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Aerobic exercise training programs for the upper body

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ABSTRACT

FRANKLIN, B. A. Aerobic exercise training programs for the upper body. *Med. Sci. Sports Exerc.*, Vol. 21, No. 5 (Supplement), pp. S141–S148, 1989. Sufficient data are available to support the inclusion of upper body or combined arm-leg training in a comprehensive physical conditioning program. There is now evidence to suggest that initial fitness, as well as the intensity, frequency, and duration of training, may be important variables in determining the extent of cross-training benefits from the legs to the arms, and vice versa. Nevertheless, the limited degree of transfer of training benefits from one set of limbs to another appears to discount the practice of emphasizing leg training alone. Aerobic exercise programs for the upper body may yield significant central ($\dot{Q}$ and SV) and peripheral (a-$\bar{v}O_2$ difference) adaptations to support improvements in peak oxygen uptake ($\dot{V}O_{2peak}$) during arm and leg work, especially in subjects who are initially unfit, with the more dominant effects specific to the upper extremities. Finally, an arm exercise prescription that is based on the maximal heart rate derived from leg testing may result in an inappropriately high target heart rate for arm training. Workloads ($kg \cdot m \cdot min^{-1}$) considered appropriate for leg training will generally need to be reduced by 50–60% for arm training.

UPPER BODY EXERCISE, ARM TRAINING, ARM $\dot{V}O_{2peak}$, TRAINING SPECIFICITY, ARM EXERCISE PRESCRIPTION

Considerable information is available on exercise training techniques, particularly those involving the lower extremities (37,40). Until recently, however, there was little or no emphasis on dynamic arm exercise training, despite research that strongly supports the inclusion of this type of exercise in adult fitness and cardiac rehabilitation programs (7,27). This review summarizes the physiological basis and rationale for complementary upper body exercise regimens, with specific reference to selected arm training studies and guidelines for arm exercise prescription.

IMPLICATIONS FOR UPPER BODY TRAINING PROGRAMS: ARE TRAINING EFFECTS TRANSFERABLE?

The extent to which training effects are transferable remains a controversial issue (7). Nevertheless, the question is an important one from a practical perspective, as such information has relevance to the mechanisms underlying cardiovascular training effects and implications for exercise prescription. Several investigators have used training programs involving either arm or leg exercise in an attempt to clarify whether or not the physical conditioning effects can be generalized to exercise with untrained limbs (10,11,62). Others have studied the acute physiological responses to one- and two-leg work (13) and the peripheral and central adaptations to one-legged exercise (55).

Evidence "against" the Transfer of Training Effects

Clausen et al. (10) initially demonstrated that leg training caused a substantial decrease in the heart rate response to leg exercise, but not to arm exercise. Conversely, arm training resulted in a relative bradycardia in response to submaximal arm exercise, but not to leg exercise (Fig. 1). Similar "muscle specific" adaptations have been shown for blood lactate (42) and pulmonary ventilation (54), expressed as the ventilatory equivalent for oxygen ($\dot{V}E/\dot{V}O_2$) (Fig. 2).

Stamford et al. (60) studied the effects of high intensity arm or leg training on the peak oxygen uptake ($\dot{V}O_{2peak}$) of the upper and lower extremities in relatively fit subjects. The physical conditioning program included only three 10 to 15 minute sessions per week for 10 weeks. Subjects who participated in the arm training regimen ($N = 8$) demonstrated a 19% increase in peak $\dot{V}O_2$ during arm work; in contrast, leg $\dot{V}O_{2max}$ in these subjects increased only slightly, from 42.7 to 43.1 $ml \cdot kg^{-1} \cdot min^{-1}$. Similarly, leg-trained subjects ($N = 9$) demonstrated a 15% increase in leg $\dot{V}O_{2max}$, whereas arm $\dot{V}O_{2peak}$ remained unchanged.

Studies of single leg training have also shown no transfer of training effects to the untrained limb, but a small increase in two-leg maximal exercise performance, as measured by somatic oxygen uptake (13,55).

Additional evidence, compatible with the above research, indicates that arm training *per se* has little

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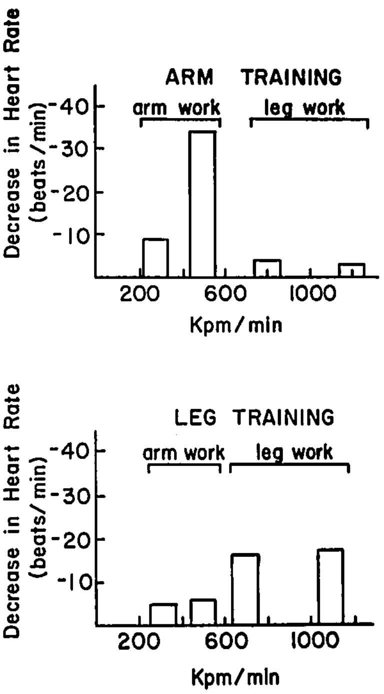

Figure 1—Group mean heart rate and workload response to arm and leg exercise before and after training. *Top*: Arm training markedly reduced the heart rate response to arm exercise; however, the heart rate response to leg exercise decreased only slightly after arm training. *Bottom*: Leg training markedly reduced the heart rate response to leg exercise; however, the heart rate response to arm exercise decreased only slightly after leg training. (Adapted from Clausen et al. (10).)

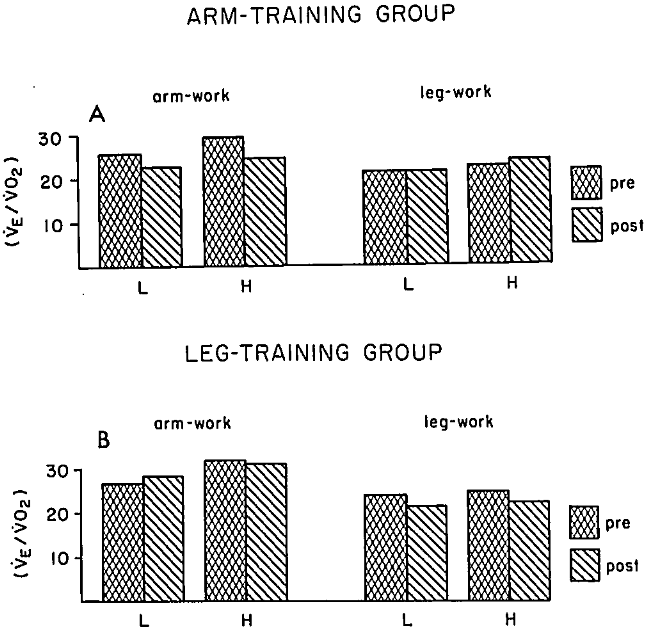

Figure 2—Ventilatory equivalents ($\dot{V}E/\dot{V}O_2$) during light (L) and heavy (H) submaximal arm and leg work before and after (A) arm training and (B) leg training. (Adapted from Rasmussen et al. (54).)

influence on the retention of leg training effects (50). These findings would appear to contradict the widely held notion that reversion to an alternative training modality during recovery from injury will result in a slowing of the detraining process, if not an absolute preservation of the cardiorespiratory fitness level.

Further support for the lack of transfer of training effects comes from the work of Gaffney et al. (31), who attempted to achieve a leg training effect at minimal levels of cardiorespiratory stress. Low-level calisthenic exercises (knee-bend, heel-lift, hip flexion, and hip extension) were performed separately with each leg, requiring less than one-third of the $\dot{V}O_{2max}$ obtained during two-leg cycle ergometer exercise. Heart rates during training were less than 125 beats·min^{-1}. The program significantly decreased the heart rate response to calisthenic exercise, but the cardiorespiratory responses to two-leg cycle ergometry remained unchanged.

Evidence "for" the Transfer of Training Effects

In contrast to the aforementioned reports, several studies (11,43,47,62) have shown some transfer of training effects, i.e., increased $\dot{V}O_{2max}$ or decreased submaximal exercise heart rate with untrained limbs, providing evidence for central circulatory adaptations to endurance training.

In a follow-up to their earlier study, using a larger number of subjects, Clausen et al. (11) confirmed that arm training failed to affect the cardiovascular response to leg exercise; however, leg training caused a significant reduction in submaximal heart rates during both forms of exercise.

Lewis et al. (43) studied the effects of arm or leg ergometer training on the peak $\dot{V}O_2$ during upper and lower extremity work in inactive subjects. The exercise program included four 30-min sessions each wk for 11 wk. Arm trained subjects ($N = 5$) demonstrated significant improvements in peak $\dot{V}O_2$ during arm and leg testing, 35% and 12%, respectively. Leg-trained subjects ($N = 5$) also showed postconditioning increases in peak oxygen uptake during leg (15%) and arm (9%) exercise. However, the findings suggested that additional limb-specific training would be required to maximize the conditioning response, particularly for the upper extremities, since the cross-trained improvement in arm $\dot{V}O_{2peak}$ was considerably below that achieved with arm training alone.

Thompson et al. (62) studied the cardiorespiratory responses of trained and untrained limbs in men with angina pectoris before and after 8 wk of arm ($N = 4$) or leg ($N = 7$) exercise training. Subjects trained for 40 min per session, 3 d·wk^{-1}, at or near the anginal threshold. Time to angina increased 3.6 min during trained limb and 1.6 min during untrained limb exercise. At a constant submaximal workload, the rate-pressure product was reduced by 35 and 18% during trained and untrained limb exercise, respectively. The arm-trained group demonstrated a 19% increase in peak $\dot{V}O_2$ during arm work and a 10% increase in leg $\dot{V}O_{2max}$; the leg-trained group showed a 10 and 8% improvement in peak oxygen uptake during leg and arm work, respectively. It was concluded that physical training improves the exercise capacity of untrained limbs in patients with angina pectoris by a generalized training effect not dependent on adaptations in trained skeletal muscle.

More recently, Loftin et al. (44) reported that endurance arm training of inactive subjects elicited significant circulorespiratory function adaptations to support improved peak oxygen uptake in both arm and leg exercise, 32% and 7%, respectively.

Although the conditions under which the interchangeability of arm and leg training effects may vary, there is evidence (Table 1) to suggest that the initial fitness of the subjects as well as the intensity, frequency, and duration of training may be important variables in determining the extent of cross-training benefits to untrained limbs (43). For example, Magel et al. (45) reported that the treadmill $\dot{V}O_{2max}$ increased only slightly after arm training in subjects with a relatively high pretraining aerobic capacity, from 56.4 to 57.2 $ml \cdot kg^{-1} \cdot min^{-1}$. In contrast, low initial arm and leg $\dot{V}O_{2peak}$ in unfit normal subjects (43) and men with angina pectoris (62) may have provided the potential for transfer effects to exercise with untrained limbs.

Rationale for Aerobic Exercise Training Programs for the Upper Body

Unfortunately, leg training programs fail to accommodate individuals who cannot perform sustained lower extremity exercise, including paraplegics, amputees, or those with orthopedic problems, neurologic disorders, disabling arthritis, or severe peripheral vascular disease (22,40). In addition, the limited degree of crossover of training benefits from one set of limbs to another appears to discount the practice of emphasizing walk-jog or cycle ergometer training exclusively. Since many recreational and occupational activities require sustained arm work to a greater extent than leg work (25,26,39), it appears reasonable to encourage individuals to train the arms as well as the legs, with the expectation of attenuated cardiorespiratory, hemodynamic and perceived exertion responses to both forms of effort.

Although upper body exercise for cardiac patients has been traditionally proscribed, numerous studies (5, 12,16,62) have now demonstrated the safety and effectiveness of arm exercise training in this population. Moreover, arm exercise in those with heart disease has not been associated with an increased incidence of dysrhythmias, ischemic ST-segment depression, or angina pectoris (23).

Several investigators (10,24) have suggested that therapeutic training programs should include the type of isometric and dynamic arm and leg exercise that most closely corresponds to that required for the person's daily activity. The rationale for this recommendation is that training effects tend to be activity-specific (7). Accordingly, such regimens should serve to maximize

TABLE 1. Age, subject characteristics, description of exercise program, and changes in trained or untrained limb $\dot{V}O_{2peak}$ after arm, leg, or combined arm-leg training in normal, cardiac, and wheelchair-confined individuals.

Reference	Subjects	Mean Age (yr)	Exercise Program Characteristics					Type Test	$\dot{V}O_{2peak}$ $(ml \cdot kg^{-1} \cdot min^{-1})$		
			Intensity	Session (min)	Frequency $(sessions \cdot wk^{-1})$	Type	Duration (wk)		Pre	Post	%Δ
Clausen et al. (11)	3 N	21–30	>170 $beats \cdot min^{-1}$	35	5	CE	5	CE	46.4	54.3	17
								AE	36.5	40.2	10
Pollock et al. (52)	8 D							AE	20.5	24.4	19
	11 N	38	≈80–85% HR_{max}	30	3	AE	20	AE	23.3	32.5	39
Magel et al. (45)	9 N	College students	≥85% HR_{max}	20	3	AE	10	AE	33.9	39.3	16
								T	56.4	57.2	1
Stamford et al. (60)	8 N	20	≥180 $beats \cdot min^{-1}$	10	3	AE	10	AE	36.9	43.9	19
								CE	42.7	43.1	1
	9 N	19	≥180 $beats \cdot min^{-1}$	15	3	CE	10	CE	42.1	48.4	15
								AE	37.0	37.0	0
Lewis et al. (43)	5 N	20	≥75–80% $\dot{V}O_{2max}$	30	4	AE	11	AE	22.8	30.8	35
								CE	37.2	41.7	12
	5 N	22	≥75–80% $\dot{V}O_{2max}$	30	4	CE	11	CE	39.2	45.1	15
								AE	25.0	27.3	9
Thompson et al. (62)	4 AP	60	To angina	40	3	AE	8	AE	12.1*	14.4*	19
								CE	13.5*	14.9*	10
	7 AP	56	To angina	40	3	CE	8	CE	14.3*	15.8*	10
								AE	13.1*	14.1*	8
Mostardi et al. (48)	6 N	31	80–95% HR_{max}	NG	3	AE, CE	6	CE	39.2	44.5	14
	5 N	30	80–95% HR_{max}	NG	3	CE	6	CE	41.3	46.8	13
DiCarlo (18)	1 SCI	24	80% HR_{max}	15–30	3	AE	8	AE	11.0	17.0	55
DiCarlo et al. (20)	4 SCI	24	60–80% HR_{max}	37	3	AE	5	AE	16.0	26.4	65
DiCarlo (19)	8 SCI	24	50–60% HRR	15–30	3	AE	8	AE	12.1	23.5	94
Loftin et al. (44)	38 N	18–35	70–90% HRR	32	4	AE	5	AE	NG	NG	32
								CE	NG	NG	7

Abbreviations: N = normals; D = disabled; SCI = spinal cord injured; AP = angina pectoris; NG = not given; CE = cycle ergometer (legs); T = treadmill; AE = arm ergometer.

* Peak $\dot{V}O_2$ values were calculated from experimental data provided.

the conditioning response through increased crossover of training benefits to real life situations.

CHRONIC ADAPTATIONS TO UPPER BODY TRAINING: RELATIVE ROLES OF CENTRAL VERSUS PERIPHERAL FACTORS

Although the acute cardiorespiratory responses to arm exercise have been well-documented (2,6,58,59, 61), few data are available regarding the effect of upper body training on the determinants of peak $\dot{V}O_2$ during arm or leg exercise, specifically cardiac output ($\dot{Q}$), stroke volume (SV) and arterial-venous oxygen difference ($a\text{-}\bar{v}O_2$ difference). With lower extremity training, the improvement in $\dot{V}O_{2max}$ appears to be more dependent on central then peripheral circulatory changes, at least for middle-aged and older men (38). On the other hand, for cardiac patients with impaired left ventricular function, it appears that peripheral adaptations predominate (17).

Magel et al. (45) studied the metabolic and cardiovascular adaptations to aerobic arm training in nine male college students. The subjects participated in 10 wk of interval training for 20 min per session, 3 $d \cdot wk^{-1}$, at a workload that elicited a heart rate of at least 85% of each subject's peak heart rate as determined by arm ergometry. The increase in peak oxygen uptake during arm work, from 33.9 to 39.3 $ml \cdot kg^{-1} \cdot min^{-1}$, was attributed to a widened $a\text{-}\bar{v}O_2$ difference, since peak $\dot{Q}$, SV, and heart rate were unchanged. These findings suggest that the conditioning response to arm training derives from extracardiac or peripheral factors, for example, alterations in blood flow and cellular and enzymatic adaptations in the trained limbs alone (13, 41,55).

In contrast, other investigators have reported significant increases in submaximal and peak $\dot{Q}$ following endurance arm training programs (11,44,59). These increases presumably contributed, at least in part, to concomitant improvements in leg $\dot{V}O_{2max}$.

Recently, Loftin et al. (44) reported that an aerobic arm training regimen in women (aged 18 to 35 yr) elicited significant central ($\dot{Q}$ and SV) and peripheral ($a\text{-}\bar{v}O_2$ difference) adaptations to support improvements in peak oxygen uptake during arm and leg work, with the more dominant effect specific to the upper extremities (Table 2). The investigators suggested that the subjects' low initial peak $\dot{V}O_2$ values during arm and leg exercise may have provided the potential for improvements in both central and peripheral metabolic and circulatory function.

Together, these studies provide some insight into the mechanisms underlying the physiologic responses to endurance arm training and the degree of adaptation in untrained limbs (i.e., transfer of training). It appears that arm training is not as effective as leg training in eliciting systemic or general effects, since it is carried out at relatively low levels of somatic oxygen uptake (7). Conditioning the upper extremities at 70% of the peak arm $\dot{V}O_2$ usually requires less than 50% of the two-leg $\dot{V}O_{2max}$. However, regular upper body aerobic exercise may yield significant improvements in central circulatory function during arm and leg work, particularly in subjects who are initially unfit (44). Moreover, SV may actually become the primary determinant of the peak $\dot{V}O_2$ during arm exercise (8).

ARM EXERCISE PRESCRIPTION

Guidelines for arm exercise prescription should include recommendations regarding four variables: (a) the "target" or training heart rate; (b) the relationship between the percentage of relative oxygen uptake (% $\dot{V}O_{2max}$) and relative heart rate (% HR_{max}) during arm ergometry; (c) the power output ($kg \cdot m \cdot min^{-1}$) that will elicit the required metabolic load for training; and (d) the proper training equipment or modalities.

Arm Exercise Training Heart Rate

Although the prescribed heart rate for upper body endurance training ideally should be derived from arm ergometer testing, this may not always be practical. Consequently, arm training heart rates are often "extrapolated" from treadmill or cycle ergometer test results. To assess the validity of this practice, we reviewed the peak heart rates (HR_{peak}) during arm and leg ergometry in normal and cardiac men, and in normal women. Table 3 shows that mean peak (or maximal) heart rates obtained during arm ergometry are equivalent to 88–98% of the maximal heart rates obtained during leg ergometry, with a mean value of 93%. In our previous studies of healthy men and women (29,63), individual peak heart rates during arm ergometry were 2–35 $beats \cdot min^{-1}$ lower than for leg ergometry.

TABLE 2. Comparison of the percent changes in central and peripheral determinants of arm and leg $\dot{V}O_{2peak}$ following endurance arm training

	$\dot{V}O_{2peak}$		$\dot{Q}$	SV	HR	$a\text{-}\bar{v}O_2$ difference
	($l \cdot min^{-1}$)	($ml \cdot kg^{-1} \cdot min^{-1}$)	($l \cdot min^{-1}$)	($ml \cdot beat^{-1}$)	($beats \cdot min^{-1}$)	($ml \cdot dl^{-1}$ blood)
Arm	33*	32*	14*	11*	2	16*
Leg	7*	7*	6*	10	−3	2

Adapted from Loftin et al. (44).

* $P < 0.05$ (pre vs post).

TABLE 3. Comparison of the peak heart rate (HR_{peak}) in response to arm and leg exercise in men and women.

Reference	HR_{peak} (beats·min^{-1}) Arms	HR_{peak} (beats·min^{-1}) Legs	HR_{peak} Diff. (legs − arms)	HR_{peak} Ratio (%) (arms/legs)
Men (normal)				
Åstrand and Saltin (2)	177	190	13	93
Stenberg et al. (61)	178	188	10	95
Bar-Or and Zwiren (4)	173	195	22	89
Bergh et al. (6)	176	189	13	93
Davis et al. (14)	184	193	9	95
Fardy et al. (22)	174	185	11	94
Magel et al. (45)	174	195	21	89
Bouchard et al. (9)	183	186	3	98
DeBoer et al. (15)	167	190	23	88
Sawka et al. (56)	169	179	10	94
Franklin et al. (29)	172	184	12	93
Pimental et al. (51)	181	188	7	96
Gleim et al. (32)	172	187	15	92
Men (cardiac patients)				
Schwade et al. (57)	122	129	7	95
DeBusk et al. (16)	142	145	3	98
Women (normal)				
Vander et al. (63)	169	177	8	95
Gleim et al. (32)	166	184	18	90
Mean	169	181	12	93

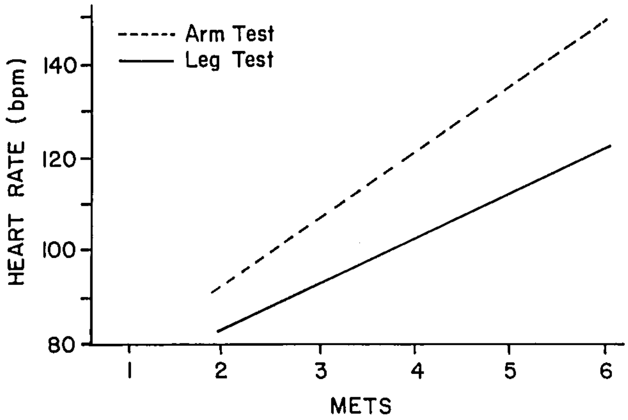

Figure 3—Comparison of the peak oxygen uptake (METs) and heart rates derived from continuous multistage arm ergometer and leg (treadmill) tests in a patient with severe arteriosclerosis in the lower extremities (Adapted from Fardy et al. (22).)

Therefore, an arm exercise prescription that is based on the chronotropic response to treadmill or leg ergometer testing may result in an inappropriately high target heart rate for arm training (29). As a general guideline, we have reduced the prescribed heart rate for leg training by approximately 10 beats·min^{-1} for arm training, using perceived exertion as a complementary method for delineating the appropriate exercise intensity.

Case report. Fardy et al. (22) provided a case report illustrating the importance of an arm ergometer evaluation in establishing the recommended heart rate for arm training. The case involved a 40-yr-old male whose peripheral vascular disease severely limited his ability for sustained walking. Preliminary arm ergometer and treadmill testing revealed a higher peak heart rate during the former, 148 vs 123 beats·min^{-1}, although peak $\dot{V}O_2$ was virtually identical for both exercise modalities (6 METs) (Fig. 3). End-points for arm and leg working capacity were muscle fatigue and ischemic pain, respectively. The patient's prescribed arm training heart rate, calculated at 85% of the peak heart rate, varied considerably depending on whether the arm or leg test results were used, corresponding to arm training heart rates of 126 or 105 beats·min^{-1}, respectively. Although the subject's functional capacity remained unchanged following a prescription that was based on the results of the initial treadmill test, he demonstrated significant improvement when the exercise training heart rate was subsequently increased on the basis of the arm ergometer test.

Relationship between % $\dot{V}O_{2max}$ and % HR_{max}

Research has shown that chronic exercise training at 57–78% $\dot{V}O_{2max}$, equivalent to approximately 70–85% of maximal heart rate (% HR_{max}), elicits favorable physiologic and metabolic adaptations that serve to enhance oxygen transport capacity (40). Since the arm and leg regressions of the % $\dot{V}O_{2max}$ on % HR_{max} are nearly identical (Fig. 4), it appears that a given percentage of peak heart rate during arm exercise (i.e., 70–85%) results in a percentage of arm $\dot{V}O_{2peak}$ that is comparable to that of leg exercise (i.e., 57–78% $\dot{V}O_{2max}$). These findings are important in that the prescribed heart rate for arm training is based on the same heart rate-oxygen uptake regression for leg training. Moreover, recent studies indicate that the heart rate-oxygen uptake relation that is determined during a graded treadmill test can be generalized to combined arm and leg exercise when the intensity is ≅70% $\dot{V}O_{2max}$ (33).

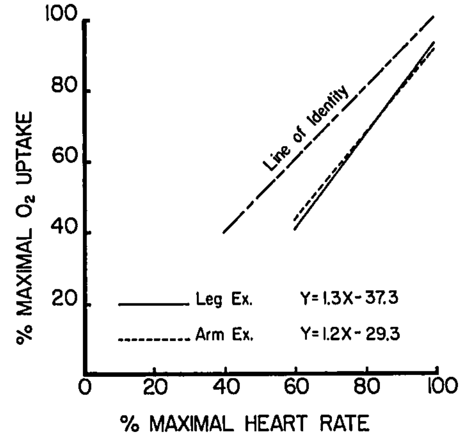

Figure 4—Regression lines during arm and leg exercise show a similar relationship between relative oxygen uptake, expressed as percent $\dot{V}O_{2max}$, and relative heart rate, expressed as percent HR_{max}. In the bivariate linear regressions, y = percent $\dot{V}O_{2max}$ and x = percent HR_{max}. (Adapted from Fardy et al. (22).)

Workloads Appropriate for Arm Training

In establishing the workload that is appropriate for arm training, it is important to emphasize that, at a given submaximal workload, arm exercise is performed at a greater physiologic cost than is leg exercise, but maximal responses are generally lower during arm exercise (2,6,32,61). Therefore, chronotropic and aerobic reserves, relative to incremental loading, are attenuated for arm training as compared with leg training, necessitating reduced workloads for the former.

In our experience, workloads approximating 40–50% of those used for leg training are appropriate for arm training (28). In other words, a subject using 300 kg·m·min^{-1} for leg training would use 120–150 kg·m·min^{-1} for arm training, demonstrating similar heart rates and perceived exertion ratings at these workloads. Others (57) have also noted comparable rate-pressure products at arm workloads approximating half of those used for leg exercise (Fig. 5).

Aerobic requirements of arm ergometry. The relative oxygen cost of arm exercise, expressed as ml·kg^{-1}·min^{-1} or METs (1 MET = 3.5 ml·kg^{-1}·min^{-1}), may be estimated from the cycle ergometer power output (kg·m·min^{-1}), corrected for body weight. Our previous studies (29) showed that the regression of oxygen uptake ($\dot{V}O_2$) on power output during arm ergometry was $y = 3.06 \times + 191$ ($y = \dot{V}O_2$ in ml·min^{-1}; x = power output in kg·m·min^{-1}), where $r = 0.91$ and $Sy \cdot x = 191.6$. Since arm $\dot{V}O_2$ (ml·min^{-1}) at a given workload demonstrated the least variability between subjects, Table 4 was constructed to predict arm $\dot{V}O_2$ in ml·kg^{-1}·min^{-1}, based on a constant absolute $\dot{V}O_2$ with a variable subject body weight (50–110 kg). These data complement previous studies (1,21,46,49,53) that facilitate the prediction of "steady-state" oxygen uptake during leg exercise, expressed as ml·kg^{-1}·min^{-1} or METs, from walking or jogging speed and percent grade, stepping height and frequency, outdoor cycling speed, or the stationary cycle ergometer load corrected for body weight.

TABLE 4. Aerobic requirements of arm ergometry.

Workload* (kg·m·min^{-1})		150	300	450	600	750
$\dot{V}O_2$ (ml·min^{-1})		648	1104	1562	2079	2431
Body Weight						
(lb)	(kg)	Oxygen consumption (ml·kg^{-1}·min^{-1})				
110	50	13.0	22.1	31.2	41.7	48.7
132	60	10.9	18.6	25.9	34.7	40.6
154	70	9.1	15.8	22.4	29.8	34.7
176	80	8.1	13.7	19.6	25.9	30.5
198	90	7.4	12.3	17.5	23.1	27.0
220	100	6.7	11.2	15.8	20.7	24.2
242	110	6.0	10.2	14.4	18.9	22.1

Adapted from Franklin et al. (29).

* Table discontinued above 750 kg·m·min^{-1} due to small sample size ($N = 1$).

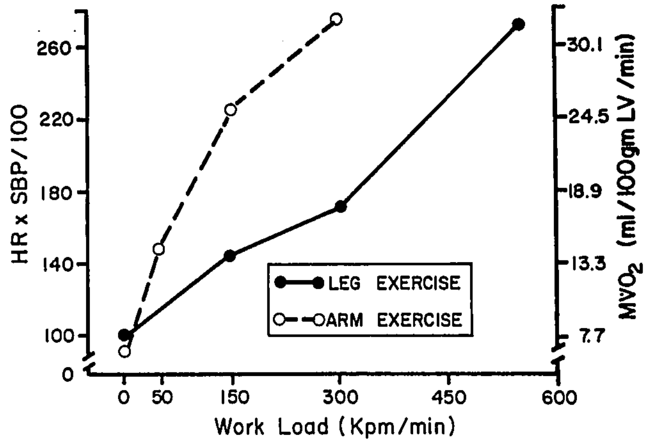

Figure 5—Rate-pressure product (HR × SBP/100) and estimated myocardial oxygen consumption ($M\dot{V}O_2$) during arm and leg exercise in patients with ischemic heart disease. Mean values for the rate-pressure product at 600 kpm·min^{-1} during leg work were not significantly different from mean values at 300 kpm·min^{-1} during arm work. (Adapted from Schwade et al. (57).)

Equipment/Training Modalities

Specially designed arm ergometers are particularly good for upper body training. Other equipment suitable for upper extremity training includes rowing machines, weight training apparatus, wall pulleys, light dumbbells, vertical climbing devices, and cross-country skiing simulators. Walking while swinging 0.45–2.27 kg hand-held weights or wrist weights can increase the oxygen consumption by 2.1–25.5 ml·kg^{-1}·min^{-1} at any given pace (3,34,64), allowing the conditioning effect to be experienced in the upper and lower extremities. However, careful observation of the blood pressure response to exercise with hand or wrist weights should be conducted before prescribing this form of exercise to hypertensive patients where an increase in cardiac afterload would be contraindicated (35).

Another excellent arm training device, particularly applicable to the gymnasium environment, includes a plastic buoy on two 6-m waxed ropes attached to four plastic handles, as previously described (30). The buoy is moved back and forth by alternately opening and closing a pair of handles.

Our experience with combined arm-leg ergometry indicates that it is more readily tolerated than arm or leg training alone. This observation has been reported by others (61) and is apparently due to the fact that more muscle mass is involved in combined arm-leg ergometry. In addition, it suggests that the perception of effort is related more to the metabolic rate per area of muscle than to the absolute oxygen uptake *per se* (48). Recently, Gutin et al. (36) found that assigning some of the power output to the arms allowed a greater metabolic load to be maintained with no greater cardiovascular or subjective strain. The investigators suggested that combined arm-leg ergometry might be particularly valuable for aerobic conditioning, cardiorespiratory rehabilitation, and weight control.

CONCLUSION

It is apparent that there is still a lack of basic knowledge regarding the degree of adaptation in untrained limbs (i.e., transfer of training). Discrepancies between studies may be attributed in part to differences in initial subject fitness, the conditioning regimens employed (i.e., intensity, frequency, duration), or both. Nevertheless, sufficient data are available to support the inclusion of arm or combined arm-leg training in a comprehensive physical conditioning program. We must conclude, as Blomqvist (7) so elegantly summarized it in 1985, that:

> ". . . .in a general sense the physiologic data support the concept that therapeutic exercise programs should not be limited to dynamic leg exercise but should include upper body activities. Exercise specifically designed to improve muscle strength may be beneficial, and the exclusion of all activities requiring predominantly static efforts is not warranted."

Like all statements of wisdom, this synopsis appears to be reasonably well-founded and practical, so clearly evident that we feel we should have known it all along.

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