WARMING UP FOR ATHLETIC EVENTS

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ABSTRACT

Warming up is a widely accepted procedure preceding every type of athletic events, although objective evidence supporting the use of warm up is limited. Coaches, physical educators and athletes of almost every athletic activity assume that the warming-up procedure is a mean by which athletic performance may be improved, and the chance of injury reduced; they also hold that the benefits of warming up have been attributed to an increased range of motion in the joints, increased circulation, decreased viscosity, increased body and muscle temperature and neural facilitation (24) and that warming up has an inherent psychological effect since it helps the athlete to achieve a state of mental readiness or mind set.

However, some athletes and coaches are inclined to question the value of warm-up activity on the basis that the athlete may have already exhausted a needed part of his energy when the time comes for the major performance. The value of warm up prior to an athletic event was not questioned until 1945 when Asmussen and Boje studied the role of increased body and muscle temperature on muscular performance. Within the past decade and still today the principle of warm up is the subject of considerable debate and it has gained favour as a topic for research among serious researchers in the physiology of exercise.

Numerous studies have investigated the effect of various warm-up procedures on muscular performance in an activity; also certain changes in the physiological phenomena such as heart rate and oxygen consumption have been used as specific warm up, as well as attitude toward warm up have been studied as they affect physical performance (7).

The evidence presented by the above research has not been conclusive with a few studies reporting that warm up has no beneficial effect on performance and in fact may even hinder it, while others have reported that warm up is neither beneficial nor harmful. The majority of the research however has reported that warm up prior to an athletic event is beneficial to performance (7). It is becoming apparent then that there is no one answer to the question and that factors such as the type of the activity, the nature of the warm-up, the extent and intensity of the warm-up, the physiological make-up of the individual and the attitude toward warming up must all be considered. If the results of the research in our field seem to be controversial at this time, that probably is due to the fact that each study has tried to find the answer to the question from a different point of view with different factors involved (24).

ELUCIDATION OF THE PHYSIOLOGICAL NATURE OF WARM-UP

Blood supply and chemical changes in the exercised muscles

At rest, the skeletal muscles, which constitute about 40% of the body weight, receive only about 15% of the total blood flow. Their arterioles are constricted by the intrinsic tone of their smooth muscle as well as by sympathetic vasoconstrictor nerve impulses. A large proportion of the muscle capillaries are closed; the individual capillaries probably open and close in alternation in response to the rhythmic activity (vasc motion) of the precapillary sphincters (17:123).

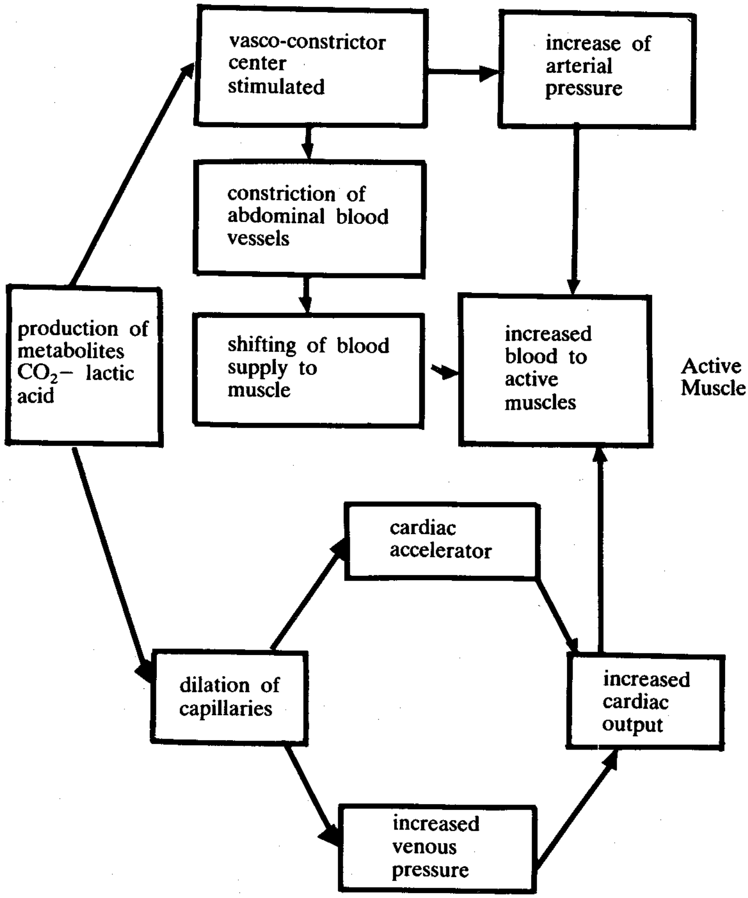
As soon as exercise begins, the metabolic demands of the active muscle tissue increase. Many physiological mechanisms co-operate to supply these demands (5:134). Blood supply is increased often to 4 or 5 times that of the resting supply as a result of; it is believed; a number of factors operating at once. The increase in heart rate and in systolic pressure increases the total circulating volume of blood, and as a result, the muscles receive their share of the increase. Muscular activity itself stimulates different nerves which stimulate the vasodilator center, thereby increasing the local blood supply. Furthermore, increased activity of the vaso-constrictor center causes constriction of arteries in another local area, such as the skin of the hands or the digestive organs, causing a shift of blood from these areas to the muscles. Another type of shift results from the contraction of the spleen. Short burst of running result in pallor of the colon and in the contraction of the spleen. The increase blood flow to the muscles is diminished during exercise. The Chemical substances which are liberated during muscular work and which delate the capillaries are the metabolites, the hormones and the humors. The metabolites are substances formed directly as a result of activity. These are lactic, adenylic, or other acids and carbon dioxide. The hormones are chemical substances formed at the nerve endings. These chemicals--adrenaline, pituitrin and sympathin (which may be identical to adrenaline)--are distributed by the blood. Acting locally, these chemicals dilate tiny vessels and thereby increase the blood flow. These substances have the opposite effect, however, on the vasoconstrictor center. Increased carbon dioxide concentration in the blood stimulates that center, increasing the vascular tone of the larger blood vessels. Although these actions seem to be antagonistic, they are actually complementary. Increased vascular tone increases the general blood pressure, whereas decreased tone in the capillaries increases the blood volume brought to the active tissues. Together, the effect is to increase the blood supply.

During muscular activity, there is an increase in adrenaline production in the adrenal gland, which produces very marked effects. It stimulates heart action and increases vasoconstriction in the skin and in the splanchnic blood vessels, thus raising the general blood pressure. Locally, it delates the capillaries.

The nerves that produce vasodilation in the blood vessels of the muscle act through the liberation of a chemical substance called sympathin. Sympathin is produced at all sympathetic nerve endings. Since these nerves are very active during intense muscular activity, sympathin is formed in the heart, in the bronchioles and in the blood vessels. Sympathin also produces local delating effects. Adenylic acid, resulting from the breakdown of adenosine triphosphate in the course of the normal chemical changes in contraction also causes capillary dilation.

In addition to these chemical dilations, the rise in temperature that comes with muscular activity also increases capillary volume and pressure (1:244-248) and accelerates other processes as well: capillary vasodilation, oxygen dissociation, cardiac output, activity of the respiratory adjustment of muscular activity; it lowers the muscle viscosity and increases the reaction of the muscle contraction (22:363).

Changes in active muscles which increase the volume of blood to the muscles during work (22:225).



Observation on the contraction of isolated muscles provides a clue as to the nature of the warming up process. If the muscle is warmed, the speed with which it contracts and relaxes and the force of contraction are increased, if a previously inactive muscle is stimulated repeatedly the first few contractions are often small and irregular, relaxation is incomplete. After this, the contractions become stronger and relaxation is complete (17:16). Van Hofts stated that when you increase the temperature of the muscle 3ºC., you increase the force of its contraction by 50% and that is exactly what

Asmussen proved in his experiment when he doubled the score of the vertical jump after warming up the leg muscles.

Therefore we find that on theoretical grounds it might be expected that a warming up which resulted in increased blood and muscle temperatures should improve performance through the mechanisms; (1) increased speed of contraction and relaxation of muscles, (2) greater efficiency because of lowered viscous resistance in the muscles, (3) hemoglobin gives up more oxygen at higher temperatures and also dissociates much more rapidly, (4) myoglobin shows temperature effects similar to those of hemoglobin, (5) metabolic processes increase their rated with increasing temperature, and (6) decreased resistance of vascular bed can be brought about by increased temperature (5:444).

Types of Warm-up

Warm-up may be classified as:

1. Passive warm up such as massage, hot showers, hot baths, turkish baths, radio-diathermy, etc... has been found effective (5:447).

2. Active warm-up

   a. Related warm-up (formal warm up), i.e. muscular activities in which the movements are those that imitate the activity which the performer getting ready to do or something close to it.

   b. Unrelated warm-up (Informal warm-up), i.e. any muscular activities designed to bring about the desired physiological changes without involving the actual movement itself (5:447).

The nature of the warm-up varies to some degree in relation to the activity; (11:76) for this reason the type of warm-up employed and its duration varies depending on the experience of the coach and the athlete in addition to environmental conditions (7). But it is advisable for the athlete to warm-up in activities similar to the event in which he will compete because warming-up through mimicking or using a modified form of the activity in which the athlete is to compete appears to improve coordination by developing the athlete's kinesthetic awareness thus establishing a neuromuscular pattern of performance. This assists him in determining when he has reached the state of readiness (11:76).

Intensity and duration of warm-up

The athlete usually starts the warming up at moderate pace and increases the tempo as he feels body temperature and cardiovascular increases taking place. It would be reasonable to hypothesize that too small an amount would have no measurable influence and that too large an amount would be detrimental because it would cause fatigue (21).

Burke has demonstrated that optimal combination of intensity and duration are needed to bring about the desired warm-up effect (5:448). Richards' (21) study in 1968 and Hugh W. Bonner's (1) study in 1974 were concerned with experiments investigating and testing the two factor theory of preliminary exercise (warm-up) as proposed by Richards and its hypothesis postulates a positive or improvement factor that increases in proportion to the amount of preliminary exercise (warm-up). Concurrently, this enhancement is opposed by a negative or detrimental fatigue factor that begins at a lower magnitude but increases more rapidly as a function of the amount of preliminary exercise. The net effect for any particular intensity of preliminary exercise is therefore the algebraic difference between the improvement and fituge factors. As the preliminary exercise is progressively increased beyond some small initial value, the net effect at first is positive, then it passes through a maximal or optimal value that will be followed by a progressive decrease through 0, to become increasingly negative or detrimental. Whereas Richards used a discrete power task, the vertical jump, and Hugh used a maximal endurance task on the bicycle ergometer. Richards (21) concluded that the greatest improvement was obtained with 1 to 2 minutes of preliminary exercise (warm-up) and that the four minutes were almost without influence, and six minutes had a pronounced deleterious effect. Bonner (1) concluded that the net positive effect is evident at 350 Kpm/min, is maximal at 650 Kpm/min, declines to approximately 0 at 800 Kpm/min, and is strongly negative at 950 Kpm/min. However, other research concluded that increasing the amount of preliminary exercises is reflected by improving performance (18). Asmussen, Boje and Muido and others cited by them have found that the positive effect is greatest when the amount of warm up is very large and that the small amount of such warm up according to their curves has only a slight influence (18). Others (2, 4, 8) said that it takqu approximately twenty minutes of gradual warm up to bring the body to a state of readiness with its attendant rise in body temperature, and to adequately mobilize the body physiology in terms is making a greater number of muscle capillaries available for extreme effort and of readying blood sugar and adrenaline, and that the amount of time necessary to achieve satisfactory warm up will vary with the individual and will tend to increase with age (11:77). Also, it has been concluded that throwing an eleven ounce baseball for a warm-up results in significantly improved velocity in subsequent tests with a ball of regulation weight, and that the accuracy response following the overload warm up is altered, yielding a significantly different pattern of successive throws (31). But how long does a warm-up persist? This question still cannot be awarded for the practical effect but for temperature changes in muscle tissue it has been shown that this effect persists for 45 to 80 minutes (5:451). Obviously, the intensity and duration of warm up must be adjusted to the individual athlete. As a rule of thumb, one may look for signs of development of heat from within and in the normal environment, this is indicated by perspiration. An increase in rectual temperature of 1^0 or 2^0F appears desirable (5:449).

Investigation into warm-up (WU)

Brief details of the nature and conclusions on research relevant to warm-up are given in tables. They are given in table form to demonstrate the great variety in (a) the type of physical work as a basis for experiment, (b) the type, duration and intensity of warm-up, (c) the duration of rest between warm-up and actual work, and (d) the nature of physiological controls. It is clear that experimental evidence is not yet available to permit reliable generalization about the effects of warm-up on physical work. There is also disagreement as to the mechanisms affected by warm up (25).

Warm-up (Preparation)		Physio. changes measured	Test (work) Performance	Type of Work	Results
Passive	Active				
Asmussen and Boje 1. Hot shower 47^{0}C for 10 minutes 2. Radiodiathermy 3. Massage 15 minutes(25)	Bicycle ergometer work rate 660mkg/min for 30 mins	Rectal Temp. Muscle Temp. Metabolism Blood Lactate	Bicycle ergometer 1. 956 mkg. 2. 9860 mkg. 3. Calf in plantar flexion (peak effort)	1. Power 2. Endurance 3. Strength	All forms of WU except massage had beneficial effect on work performance
Muido Hot bath 40^{0}C - 43^{0}C 15-18 minutes (25)	Light gym. work for 10 minutes	Rectal Temperature	Swimming 1. 50m crawl 2. 400m crawl 3. 200m breaststroke	Swimming Speed and endurance	Both active and passive WU benefited performance

Warm-up (Preparation)		Physio. changes measured	Test (work) Performance	Type of Work	Results
Passive	**Active**				
Carlisle (3) Showers as hot as tolerable 1. 8 minutes 2. 16 minutes		Rectal Temperature	Swimming 1. 220 yards 2. 40 yards	Swimming speed and endurance	Passive heating improved performance.
Hipple (9)	50 yards sprint at max. speed effect of this on successive sprints noted		50 yards sprint 5 efforts with rests of approx. 5 min between	Running speed	No beneficial effect of 1st run (considered as (WU) on 2nd or 2nd on 3rd etc.
Skubic (27) and Hodgkins	1. 12 Jumping Jacks (informal), 8 revers bicycle ergometer (formal) 2. 12 Jumping Jacks (informal), 5 softball throws (formal) 3. 12 Jumping Jacks (informal) 3 basketball shots (formal)		1. Bicycle ergometer 1/10th mile as fast as possible 2. Softball throw for distance. 3. 10 basketball free shots	1. Speed 2. Power 3. Skill accuracy	WU had no significant effect on performance.

Warm-up (Preparation)		Physio. changes measured	Test (work) Performance	Type of Work	Results
Passive	Active				
Sills and O'Reilly (26) Abdominal spray 44^0 - 48^0F for 8 min. Rest 8 minutes.	Walk or Jog for 10 mins.		10 second spot running 5 efforts, 10 sec. intervals in between efforts The followed preparation for another 5 bouts.	Speed/ Endurance	Performance of second 5 bouts improved more by cold spray than rest or exercise, and more by rest than exercise
Grose (8) 1. Hot water 48^0C. for 8 minutes 2. Cold water 10^0C for 8 minutes 3. Massage 4 mins.			Grip Ergometer 30 max. contractions per min. for 6 mins.	Strength/ Endurance	Heat caused significant decline in performance. Cold caused large decline in performance Massage no effect Rate of fatigue slower in cold muscle
Thompson (29)	1. Hot shower 3 min. plus swimming movements plus 5 minutes rest. 2. Calisthenics plus 5 min. rest 3. Finger calisthenics. 4. Practice of Basketball shooting typing, bowling as formal warm-up		1. Swimming 30 yrd. 2. Swimming max. distance in 5 minutes 3. Basket-ball shooting 4. Bowling 5. Typing 6. Back and leg dynamometer.	1. Swimming speed 2. Endurance 3. Skill 4. Skill 5. Skill 6. Strength	Formal WU improved 30 yrd. swim, basket ball shooting, bowling but did not improve typing. Informal WU had no significant effect upon any of these activities.

Warm-up (Preparation)		Physio changes measured	Test (work) Performance	Type of work	Results
Passive	**Active**				
Michael, Skubic and Rochelle (16)	1. Catching Softball (formal). 1 min. at 25 ft. 1 min. at 50 ft. 1 min. at 75 ft. 1 min. at 100 ft. 1 min. at 100+ft. 2. 1 min. jumping jacks, 1 min. toe touching. 1 min. alternate toe touching 2 min. spring running.		Softball throw for max. distance	Power	Both formal and informal WU's improved performance to a similar extent
DeVries (4) 1. Showers as hot as tolerable for six minutes 2. Massage 10 minutes	1. Swimming 500 yards at pace chosen by subjects. 2. Calisthenics		Swimming 100 yrds. 1. Crawl. 2. Breast stroke 3. Dolphin.	Swimming speed	Massage had no effect. 500 yard swim benefited performance of total group. Calisthenics no effect on total group. Calisthenics slowed down crawl swimmers speeded up breast and dolphin swimmers.
Nukada (25) 1. Immersion of arm in water, 20°C-40°C for 15 minutes 2. Radio diathermy, 6-10 min.		Muscle Temperature	Holding arm at 90° to body for max time with loads 7 kg., 10 kg. 15 kg.	Isometric Endurance	Passive heating produced decline in performance.

Warm-up (Preparation)		Physio. changes measured	Test (work) Performance	Type of Work	Results
Passive	Active				
Robbins (23) 1. Hot Showers up to 115⁰F for 10 min. 2. Cold Showers 65⁰F for 10 minutes.		Body temperature Hear rate Blood Pressure	Grip dynamometer	Grip Strength	Strength decreased slightly following hot shower and increased slightly following cold shower
Massey, Johnson and Kramer (13)	Moderate Calisthenics 10 min.		Bicycle Ergometer 100 revolutions (9,399 ft. lbs)	Strength/ Endurance	No advantage for WU.
Mathews and Snyder (14)	1 lap jogging 440 yrds. 6 push ups, 6 leg pulls, 10 toe touches, 6 sit ups, 3x10 yrd sprints, 5 10 min. rest after.		440 yrds. dash	Running Speed/ Endurance	No significant improvement in running time with WU
Pacheco (18)	3 minutes spot running 1½ minutes rest.		5 vertical jumps	Power	Significant improvement in jumping ability after WU

Warm-up (Preparation)		Physio. changes measured	Test (work) Performance	Type of work	Results
Passive	Active				
Pacheco (19)	1. 3 minutes leg and hip mobilizing. 2. Stationary running 3. Deep knee bends 4. Sessions at 6 bends per 30 sec. with 15 sec. rest between sessions.	1. Increased heart rate 14.2 beats per minutes. 2. Increased heart rate 43.6 beats per minute. 3. Increased heart rate 22.8 beats per min.	6 vertical jumps with 1.5 minute intervals between jumps.	Power	WU benefited performance. Order of benefit: running, mobilizing, deep-knee bends.
Merlino (15) Massage			Vertical jumping	Power	WU improved Performance
Karpovich and Hale (25) Deep Massage	Jog 440 yards Sprints 20, 30, 50 yards over 10 minutes period		440 yards Sprint	Running/ Speed endurance	WU had no significant effect on performance

Warm-up (Preparation)		Physio. changes measured	Test (work) Performance	Type of work	Results
Passive	**Active**				
Sedgwick and Whalen (25) 1. Short wave diathermy for 10 minutes.		Muscle Temperature	1. Strength measuring instrument (elbow-flexion) 3 secs. 2. Spring loaded ergometer (grip) 30 seconds.	1. Mascular Strength 2. Muscular endurance	Passive heating at intensity to raise muscle temperature about 5⁰C decrease muscle strength by 0.5 lb. Passive heating at intensity to raise muscle temperature between 2⁰C-4⁰C had no effect on muscle endurance
Phillips (20)	1. Stepping up and down on 45Cm. stool for 10 minutes (unrelated) 2. Turning a vertical 2 handed friction arm crank very fast for 2.5 minutes (related)		Arm Crank	1. Speed of arm movement 2. Reaction time	1. Heavy unrelated WU improve the arm speed. 2. Moderate related WU failed to improve arm speed. 3. Reaction time not influenced by WU 4. Reaction time and speed of movement are substantially uncorrelate. 5. There are reliable individual differences in fatigability

Warm-up (Preparation)		Physio. changes measured	Test (work) Performance	Type of work	Results
Passive	**Active**				
Van Huss, Albrecht, Nelson and Hagerman (31)	15 throws with gradually increased velocity followed by 10 maximal throws with 11 ounce baseball		10 throws with 5 ounce baseball using a chronoscope calibrated to 1/1,000 of a second.	Velocity and accuracy of throwing	1. Overload WU (throwing 11 ounce ball) improved the velocity of throwing. 2. The accuracy following overload WU is altered yielding a significantly different pattern of successive throws.
Falls and Weibers (6) 1.6 minute cold shower 2.6 minute hot shower	(Informal WU) (3) 25 side straddle hops; 10 push-ups; 25 sit-ups; 15 deep knee bends, 50 running on place (Formal WU) 1 minute on bicycle ergometer at 1080 Kgm/minute.	Heart rate oxygen up-take	Bicycle ergometer for 5 minutes at 1080kgm/min. Sanborn visette electro cardiograph for heart rates.	Heart rate oxygen up-take	1. Heating and cooling have physiological effects on heart rate 2. Heart rate is lower after a cold shower than a hot shower or exercise WU 3. 0_2 consumed during recovery after exercise is less after cold shower and complete rest than after hot shower

Warm-up (Preparation)		Physio. changes measured	Test (work) Performance	Type of work	Results
Passive	Active				
Richards (21)	Stool stepping. 1 minute 2 minutes 4 minutes 6 minutes		6 Trials of vertical jump.	Power	1 and 2 minute of WU improved performance 20%. 4 minutes of WU had no effect. 6 minutes of WU impaired performance 27%
Grodjinovsky and Magel (7)	Regular WU 5 minutes jogging and 8 calisthenic exercises Vigorous WU Regular WU and run 176 yards at near maximum speed	0_2 up-take	Running 60 yards Running 440 yards. Running 1 mile	Speed Speed/ Endurance Endurance	1. Regular and vigorous WU improved performance, Run time in 60 yards and 440 yards 2. Vigorous WU improved performance in 1 mile run than did regular WU. 3. No difference between 0_2 Up-takes

Warm-up (Preparation)		Physio. changes measured	Test (work) Performance	Type of work	Results
Passive	Active				
Stewart, Gutin and Lewis (28)	Pedaling 10 minutes bicycle ergometer at 60 rpm.	1. Rectal temperature 2. Heart rate (HR) 110-140-170 Muscle temperature	Monark bicycle ergometer for 10 minutes with work load at 1224 Kpm/mi.	Circulor-espiratory endurance	1. WU at 170 HR depressed the performance slightly 2. Low WU at (110 HR) did not improve endurance performance.
Bonner (1)	Pedaling a bicycle ergometer for 10 min. against 350, 500, 650, 800 or 950 kpm/min.		Pedaling a bicycle ergometer for 10 minutes against 1,632 Kpm/min.	Endurance	1. WU has net positive effect at 350 Kpm/min. and maximum effect at 650 Kpm/min. after that declines to 0 at 800 Kpm/min. and is strongly negative at 950 Kpm/min.

Warm-up and prevention of muscle injury

Although there is much uncertainty about the value of warm-up in improving performance, warm-up has been retained as standard practice on the grounds that if it has no other value it might nevertheless prevent injury to muscles; however there is no evidence to support this condition. The lack of evidence is understandable for no investigator would intentionally subject his subjects to experiments designed to bring about injury (5:452).

The main purpose of warm-up is to raise both the general body and the deep muscle temperature and to stretch the ligaments and other collagenous tissue in order to permit greater flexibility and thus to generally supply the body, thereby reducing the possibility of muscle tears, muscle soreness and ligamentous strains (11:76). It appears that muscle injury can result when vigorous exercise are not preceded by warm-up (2) because the muscles most frequently torn during strenuous activity that has not been preceded by a warm-up period are the antagonists to the strong contracting muscles. The cold antagonistic muscles relax slowly and incompletely when the agonists and the momentum of the moving part exert a terrific strain on the unyielding antagonists, with consequent tearing of the muscle fibers or their tendinous attachments (17:16).

For that, all experienced trainers believe that the best way to protect the athlete is to have him gradually fully prepared for the event; to have him properly taped where injuries may occur and that inadequate warm-up is the main cause of sudden strains or may lead to an actual tearing loose of muscle fibers from their tendinous attachment (10:329). Some athletes fail to warm-up sufficiently, intending to save themselves for competition. This is a mistaken concept.

The amount of time necessary to achieve satisfactory warm-up will vary with the individual and will tend to increase with age, (11.77) and cold weather. Objective evidence has become available in DeVries's laboratory. In an unrelated study, four college male subjects ran 100 yard dashes (against time) to measure metabolic efficiency when the subjects ran without warming up (control procedure). Two of them developed muscular soreness that might have become severe in the absence of appropriate preventive measures. Thus it seems that muscle injury is indeed a real possibility when vigorous exercise is not preceded by proper warming-up to bring about increased body temperatures (5:452). Injury obviously can occur even after warm-up but the stretching and pulling kind of muscle injury can be minimized and rendered less probable after warm-up (30).

Psychological effect of warm-up

There is a psychological effect inherent in warm-up since it helps the athlete to achieve a state of mental readiness or mind set (11:76). An effective warm-up can be an effective motivator. Athletes who get satisfaction from an effective warm-up usually have a stronger desire to participate in the activity. In contrast, a poor warm-up can lead to fatigue and boredom, limiting the athlete's attention (2).

CONCLUSIONS

Although all the results are not yet in for the warming-up phenomenon, an intelligent coach and athlete uses the best evidence to govern his activities, and the best available evidence justifies the following principles for warming-up.

1. Whole body warm-up that raises muscle and blood (rectal) temperatures can significantly improve athletic performance.

2. Wherever possible, a related warm-up (which raises muscle and blood temperatures) is preferable so that a practice effect may be simultaneously achieved.

3. Warming-up is important for preventing muscle soreness or injury.

4. Warming-up procedures must be suited to the individual.

5. Warming-up procedures must be suited to the athletic event.

6. A combination of intensity and duration of warm-up must be achieved that results in temperature increases in the deep tissues without undue fatigue. Sweating is an indication of increased internal temperature. For high level competitive performances, the additional effort of taking the rectal temperature appears worthwhile; an increase of 1 or 2^0F is desirable.

7. If active, related warm-up is impossible; passive heating can be used effectively.

8. Warming-up appears to be most important (and makes the greatest contribution) in activities that directly involve strength, and indirectly in events that have a large element of power or acceleration of body weight.

9. Overload warm-up may be valuable for events in which neuromuscular coordination patterns are of major importance.

10. Tissue temperature changes brought about by warming up probably persist for 45 to 80 minutes (5:452).

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