The dualistic view of the mind and the body being distinct entities has long been abandoned in the research community. The adoption of a holistic approach has resulted in a vast quantity of research designed to define the precise relationships between the brain and the body. An aspect of research with a holistic approach is concerned with the influence of exercise of the body on the brain. Both acute exercise and chronic exercise have been examined, and researchers have examined both the direct effects and the indirect (behavioural) effects of exercise upon the brain. In examining the direct influence of exercise upon the brain, research has primarily been devoted to the influence of exercise upon cerebral blood flow (CrBF), neurotransmitter availability and neural efficiency. The indirect influence of exercise upon the brain has primarily been examined in terms of its influence upon mental health and cognitive ability.

1. Direct Relationships

Research that has examined changes in cerebral blood flow in humans during an acute bout of exercise has produced mixed results. Authors who have used the nitrogen oxide technique, and therefore have measured average blood flow through the entire brain,[1] have typically reported that cerebral blood flow remains stable during exercise.[2-4] However, authors who used the Xenon clearance technique, which allows for the determination of regional cortical blood flow,[1] have typically found that participants who exercise at moderate to high intensities show large elevations in CrBF.[1,5-7] It is likely that the discrepancy in the findings is a result of the technique which was used to measure CrBF and of the intensity of the exercise which was examined. Future study is needed to elucidate this relationship. This is of particular importance because increases in CrBF with exercise have been suggested as an explanation for the relationship between exercise and cognitive functioning.

Researchers have also examined the influence of exercise upon brain neurotransmitters. Several authors have shown that neurotransmitter levels change after an acute bout of exercise. Gordon et al.[8] and Mitchell et al.[9] found increases in noradrenaline (norepinephrine) levels after an acute bout of exercise. Ebert et al.[10] found increases in the precursors of noradrenaline as a function of exercising for 8 hours. Additionally, research with marathon runners has shown that endorphin levels increase after long periods of exercise.[11] Barchas and Freedman[12] found increases in brain serotonin levels following running for 3 hours, and Jacobs[13] has recently reported that firing rates of serotonin neurons increased when cats were in an active waking state. These findings with acute exercise are important because of the relationship between an acute bout of exercise and the 'feel good' phenomenon which has been described in the popular literature.

Studies have also shown that plasma levels of noradrenaline increase as a result of aerobic training.[14] Poehlman and Danforth[15] and Poehlman et al.[16] found that, in older adults (average age 64 and 69 years, respectively) who had trained for 8...
weeks, plasma noradrenaline levels increased by as much as 29%. In animals, studies have shown that training results in higher noradrenaline and serotonin levels in the brain. These findings with chronic exercise are especially important because the neurotransmitters mentioned (noradrenalin, adrenalin and serotonin) are thought to be associated with memory storage and retrieval and also with mood state.

Results from the animal studies suggest that chronic exercise may also result in permanent structural changes in the brain. In these studies, rats were placed in 1 of 4 conditions: an acrobatic condition, a forced exercise condition, a voluntary exercise condition and a nonexercising control condition. Results from the study by Black et al. showed that rats who were exposed to either of the exercise conditions had an increase in vasculature density in the cerebellar cortex as compared with control rats and with rats who had performed acrobatic exercise. Results from the study by Isaacs et al. showed that rats in the exercise group had shorter vascular diffusion distances than did rats in either the acrobatic exercise group or the control group. The results of both studies showed that the acrobatic rats had an increase in the number of synapses per Purkinje cell. The authors concluded that physical exercise improves vascularisation in the cerebellar cortex while a combination of motor learning with physical activity results in a greater communication network in the brain.

Electroencephalographic (EEG) techniques have also been used to examine the influence of exercise upon neural firing patterns. Dustman et al. measured EEG in 4 groups of participants who were categorised based upon age and maximal oxygen uptake (VO2max). Their results showed that the resting EEGs of the young men and of the older, fit men (average ages 25.2 and 53.8 years, respectively) had significantly more slow α-activity (8 to 10 Hz) than did the resting EEGs of the older, unfit men (average age 55.9 years). Additionally, cortical coupling, which is thought to represent 'functional autonomy' of areas within the brain, was found to be greater in older, unfit men than in any other group. This suggests that fitness in elderly populations may result in a maintenance of functional autonomy. Campbell et al. measured EEG prior to and after a 10-week exercise programme. Their results showed that the exercise programme resulted in increased central nervous system (CNS) inhibitory abilities in 21 of the 22 participants who had initially had poor CNS inhibitory abilities.

Dustman et al. examined brain activity of older people who were classified as high-fit or low-fit. Results of the study showed that the P300 event-related potential latency (a measure of information processing) was longer for the older low-fit subjects than it was for the older high-fit subjects. Bashore measured reaction time and P300 latency in older men who were categorised as exercisers or as nonexercisers. Results showed that the exercisers had faster reaction times and shorter P300 latencies than did the nonexercisers. Thus, research suggests that fitness enhances neural efficiency and maintains functional autonomy and that this is especially true with older adults.

The direct research, which has examined the relationship between exercise and the brain, has shown that exercise can have a significant effect on CrBF, neurotransmitter availability, brain structure and on neural efficiency. Researchers have also devoted a great deal of effort to determining the indirect relationship between exercise and the brain; that is, to looking at the influence of exercise upon behaviour. In particular, research has focused on the influence of exercise upon mental health and cognitive functioning.

2. Indirect Relationships

The relationship between mental health and physical activity has been studied extensively. This relationship is important in terms of brain function because mental health has been shown to be linked to cognitive function. For example, several researchers have shown that neuropsychological dysfunction is evident in depressed patients. Therefore, if exercise is linked to mental health, then this may have an indirect impact upon brain