman et al., 2009; Stroth et al., 2009; Tomporowski et al., 2008a); and healthy adults. Some intervention effects were found for all target populations. There was repeated evidence of intervention effects in healthy adults, indicating that physical activity effects are not restricted to older adults. Moreover, two of three studies with children as participants found behavioral and neuroelectrical intervention effects, respectively (Hillman et al., 2009; Stroth et al., 2009). In terms of format, intensity, and duration, the variation between the short-term interventions was less notable than that between the long-term interventions. Ergometer cycling and treadmill running were the physical activities used. Intervention effects were found at all duration levels. The variation in the studies’ assessment of executive functions was again of interest. Ten studies applied a single measure of executive function (Audiffren, Tomporowski & Zagrodnik, 2009), whereas the remaining four applied up to four measures (Kubesch et al., 2003). Reaction time measurement as in set switching (Coles & Tomporowski, 2008) was the main focus, but several tasks such as random number generation (Audiffren et al., 2009) also measured the correctness of responses or complex scores. Intervention effects were found for all types of measurement. The effectiveness of short-term interventions appeared to depend on the type of executive function required, with the most compelling evidence being found for inhibition tasks. In a study by Pontifex et al. (2009), it was seen that participants’ reaction time on a modified Sternberg working memory task improved immediately and 30 minutes after acute aerobic exercise relative to the pre-exercise baseline. No such effects were observed after resistance exercise or seated rest.

In conclusion, there is also accumulating support from empirical data for the effectiveness of short-term physical activity interventions on executive functions, and findings from a growing number of studies, with samples of healthy adults and children indicate that physical activity effects are not restricted to older adults. In terms of variations in physical activity, the differences between studies were so marginal that no clear pattern of influence could be detected. The only study varying intensity levels did not yield conclusive results. To conclude, eight of the nine long-term intervention studies and 10 of the 14 short-
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reported improvement in cancellation scores (either total errors or net scores) after engaging in a yoga breathing technique, which was characterized by forceful exhalation and high-frequency breathing. A systematic review using 10 randomized controlled trials was conducted by Canter and Ernst (2003). They evaluated the effect of transcendental meditation on cognitive function. Large positive effects on cognitive function were reported on four trials; 4 trials provided only weak evidence for a positive effect and 2 trials showed no effect. Corresponding to the aerobic research literature, clearly mixed evidence regarding acute yoga benefits and cognitive function was seen. The primary focus of the studies on exercise and executive function has been inhibitory control. However, other critical executive processes such as working memory also need to be explored.

Gothe, Pontifex, Hillman, and McAuley (2013) conducted a study to examine the effects of an acute yoga exercise session, relative to aerobic exercise, on cognitive performance, using a repeated measures design. The sample consisted of 30 female college-aged participants (Mean age = 20.07, SD = 1.95). They completed 3 counterbalanced testing sessions: a yoga exercise session, an aerobic exercise session, and a baseline assessment. The flanker and n-back tasks were used to measure cognitive performance. Results showed that cognitive performance, measured in terms reaction times and accuracy, after the yoga exercise bout was significantly superior (i.e., shorter reaction times, increased accuracy) as compared with the aerobic and baseline conditions for both working memory and inhibition. There was no significant difference between the aerobic and baseline performance, contradicting some of the previous findings in the acute aerobic exercise and cognition literature.

In a study by Chang et al. (2014), healthy college-aged adults completed a maximal graded exercise test and on the basis of performance were categorized as low, moderate, or high in cardiovascular fitness. Participants then performed the Stroop Test prior to and after an acute bout of cycling exercise that consisted of a 5-min warm-up, 20 min of exercise at moderate intensity (65% VO$_{2\text{max}}$), and a 5-min cool-down. The beneficial relationship between performance of an acute bout of exercise and cognitive performance were observed for both cognitive task types and for participants of all fitness levels. Although, it was seen that participants of all fitness levels improved in cognitive performance following exercise, the relationship between fitness and cognitive task type performance was curvilinear, i.e., the participants who were moderately fit performed the best on the incongruent trials, implying that maintaining fitness at a moderate level is associated with better executive function.
Studies exploring the relationship between physical activity, fitness, and cognitive function vary across the lifespan in terms of both their number and the apparent strength of the associations. Studies of children are relatively few in number but generally show a positive association between physical activity and cognitive function. More studies are needed to establish a causal relationship, not merely associations, between exercise and cognitive function. These studies need to better quantify physical activity. Also, more work is needed to determine the mechanisms by which exercise alters brain function (Zoeller, 2010).

### 3.3 Explanatory Styles

People with an optimistic explanatory style fare usually better than those with a pessimistic explanatory style (Peterson & Park, 1998). Very few studies have investigated the link between explanatory style and athletic performance.

Deaux and Emswiller (1974) conducted two experiments to determine the effect of sex of subject, stated sex linkage of task, and task outcome on causal attributions of an actor's performance. Results from both studies showed that males evaluate their performance more favorably than do females, despite equivalent objective scores. It was also found that males claim greater ability than do females following task performance; and lastly, females were more prone to use luck to explain performance. The evidence also suggested that the difference between males and females in performance evaluation and self-attribute occurred most strongly in response to failure and on masculine tasks. Thus, it was clearly seen that females are less likely to attribute successful outcomes to ability than are males.

Research by White (1993) examined the causal attributions among softball players. It was found that males were more likely to attribute successful outcomes to internal factors than were females, and females were more likely to attribute winning to more controllable factors than were males. Additional data have also suggested that females may be more likely to adopt what has been referred to as a defensive pessimistic attributional style. According to this concept of defensive pessimism, individuals, even though they have experienced a history of successful outcomes, do not assume that they will experience future success. This pessimistic expectation creates anxiety. However, unlike depressive pessimists, defensive pessimists use their anxiety to motivate additional effort which leads to positive outcomes. It is suggested that the anxiety experienced by athletes who are defensive pessimists may lead to enhanced performance.

McAuley and Gross (1983) looked at the attributions made by college students enrolled in physical education skills classes. Participants in the study competed in a table tennis match against the member of the same sex and completed a Causal Dimension Scale,
following the match. Generally, research has supported a general self-serving tendency (i.e., attributing successful performance internally and failure externally) among athletes has shown that high ability players tend to make internal, stable attributions for success, whereas lower ability athletes tend to make internal attributions for failure. The results of their study showed that, winners' attributions were more internal, stable, and controllable than losers; however, both winners and losers made attributions that were internal, unstable, and controllable.

The purpose of the study by Hamilton and Jordan (2000) was to examine the causal attributions for most successful and least successful performances made by male high school track athletes in two different age categories. Participants were asked to recall the most successful and least successful performances of their track careers and then complete the revised Causal Dimension Scale, which measured the athletes' attributions along three dimensions, stability, locus of causality, and controllability. Level of performance (most successful vs. least successful) and age (freshmen vs. seniors) were the independent variables. Results indicated that participants attributed outcomes to controllable (vs. uncontrollable) factors, and this controllability was significantly greater in the "best" performance attributions. The locus of causality scores were more internal (vs. external) and were significantly more internal in the "best" performance attributions, and participants attributed outcomes to more stable (vs. unstable) factors and were significantly more stable in the "best" performance attributions. Freshmen and seniors did not significantly differ from each other in their attribution making.

Research on the relationship between the explanatory style of athletes and their athletic performance has shown that optimism is positively related to the performance of baseball players, basketball players, and collegiate swimmers (Rettew & Reivich, 1995). However, among the three studies described by Rettew and Reivich (1995) only the study involving collegiate swimmers used the ASQ to assess explanatory style (Seligman et al., 1990). The other two investigations report findings from previously unpublished research that used the Content Analysis of Verbatim (CAVE). The results for baseball and basketball teams showed that the teams with a more optimistic explanatory style won more games in the target season, and performed significantly better in games following a loss than teams with a pessimistic explanatory style. Nevertheless because the CAVE technique measures explanatory style only in an indirect way, and as it employs retrospective data, this design cannot unambiguously support a causal association between explanatory style and athletic performance.
The examination of the relationship between explanatory style and athletic performance among collegiate swimmers using ASQ demonstrated that swimmers with a pessimistic explanatory style showed a greater number of poor performances during competition than did the optimistic swimmers (Seligman et al., 1990). In addition, to provide a more direct test of explanatory style as a possible mechanism related to athletic performance, the study involved an experimental manipulation in which false feedback was provided to swimmers. Swimmers were asked to swim their best event and were subsequently informed that their times were slightly slower than they actually were. After an appropriate rest period, the swimmers swam their event again. The resulting performances revealed that pessimists swam significantly slower than their initial times, whereas optimists’ times did not vary significantly from their initial races. These data suggest that a pessimistic explanatory style may reduce motivation level after a defeat, thus lowering response initiation (Seligman et al., 1990), whereas an optimistic style should facilitate a consistent level of motivation, and thus, maintain or enhance performance.

The results from more assessments that have involved the ASQ as a measure of explanatory style have revealed inconsistent results. For example, a study by Hale (1993) that investigated the relationship between explanatory style and athletic achievement failed to find a significant relationship. However, this study did not involve any direct assessments of performance. Instead, Hale (1993) examined the relationship by comparing the ASQ scores of athletes who were classified as being elite vs. non elite (i.e., college athletes who had dropped out of varsity athletics by their junior year). Another investigation used the ASQ to examine explanatory style among ice hockey athletes (Davis & Zaichkowsky, 1998). However, in this study the outcome variable was a measure of ’mental toughness’ obtained by asking coaches, scouts, and managers to rate various players in terms of their tendency toward overachievement, enthusiasm, effort, skill, and responses to adversity. Contrary to these researchers’ hypothesis’, ice hockey players with pessimistic attributional styles received more positive evaluations on the composite measure of mental toughness. Although both of the above studies claim to have examined the relationship between explanatory style and athletic performance, they have done so, at best, indirectly.

In a cross-sectional survey with 50 young elite tennis players, Prapavessis and Carron (1988) found that players presenting cognitive, motivational, and emotional maladaptive achievement patterns (evaluated by a questionnaire) gave ratings that were internal, persistent, and recurrent for explaining failure performances, and were judged by their
coaches to be less persistent in their matches. Nevertheless the cross-sectional nature of the
design made the inference of causality difficult between the explanatory style and the
maladaptive achievement patterns.

In the study by Martin-Krumm, Sarrazinb, Petersonce & Famose (2003), the role of
two potential mediator variables: success expectation and state anxiety was investigated.
Success expectation represents the perceived chances of performing well on the task. It was
expected that individuals with a pessimistic explanatory style will perform more poorly after
a negative outcome than people with an optimistic explanatory style, because they attribute
the failure to a stable cause (such as their own lack of ability) and come to expect that
negative events will be pervasive and enduring. It was also expected that after failure,
pessimistic style leads (1) to lower expectations of success, (2) to more state anxiety
(somatic arousal) and in turn, (3) to poorer achievement in the second test than an optimistic
style, controlling for variables likely to influence motor performance such as ability, gender,
perceived competence and importance to succeed. The “neutral” explanatory style will
obtain scores of expectation, anxiety and recovery located between the two other groups.
Sixty-two participants performed a basketball dribbling trial and were given false feedback
indicating that they had failed. Consistent with prediction, in a second trial, the optimistic
participants (N=22) were less anxious (assessed by heart rate acceleration), more confident,
and performed better than pessimistic participants (N=20). The neutral explanatory style
group (N=20) obtained scores which were between the two other groups. The results showed
that explanatory style also affected two other components, one cognitive and another
affective in nature: success expectation and state anxiety. It was observed that participants
with the pessimistic style had a greater fall in success expectations after failure than the most
optimistic ones. Individuals with a pessimistic explanatory style usually explain their lack of
control over consequences with stable causes such as their own lack of ability and expect that
negative events will be pervasive and enduring in their lives (Helton, Dember, Warm &
Matthews, 2000). This attributional pattern leads to a drop in expectation of success. By
contrast, it is likely that individuals with an optimistic explanatory style usually explain
failure with more unstable and contextual causes such as the use of a bad strategy or the lack
of effort, which allows relatively consistent success expectations for the events to come. In
addition, the results showed that participants with the pessimistic style had greater stress
reactivity (assessed by an increase in heart rate before the second testing) than the ones with
the optimistic style; a result which is in keeping with certain former works showing that
pessimism correlates positively with anxiety (Mineka, Puruy & Luten, 1995; Helton et al.,
2000; Jackson, Sellers, & Peterson, 2002). To explain the lack of control over bad events with stable and general causes can increase the perceived threat and in turn the level of anxiety. By contrast, to explain failure with more unstable and contextual causes can lead to the feeling of “keeping control” of the situation and to provoke less anxiety. Neutral participants obtained scores which were between the two other groups for both performances, for success expectations and for state anxiety. In view of failure, optimistic explanatory style seems to be more adaptive than pessimistic explanatory style is, but also more adaptive than neutral explanatory style is. Optimistic explanatory style could lead to a better protection against adversity, whereas a pessimistic explanatory style could lead to intensify the failure’s consequences (i.e. more decreased self-confidence and higher anxiety level). The unique contribution of the results is the demonstration that the explanatory style effects on performance were mediated by expectancies and state anxiety.

Gordon (2008) examined the relationship between explanatory style measured with the Attributional Style Questionnaire (ASQ) and athletic performance. Attempt was made to compare performance of optimists and pessimists during a losing effort and during a winning effort. 20 male soccer players were studied and relationship between the predictor variables of attributional style and dispositional optimism and the criterion variable of athletic performance was obtained. The effect of soccer match outcome as a moderational factor was also examined. Optimistic attributional style was shown to be a strong predictor of pass completion accounting for 59% of the variability on this performance measure. A significant positive relationship was found between the ASQ measure of optimism and athletic performance among the soccer players. The optimistic soccer players demonstrated better performance during a loss than did pessimists, whereas no significant performance differences were found between these two groups during a subsequent win. In addition, the results of the significant moderational assessment suggested that optimists are likely to perform at a relatively consistent level regardless of whether a team was winning or losing a match. On the other hand, the lowered performance among the pessimistic athletes during the loss were consistent with findings from Seligman et al. (1990), who found that pessimistic soccer players expected to perform significantly worse than optimistic soccer players during a loss. It was suggested that motivation level may be significantly reduced among pessimistic athletes when their team is not leading during a match. This outcome supported Seligman’s contention that the expectation of defeat may contribute to lowered response initiation among those who manifest a depressive attributional style.
In another study by Gordon (2008), eighteen female basketball players were studied to examine the relationship between attributional style and athletic performance. Findings were less consistent, revealing both positive (optimists had more assists and steals) and negative (optimists had fewer rebounds and more fouls) relationships. Significant positive relationships were found between the composite optimism score on the ASQ and assists \( r(16) = .72, p < .002 \) and steals \( r(16) = .73, p < .001 \). However, contrary to predictions, optimists had fewer rebounds and were more likely to foul out of games than were pessimists. This latter finding may represent optimistic players’ confidence and positive expectations. Such expectations could prompt these athletes to take more chances in attempts at intercepting passes or stealing the ball, leading to the commission of more fouls. No significant relationships were found between any of the ASQ measures and points scored. Surprisingly, LOT responses revealed higher performance among pessimists. Failure to replicate the findings from earlier, above mentioned could be due to a variety of factors including differences in gender, ability level, or the specific type of pessimists who participated in the present study i.e., participants may have been defensive pessimists, who expect negative outcomes, but use the anxiety generated by their expectations to mobilize efforts to avoid such negative outcomes, thereby, employing an adaptive strategy that fosters goal attainment.

The impact of attributional style on athletic performance can be further demonstrated via research that attempted to manipulate the attributional style of an athlete in order to positively affect the athlete’s performance. A study by Miserandino (1998) involved attributional retraining for male basketball players. The treatment involved feedback that was designed to help players attribute positive outcomes to ability and negative outcomes to lack of effort as opposed to lack of ability. A significant increase in performance was found among those players who underwent the retraining treatment. Additional work in the sport of basketball (Orbach, Singer, & Murphey, 1997) and among beginning tennis players (Orbach, Singer, & Price, 1999) has revealed that it is possible to change attributions toward performance regarding both controllability and stability dimensions. Both these studies support the use of an attributional strategy where the causes for low performance are perceived as controllable and unstable.

Generally, it was seen that attributing failure to lack of effort is typically adaptive, whereas attributing failure to lack of ability is likely to be maladaptive. Attributing negative outcomes to external factors may be adaptive if such factors are likely to change, but maladaptive if such factors are perceived as stable and uncontrollable. The findings may also
be viewed as consistent with the gender differences found by White (1993) in as much as the formation of lack of effort attributions by female athletes would appear to be a strategy that allows an individual to exercise some degree of control over future outcomes. But it should be noted that the impact of attributional training programs on performance has been mixed. For example, in addition to the perceptual changes induced, Orbach, Singer, and Murphey (1997), found a significant impact on performance, whereas Orbach et al. (1999) did not.

Adopting an adaptive method of interpreting the cause of low performance is no guarantee of increased performance in the future. However, as suggested in Orbach et al. (1999), coupling an adaptive attributional strategy with specific training regarding relevant skill acquisition, is likely to lead to increased performance. Findings from a study conducted by Le Foll, Rasce and Higgins (in press) provide additional supportive evidence. They found that novice golfers who received a functional attributional treatment (i.e., attributing failure to internal, controllable, and unstable factors) demonstrated increased short-term persistence at a task; whereas persistence among golfers who received a less functional treatment decreased. On the basis of these data, future research that attempts to enhance performance via modifying dysfunctional attributional style among athletes need to be conducted.

Generally explanatory style has been studied in the context of competitive performance, no study was found on how physical activity may result in change in the explanatory style of the person.

Thus, research studies have generally shown that exercise impacts on emotional intelligence, executive functions and explanatory style. In the present study, attempt is made to study these variables in the context of traditional Indian sport, Mallakhamb.