Current Review

Physical activity and the healthy mind

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Physicians should seek to enhance the quality rather than the quantity of human life. Physical activity programs can increase life satisfaction through an immediate increase of arousal and a long-term enhancement of self-esteem and body image. In the young child competition can cause excessive arousal, but long-term adverse effects are rare. In the adult a reduction of anxiety and stress and a general feeling of well-being reduce the frequency of minor medical complaints, generating important economic benefits. Physical activity programs also help to correct the reactive depression that accompanies conditions such as myocardial infarction. Interest in physical activity should be stimulated from the earliest years of primary school. The allocation of curricular time to physical education does not hamper academic achievement. Rather, through its impact on psychomotor learning, it enhances the total process of intellectual and psychomotor development.

Le médecin devrait chercher à améliorer la qualité plutôt que la durée de la vie humaine. Les programmes d'activité physique peuvent augmenter le degré de satisfaction dans la vie par une stimulation immédiate et une amélioration à long terme du respect et de la perception de soi. Chez le jeune enfant la compétition peut causer une stimulation excessive, mais à long terme les effets défavorables sont rares. Chez l'adulte une diminution de l'anxiété et du stress et un sentiment général de bien-être réduisent la fréquence des doléances concernant des affections bénignes, produisant de la sorte des avantages économiques importants. Les programmes d'exercice physique contribuent également à corriger la réaction dépressive qui accompagne les maladies telles que l'infarctus du myocarde. L'intérêt envers les activités physiques devrait être stimulé dès les premières années d'école primaire. A l'intérieur des programmes d'enseignement, le temps consacré à l'éducation physique ne nuit pas à la réussite scolaire. Bien plus, par son impact sur l'apprentissage psychomoteur, il améliore le processus de développement intellectuel et psychomoteur.

Most physicians measure service to the ill by a lengthening of life. Certainly most exercise specialists approach their task from this perspective. They will point to the studies that suggest that vigorous physical activity is associated with a halving of mortality from cardiovascular disease,[1-4] although the practical importance of small differences in longevity between experimental and control populations and the inferences derived from studies of self-selected volunteers have been questioned.

However, concentrating on longevity ignores the more important issue of the quality of life. A patient who has suffered a myocardial infarction will not be excited at the prospect that vigorous exercise will allow him to live 50.7 rather than 50.3 months. Rather, he is likely to enjoy exercise for its immediate reward: it makes him "feel better".

This paper will review the proposition that prolonged, endurance-type physical activity of moderate intensity, as currently prescribed, makes a person feel better. Benefits from a well designed physical activity program include increase of arousal, improvement of self-esteem and body image, relief of anxiety, stress and reactive depression, and maximization of intellectual and psychomotor development, all of which contribute to a "healthy mind".

Arousal

Arousal is closely related to wakefulness or vigilance and may be objectively assessed by the performance of certain tests, such as determining the frequency at which a flickering light appears to be a continuously illuminated light. Arousal differs substantially from one person to another, and within an individual it shows a circadian rhythm, reaching its lowest level between 3 and 4 am, even if the subject attempts to remain awake. The physiologic basis of arousal is an increase in the activity of reverberating neuronal circuits in the reticular formation of the brain stem.

Human physical and mental performance shows an inverted U-shaped relation to the degree of arousal. If neuronal activity is insufficient a person feels bored, tired and even depressed. In contrast, overarousal leads to anxiety, nervousness, sleeplessness and poor performance. Medical treatment should suggest changes in occupation and lifestyle that will keep the individual at the peak of the arousal curve[5] (i.e., in a "eustress" condition[6,7]). Tasks that demand too much or too

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little from an individual lead to excessive stress, with adverse psychologic and psychosomatic consequences.[8-11]

The optimum level of arousal varies with the personality of the individual. An extrovert requires much greater stimulation than an introvert in order to reach optimum performance.[12,13] A second variable is the difficulty of the task that must be undertaken relative to the ability of the individual. More arousal is needed for performance of an easy task than one that is more difficult. A demanding executive appointment is in itself arousing, and optimum performance is then reached with much less external stimulation than in simple production-line employment. A third factor is environment. Any form of external stimulation increases arousal, whether this be noisy music, a cold draught or brightly painted walls. The ambiance needed for an executive office suite thus differs markedly from what is desirable around a conveyor belt.[5,14]

Activity and arousal

Physical activity has a strong and immediate effect on a person's level of arousal. Movement stimulates muscle and joint proprioceptors, and the central projection of this information through spinothalamic pathways increases activity within the reticular neuronal loops.[15,16] For example, a driver on a deserted highway at night in a well heated car is in an environment that is bland in relation to the difficulty of the task. The level of arousal drops and the driver may fall asleep. A more appropriate level of cerebral function can be restored by getting out of the car and taking a brisk walk.[14] On the other hand, an overworked person who is an obsessive exerciser may find it difficult to fall asleep after a long stint of late-night jogging has increased arousal.

Chemical factors may increase arousal during and following physical activity. The stimulant action of drugs such as the amphetamines is well recognized, and there is increasing evidence that some disorders of affect are due to disturbances of catecholamine metabolism.[11,17,18]

Vigorous physical activity leads to a release of both norepinephrine and epinephrine,[19] partly in the active regions of the brain, but also at the sympathetic nerve endings, which secrete norepinephrine plus small amounts of epinephrine. The triggering stimuli for this are a fall of central blood pressure and radiation of impulses from the motor cortex. The adrenal medulla, a third source of catecholamines, releases epinephrine if the activity is perceived as stressful or if the blood glucose level drops below 50 to 70 mg/dl (2.8 to 3.9 mmol/l).[16]

Mechanisms for the breakdown of the natural catecholamines are very efficient, and plasma levels of norepinephrine and epinephrine do not increase unless the intensity of activity is greater than 70% of the maximum oxygen intake or if there is the pressure of intense competition, such as during a hockey game.[20] However, failure to detect an increase of catecholamine production with lesser levels of activity is partly a criticism of technique. Brain catecholamines are largely excreted as 3-methoxy-4-hydroxyphenyl glycol (MHPG), while catecholamines from peripheral sources are eliminated as a mixture of MHPG and vanillylmandelic acid (VMA). We have observed an increase of plasma levels and urinary output of both MHPG and VMA with sustained exercise at only 40% of the maximum oxygen intake. The MHPG:VMA ratio in the plasma decreases during exercise but rises during recovery. The findings are consistent with a peripheral rather than a central secretion of catecholamines, with more ready excretion of VMA than of MHPG.[21]

It is tempting to suggest that physical activity increases arousal much as if one had taken a "shot" of Dexedrine (dextroamphetamine sulfate). Internal secretion of chemicals may contribute to the "runner's high", but our data suggest that changes in levels of cerebral catecholamines are minimal during moderate exercise.

A third possible variable governing interactions between mood and movement is the setting of the hypothalamic activity centre. Electrical stimulation of this region of the brain can persuade animals to run to exhaustion and even death.[22,23] Humans also seem to engage in physical activity until the hypothalamic centre is in some way satiated. This hypothesis can be tested very simply by asking a small boy to sit for an hour on a chair in the front parlour of his grandmother's house. The nature of the input to the activity centre is still uncertain but probably includes impulses from the hypothalamic temperature and glucose receptors, and feedback loops from the limb proprioceptors. If the combined input to the activity centre is inadequate, activity is increased until the "setting" of this regulator is reached.

"Hyperactivity" is probably an overworked diagnosis. Nevertheless, it is easy to envisage a situation in which the normal control setting of the activity centre is inappropriately adjusted. In some cases the individual concerned "feels good" despite too small a level of habitual activity to control obesity, while in other instances the midbrain centres demand an excess of activity, to the discomfiture of parents and teachers alike. Such a hypothesis certainly gives a simple explanation for the paradox that a hyperactive child can be helped by a chemical increase of arousal (through the administration of caffeine or amphetamines).[24] It also raises the possibility that control of overeating by the use of sympathomimetic amines may reduce activity, thus hampering efforts to create a negative energy balance.

Competition and overarousal of children

While some arousal is advantageous to performance, child psychologists and educators have argued that the intense arousal and heavy praise associated with minor-league sports have a harmful effect on children. It has been suggested that the normal scale of values is distorted and that the participants are subjected to excessive stress.[25]

Skubic[26] reported that a third of the students involved in little-league baseball became too excited to eat normally following competition and that in some instances arousal delayed the onset of normal sleep. While batting, the players' heart rates were high (148 to 195 beats/min), but recovery was rapid, the postgame heart rates averaging only

101 beats/min. Blimkie and associates[20] observed that boys excreted more epinephrine and norepinephrine during a hockey game than during an equivalent bout of cycle ergometer exercise. This effect was more obvious for players aged 16 and 23 years than for those aged 11 and 12 years.

The long-term influence of competition is small, though. Rivard and colleagues[27] had teachers evaluate students' behaviour before and immediately after participation in a major province-wide hockey competition. Before competition 88% were placed in the upper half of the class, and 82% of the participants maintained this category when they returned to school. Favourable scores were reported for motivation, group integration, school attendance and obedience. Frustration scores were generally the same before and after a match, irrespective of the outcome. A major determinant of behaviour was the attitude of the coach. A victory created a sense of achievement, but a loss was only well accepted if the coach showed enough maturity to accept defeat.

Self-esteem and body image

Adequate self-esteem is an important facet of mental health. Regular physical activity may have indirect effects on self-esteem by increasing an individual's ability to undertake physical or mental work. It also has a direct impact on body image, one major factor influencing self-esteem. A sense of self-worth in turn influences lifestyle and thus general health.

The exercise specialist commonly assesses body image in terms of responses to Likert scales, in which the subject is asked to rate "my body as I would like it to be" and "my body as it really is" relative to a series of adjectival pairs such as "strong–weak" and "beautiful–ugly". Discrepancies arise between the two ratings if the subject has a negative self-image.

Body image of the young

Participation in a sports or physical activity program usually enhances the self-image of the young. In part this reflects adulation of successful young athletes. Nevertheless, gains are also registered by children who initially had a poor self-image, provided that the program is geared to their abilities and they receive appropriate praise for success they achieve.[28]

Body image of the elderly

Regular daily physical activity can also improve the self-image of a middle-aged or elderly person. Heinzelmann and Baggley[29] found that an 18-month conditioning program gave employees of the National Aeronautics and Space Administration a more positive self-image, with associated increases in stamina and energy, feelings of positive health and a greater ability to cope with stress.

Responses of adults are partly influenced by the gap between the perceived and the desired body image and also by the acceptance of the need for training. Thus, McPherson and collaborators[30] observed larger gains of self-image in patients who had suffered a myocardial infarction than in healthy subjects when the two groups undertook 24 weeks of training. A colleague and I[31] found that average scores of body image changed little for 65-year-old men and women who exercised for 3 months. An improvement in body image was registered by subjects who showed a good training response; those with little improvement of aerobic power had a wider discrepancy between actual and ideal body images.

Implications for programming

Improvements in body image undoubtedly encourage compliance with an exercise program. However, overzealous admonishment of an unsuccessful exerciser by a well built physical instructor can have a negative effect. Good judgement is needed to provide an effective stimulus to conditioning without the use of excessive persuasion.[32]

Body image and lifestyle

It has been suggested that an adverse lifestyle is one expression of alienation in the labour force.[33] The positive changes of mood and self-image that accompany an appropriately graded exercise program may have a favourable effect upon attitude to work and general lifestyle.

When the Canadian Health Hazard Appraisal test was given to participants in an employee fitness program the program adherents fared significantly better than controls over a 10-month period of evaluation, adding almost 2 years to their predicted lifespan through the correction of adverse health habits.[34] Given a 20% rate of participation in an employee fitness program, a corresponding increase of "useful" working life in the participants would yield an economic dividend of at least $150 per employee per year, averaged over a 40-year workspan.

Anxiety, perceived health, stress and depression

Because vigorous physical activity makes most patients feel better it also tends to reduce manifest anxiety, stress and depression, thus lessening the frequency of minor medical complaints and industrial absenteeism[35] as well as reducing health care costs.[36]

Anxiety

The influence of activity programs upon anxiety is greatly influenced by the initial status of the individual. When well balanced middle-aged men participated in a regular training program there was no change in manifest anxiety scores,[37] but in a preretirement exercise class there was a modest long-term decline of anxiety scores.[31] In the latter group the changes of score were largest in subjects who attended the class regularly but exercised at only a low intensity. This suggests that the observed response may have been due to group support rather than a more specific influence of the physical activity.

McPherson and collaborators[30] found significant decreases of manifest anxiety over 24 weeks of conditioning but commented that the change was more marked in those who had recently suffered a myocardial infarction. Among this group the participation in light recreational activity was sufficient to reduce anxiety scores.

Perceived health

Cheraskin and Ringsdorf[38] noted lower Cornell Medical Inventory scores in old people who were taking

daily exercise. Likewise, Palmore[39] commented that poor health (defined as more than 2 weeks of bed rest, more than three visits to a doctor or a stay in hospital for any one episode of illness) was four times more frequent among old people who took little regular exercise. Unfortunately, it is difficult to distinguish cause and effect in such studies.

In a longitudinal experiment on a preretirement exercise class a colleague and I[40] found that overall changes of Cornell Medical Inventory scores were slight but that there was a significant decline in positive responses to the section on miscellaneous diseases; in addition, subjects who had adopted a high-frequency/high-intensity pattern of training showed a decrease in the frequency of complaints relating to anxiety.

Stress

Several reports have suggested that joggers have low scores on somatic indices of anxiety (e.g., heart rate and muscle tension) and that one long-term benefit of regular vigorous physical activity is a relief of chronic overarousal.[41-45]

Raab and Krzywanek[46] and Cox and associates[43] have also claimed that physically active subjects show a below-average response to sensory and emotional stimulation. Other possible mechanisms for the commonly reported relief of mental stress include an improved oxygen supply to the brain,[47] a sense of greater control over one's destiny,[48] a reduction of type A behaviour,[44] an improvement of sleep habits,[49,50] a "conditioning" of the stress-and-strain mechanism through the physical demands of exercise,[51] and cognitive perceptions of the instrumental value of physical activity.[52,53]

It has been argued that much of present-day stress reflects the total submission to corporate objectives demanded of the modern executive, but questions have arisen about how far vigorous physical activity can provide a controlled outlet for hostile, aggressive impulses.[54-56] Although participation in contact sports has sometimes been recommended for this purpose,[57] a more likely outcome is a sense of guilt, with an increase of anxiety.[58] Watching violent sports also seems to increase rather than to decrease aggressive tendencies.[59,60]

Depression

The elevation of mood associated with regular physical activity seems particularly helpful in countering the acute reactive depression associated with conditions such as myocardial infarction.[61] Application of the Minnesota Multiphasic Personality Inventory (MMPI) to patients between 12 and 15 months after they were recruited to a post-coronary rehabilitation program showed that almost all the patients exceeded the theoretical depression score of 50 and that about one third had very high scores (more than two standard deviations greater than normal).[62] This subgroup also showed high values for the neurotic triad of hysteria, hypochondriasis and psychasthenia.

Brozek and collaborators[63] argued that men who subsequently suffered a heart attack had high initial scores for hypochondriasis. On the other hand, Ostfeld and coworkers[64] found no abnormalities of the MMPI in patients who subsequently had a myocardial infarction. I do not believe that the depression of the post-coronary patient has an inherent, constitutional basis. More probable reasons for the depression include weakness resulting from the heart attack and subsequent bed rest, sexual problems, inadequate or inappropriate advice from the attending physician, interaction with an over-anxious wife, frequent hospital admission and the patient's lack of confidence and fear of sudden death. The arousal and improvement of body image associated with a regular exercise program bring welcome relief from all of these natural reactions. A 4-year longitudinal study of 44 patients with particularly high scores for depression showed a substantial improvement in response to progressive exercise.[65] This finding is worth noting since many authors have maintained that the MMPI measures personality traits rather than mood state. More recently Kavanagh and I, using the Profile of Mood States test, found that patients had abnormal scores immediately after infarction but that the scores improved as the patients underwent rehabilitation (unpublished observations, 1982).

Intellectual and psychomotor development

Intellectual development

We know the value of regular physical activity; however, it is by no means easy for a physician to motivate a middle-aged adult to adopt a more active lifestyle. The process of indoctrination should begin in primary school.[28] While physical educators have urged such action for many years, school boards are often reluctant to sacrifice the necessary curricular hours, arguing that such a plan could stunt the intellectual development of children. This objection was recently examined in a study in Trois Rivières, PQ. Entire classes of primary school students undertook 5 additional hours of physical activity each week under the direction of a physical education specialist. Immediately preceding and succeeding classes at the same schools served as controls, following the standard Quebec primary school program of one 40-minute period of physical activity per week under the supervision of the usual classroom teacher.[66] The enhanced activity program produced the expected gains of maximum oxygen intake, muscle strength and physical performance but had no effect on growth.

Although the time available for classroom study was necessarily curtailed 13% to 14% by the activity program, the students in grades two to six from the experimental classes had consistently higher marks than the students in the control classes. Marks for French-language instruction were improved in 13 group comparisons, worse in 6 and unchanged in 26. Mathematics marks were improved in four group comparisons and unchanged in eight. There were lesser benefits in natural science and in English-language instruction. The only unchanged score was the mark awarded for behaviour.[67] This finding is at variance with the study done in Saskatoon by Bailey.[68] There, increased concentration and less disruptive behaviour was reported for students who devoted a lot of their class time to physical activity.

It could be argued that the marks observed at Trois Rivières reflected teachers' attitudes, since 80% of the teaching staff were in favour of the activity program, and the remainder were neutral rather than hostile. However, the gains in French-language instruction and mathematics were confirmed by independent province-wide examinations held during grade six. Moreover, any "halo" effect was subconscious, since the teachers were unaware that the girls benefited more than the boys from the additional activity. Teachers also suggested, in agreement with Bailey,[68] that the activity program improved behaviour, whereas objective reports for the classes showed that it did not.

Certainly the results are sufficient to show that the usual objection (lack of curricular time) to enhanced physical educational programs is invalid and that greater physical activity may even enhance academic performance. The results cannot be explained simply by improvements of body image. Involvement of the entire class avoided the complication of extra status that would have resulted from participation in the physical activity program by some students from each class. Arousal of the students by the exercise period may have increased their vigilance in the remaining classes, while a shortening of the working day for the usual classroom teachers may have enabled them to face their duties with greater vigour and enthusiasm.

Psychomotor development

French psychologists have long insisted on the close relationship between psychomotor and mental growth. In the Trois Rivières study several attributes of psychomotor development were accelerated by the enhanced physical activity. The students in the experimental program had a more realistic perception of their stature than the controls, the advantage being particularly obvious in the youngest children (for whom the gymnasium program stressed psychomotor learning). Accuracy in estimating arm span was better in the experimental group. Recognition of the vertical plane and finger recognition also developed earlier in the experimental group than in the controls.[69] These changes could all help the early stages of academic learning. Acquisition of numerical skills, for example, depends on use of the fingers,[70,71] and the impact of psychomotor learning on other skills, such as writing, is even more apparent.

Conclusions

Obviously the early Greeks were correct when they emphasized the concept of a healthy mind in a healthy body. Today we should remember that one of the most important ways in which medical scientists can serve patients is by appreciating the link between the body and the mind and by seeking to fully develop human potential in both areas.

References

1. MORRIS JN: The epidemiology of coronary artery disease. In KAVANAGH T (ed): *International Symposium on Exercise and Coronary Artery Disease*, Toronto Rehabilitation Centre, Toronto, 1975: 76–89
2. PAFFENBARGER RS: Physical activity and fatal heart attack: protection or selection? In AMSTERDAM EA, WILMORE JH, DEMARIA AN (eds): *Exercise in Cardiovascular Health and Disease*, Yorke Med, New York, 1977: 35–49
3. PAFFENBARGER RS JR, WING AL, HYDE RT: Physical activity as an index of heart attack risk in college alumni. *Am J Epidemiol* 1978; 108: 161–175
4. SHEPHARD RJ: *Ischemic Heart Disease and Physical Activity*, Croom Helm, London, 1981
5. CORCORAN DWJ: Personality and the inverted U-relation. *Br J Psychol* 1965; 52: 267–273
6. SELYE H: The role of stress in the production and prevention of experimental cardiopathies. In RAAB W (ed): *Prevention of Ischemic Heart Disease*, CC Thomas, Springfield, Ill, 1966: 163–168
7. FRENCH JRP, KAHN RLA: A programmatic approach to studying the industrial environment and mental health. *J Soc Issues* 1962; 18: 1–47
8. COBURN D: Job alienation and well-being. *Int J Health Serv* 1979; 9: 41–59
9. FRANKENHAUSER M: Psychoneuroendocrine approaches to the study of emotion as related to stress and coping. In HOWE HE, DIENSTBIER RA (eds): *Nebraska Symposium on Motivation 1978*, U of Nebr Pr, Lincoln, 1979
10. JOHANSSON G: Psychoneuroendocrine correlates of unpaced and paced performance. In SALVENDY G, SMITH MJ (eds): *Machine Pacing and Occupational Stress*, Taylor & Francis, London, Engl, 1981: 277–286
11. MCCORMICK EJ: Comments from the side lines. Ibid: 1–4
12. BROADHURST PL: The interaction of task difficulty and motivation — the Yerkes Dodson Law revived. *Acta Psychol (Amst)* 1959; 16: 321–338
13. MARTENS R: Arousal and motor performance. *Exerc Sport Sci Rev* 1974; 2: 155–188
14. SHEPHARD RJ: *Men at Work. Applications of Ergonomics to Performance and Design*, CC Thomas, Springfield, Ill, 1974: 1–396
15. PHILLIPS CG, PORTER R: *Cortico-spinal Neurones. Their Role in Movement*, Acad Pr, New York, 1977: 1–450
16. SHEPHARD RJ: *Exercise Physiology and Biochemistry*, Praeger, New York, 1982: 1–672
17. MAAS JW, FAWCETT JA, DEKIRMENJIAN H: Catecholamine metabolism, depressive illness and drug response. *Arch Gen Psychiatry* 1972; 26: 252–262
18. SCHILDKRAUT JJ: Norepinephrine metabolites as biochemical criteria for classifying depressive disorders and predicting responses to treatment: preliminary findings. *Am J Psychiatry* 1973; 130: 695–698
19. VON EULER US: Sympatho-adrenal activity in physical exercise. *Med Sci Sports* 1974; 6: 165–173
20. BLIMKIE CJ, CUNNINGHAM DA, LEUNG FY: Urinary catecholamine excretion and lactate concentrations in competitive hockey players aged 11 to 23 years. In LAVALLÉE H, SHEPHARD RJ (eds): *Frontiers of Activity and Child Health*, Pélican, Quebec, 1977: 313–321
21. TANG SW, SHEPHARD RJ, TAKAHASHI S, WARSH JJ, STANCER HC: Central and peripheral metabolites of noradrenaline and serotonin during sustained exercise. In POORTMANS JR, NISET G (eds): *Biochemistry IVb*, Univ Park, Baltimore, 1981: 82–92
22. ANEND BK: Nervous regulation of food intake. *Physiol Rev* 1961; 41: 677–708
23. HORVATH SM: The physiological stimuli to training in a normal climate. *Can Med Assoc J* 1967; 96: 791–793
24. SCHNACKENBERG RC: Caffeine as a substitute for schedule II stimulants in hyperkinetic children. *Am J Psychiatry* 1973; 130: 796–798
25. RARICK GL (ed): Competitive sports in childhood and early adolescence. In *Physical Activity: Human Growth and Development*, Acad Pr, New York, 1973: 364–386
26. SKUBIC E: Emotional responses of boys to little-league and middle-league competitive baseball. *Res Q* 1955; 26: 342–352
27. RIVARD G, LAVALLÉE H, RAJIC M, SHEPHARD RJ, THIBAUDEAU P, DAVIGNON A, BEAUCAGE C: Influence of competitive hockey on physical condition and psychological behaviour of children. In LAVALLÉE H, SHEPHARD RJ (eds): *Frontiers of Activity and Child Health*, Pélican, Quebec, 1977: 335–354
28. SHEPHARD RJ: *Physical Activity and Growth*, Year Bk Med, Chicago, 1982
29. HEINZELMANN F, BAGGLEY R: Response to physical activity programs and their effects on health behaviour. *Public Health Rep* 1970; 85: 905–911
30. MCPHERSON BD, PAIVIO A, YUHASZ MS, RECHNITZER PA, PICKARD HA, LEFCOE NM: Psychological effects of an exercise program for post-infarct and normal adult men. *J Sports Med Phys Fitness* 1967; 7: 95–102
31. SIDNEY KH, SHEPHARD RJ: Attitudes towards health and physical activity in the elderly. Effects of a physical training programme. *Med Sci Sports* 1977; 8: 246–252
32. SHEPHARD RJ: *Physical Activity and Aging*, Croom Helm, London, 1978
33. ARO S: Stress, morbidity and health-related behaviour. A five year follow-up study among metal industry employees. *Scand J Soc Med [Suppl]* 1981; 25: 1–130
34. SHEPHARD RJ, COREY P, COX M: Health hazard appraisal — the influence of an employee fitness program. *Can J Public Health* 1982; 73: 183–187
35. COX M, SHEPHARD RJ, COREY P: Influence of an employee fitness programme upon fitness, productivity and absenteeism. *Ergonomics* 1981; 24: 795–806
36. SHEPHARD RJ, COREY P, RENZLAND P, COX M: The influence of an industrial fitness programme upon medical care costs. *Can J Public Health* 1982; 73: 259–263
37. MASSIE JF, SHEPHARD RJ: Physiological and psychological effects of training. *Med Sci Sports* 1971; 3: 110–117
38. CHERASKIN E, RINGSDORF WM: *Predictive Medicine. A Study in Strategy*, Pacific Pr Pub Assoc, Mountain View, Calif, 1973
39. PALMORE E: Health practices and illness among the aged. *Gerontologist* 1970; 10: 313–316
40. SIDNEY KH, SHEPHARD RJ: Perception of exertion in the elderly. Effects of aging, mode of exercise and physical training. *Percept Mot Skills* 1977; 44: 999–1010
41. ELIOT RS, FORKER AD, ROBERTSON RJ: Aerobic exercise as a therapeutic modality in the relief of stress. *Adv Cardiol* 1976; 18: 231–242
42. GREIST JH, KLEIN MH, EISCHENS RR, FARIS J, GURMAN AS, MORGAN WP: Running as treatment for depression. *Compr Psychiatry* 1979; 20: 41–54
43. COX JP, EVANS J, JAMIESON J: Aerobic power and tonic heart rate response to psychological stressors. *Pers Soc Psychol Bull* 1979; 5: 160–163
44. BLUMENTHAL J, WILLIAMS R, WILLIAMS R, WALLACE A: Effects of exercise on type A (coronary prone) behaviour pattern. *Psychosom Med* 1980; 42: 289–296
45. LEDWIGE B: Run for your mind: aerobic exercise a means of alleviating anxiety and depression. *Can J Behav Sci* 1980; 12: 126–139
46. RAAB W, KRZYWANEK HJ: Cardiac sympathetic tone and stress response related to personality patterns and exercise habits. In RAAB W (ed): *Prevention of Ischemic Heart Disease*, CC Thomas, Springfield, Ill, 1966: 121–134
47. ISMAIL AH, TRACHTMAN LE: Jogging the imagination. *Psychol Today* 1973; 6: 79–82
48. MORGAN WP, POLLOCK M: Physical activity and cardiovascular health: psychological aspects. In LANDRY F, ORBAN WAR (eds): *Physical Activity and Human Well-Being*, Symposia Special, Miami, 1978: 163–184

49. BAEKLAND F, LASKY R: Exercise and sleep patterns in college athletes. *Percept Mot Skills* 1966; 23: 1203–1207

50. FOLKINS CH, AMSTERDAM EA: Control and modification of stress emotions through chronic exercise. In AMSTERDAM EA, WILMORE JH, DEMARIA AN (eds): *Exercise in Cardiovascular Health and Disease*, Yorke Med, New York, 1977: 280–294

51. MICHAEL ED: Stress adaptation through exercise. *Res Q* 1957; 28: 50–54

52. HEAPS R: Relating physical and psychological fitness: a psychological point of view. *J Sports Med* 1978; 18: 399–408

53. JASNOSKI M, HOLMES D: Influence of initial aerobic fitness, aerobic training and changes in aerobic fitness on personality functioning. *J Psychosom Res* 1981; 25: 553–556

54. LAYMAN EM: Aggression in relation to play and sports. In KENYON GS (ed): *Contemporary Psychology of Sport*, Athletic Inst, Chicago, 1970: 25–34

55. SCOTT JP: Sport and aggression. Ibid: 11–24

56. BUZINA R: Nutrition status, working capacity and absenteeism in industrial workers. In DEBRY G, BLEYER R (eds): *Symposium International sur "Alimentation et Travail"*, Masson, Paris, 1972

57. INGHAM AG, SMITH MD: Social implications of the interactions between spectators and athletes. *Exerc Sport Sci Rev* 1974; 2: 189–224

58. RYAN ED: The cathartic effect of vigorous motor activity on aggressive behaviour. *Res Q* 1970; 41: 542–551

59. TURNER ET: *The Effects of Viewing College Football, Basketball and Wrestling on the Elicited Aggressive Responses of Male Spectators*, PhD thesis, U of Maryland, College Park, Md, 1968

60. GOLDSTEIN JH, ARMS RL: Effects of observing athletic contests on hostility. *Sociometry* 1971; 34: 83–90

61. RUSKIN HE, STEIN LL, SHELSKY IM, BAILEY MA: MMPI comparison between patients with coronary heart disease and their spouses and other demographic data. *Scand J Rehabil Med* 1970; 2: 99–104

62. KAVANAGH T, SHEPHARD RJ, TUCK JA: Depression after myocardial infarction. *Can Med Assoc J* 1975; 113: 23–27

63. BROZEK J, KEYS A, BLACKBURN H: Personality differences between potential coronary and non-coronary subjects. *Ann NY Acad Sci* 1966; 134: 1056–1064

64. OSTFELD AM, LEBOVITS BZ, SKELLE RB, PAUL O: A prospective study of the relationship between personality and coronary heart disease. *J Chronic Dis* 1964; 17: 265–276

65. KAVANAGH T, SHEPHARD RJ, TUCK JA, QURESHI S: Depression following myocardial infarction: the effects of distance running. *Ann NY Acad Sci* 1977; 301: 1029–1038

66. JÉQUIER JC, LAVALLÉE H, RAJIC M, BEAUCAGE C, SHEPHARD RJ, LABARRE R: The longitudinal examination of growth and development: history and protocol of the Trois Rivières Regional Study. In LAVALLÉE H, SHEPHARD RJ (eds): *Frontiers of Activity and Child Health*, Pélican, Quebec, 1977: 49–54

67. VOLLE M, SHEPHARD RJ, LAVALLÉE H, LABARRE R, JÉQUIER JC, RAJIC M: Influence of a programme of required physical activity upon academic performance. In LAVALLÉE H, SHEPHARD RJ (eds): *Croissance et Développement de l'Enfant*, U de Québec, Trois Rivières, 1982: 91–109

68. BAILEY D: Exercise, fitness and physical education for the growing child. In ORBAN WAR (ed): *Proceedings of the National Conference on Fitness and Health*, Dept of National Health and Welfare, Ottawa, 1973: 13–22

69. VOLLE M, TISAL H, LABARRE R, LAVALLÉE H, SHEPHARD RJ, JÉQUIER JC, RAJIC M: Influence d'un programme expérimental d'activités physiques intégré à l'école primaire sur le développement de quelques éléments psychomoteurs. In LAVALLÉE H, SHEPHARD RJ (eds): *Croissance et Développement de l'Enfant*, U de Québec, Trois Rivières, 1982: 201–222

70. CURCIO R, ROBBINS O, ELA SS: The role of body parts and readiness in acquisition of number conservation. *Child Dev* 1971; 42: 1641–1646

71. RIGAL RA: Influence de l'évolution des composantes du développement psychomoteur sur le rendement en mathématiques chez les enfants de 6 à 9 ans. *Enfance* 1976; 29: 346–355