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Physiological Effects of Exercising with Handweights

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Summary

Research demonstrates a positive and graded relationship between handweighted exercise energy costs, the distance through which handweights are swung and the weight used. The energy costs of handweighted exercise when swinging 0.45 to 1.36kg handweights have been shown to be 3 to 155% greater than costs of unweighted exercise at any pace. The upper limit of such increases is unknown. Moreover, the use of handweighted arm swings can convert walking, benchstepping or running from leg dominated endurance training modalities to exercises that simultaneously challenge muscles of both the upper and lower body.

The use of handweights may induce a pressor response characterised by elevated heart rate and blood pressure responses at a given exercise intensity. However, such elevations have not been consistently reproduced and when they occurred, were on average small and of little physiological concern. Individual blood pressure responses may vary more widely between handweighted and unweighted walking, with some exhibiting higher and others lower blood pressures when using handweights. Taken together, research suggests that the prescription of handweighted exercise is safe for most individuals. However, it should be prescribed using precautions similar to those used when implementing new exercise regimens, particularly among those with cardiovascular complications. Potential strength and endurance training adaptations to handweighted exercise that incorporates large arm and leg range of motion movement patterns have yet to be determined.

Handweights have become an increasingly popular addition to aerobic exercise regimens such as walking, jogging and aerobic dance. It has been suggested that handweights increase energy costs, provide a stimulus for combined upper as well as lower body endurance conditioning and strengthen the muscles of the upper torso (Schwartz 1982, 1989). However, energy costs of and cardiovascular responses to handweighted exercise have varied between investigations. Some studies demonstrate no effect of handweight on energy costs (Francis & Hoobler 1986; Zarandona et al. 1986), others a substantial effect (Auble et al. 1987; Von Hofen et al. 1989). Some advise caution when prescribing handweights for those with left ventricular complications or where an increase in afterload is contraindicated (Franklin 1989; Graves et al. 1987, 1988a,b).

This review summarises in 4 major sections the physiological effects of using handweights during aerobic exercise.These sections describe: (a) the effect of handweights on the energy costs of aerobic exercises; (b) handweights as a stimulus for both upper and lower body conditioning in a single aerobic training exercise bout; (c) potential cardiovascular risk associated with the use of handweights; and (d) the physiological adaptations that occur consequent to habitual handweighted exercise.

1. The Effect of Handweights on Aerobic Exercise Energy Costs

Research findings regarding the effect of handweights on the energy costs of exercise are mixed (table I). Studies reported energy costs for walking while using handweights that were no different than those of unweighted walk (Frances & Hoobler 1986; Zarandona et al. 1986). Others demonstrated significant but modest differences of no more than 5.9 ml/kg/min or 33% between handweighted and ordinary walk energy costs (Graves et al. 1987, 1988b; Makalous et al. 1988; Maud et al. 1990). Miller & Stamford (1987) and Zarandona et al. (1986) re-

Table I. The effect of handweight on the energy costs of walking

Handweight (kg)	$\Delta\dot{V}O_2$ (ml/kg/min)	% increase over walk	Total $\dot{V}O_2$ (ml/kg/min)	Arm movement(s)	Reference
0.45-1.36	3.6-25.5	22-155	17.3-42.7	Arm pumps through vertical distance of 0.6-1.1m	Auble et al. (1987)
0.91, 1.82	0.8-1.3	5-11	13.0-17.1	Normal arm swing of walk	Francis & Hoobler (1986)
0.45, 1.36	1.7-3.3	5-12	27.2-32.5[a]	Waist to shoulder high arm swings with 90° angle at elbow	Graves et al. (1987)
1.36	3.8	14	30.4[a]	Waist to shoulder high arm swings with 90° angle at elbow	Graves et al. (1988b)
0.45	1.0	7	14.0	Arm pumps through vertical distance of 0.3m	Makalous et al. (1988)
1.36	5.9	33	24.8	Below the waist to shoulder high arm swings with 90° angle at elbow	Maud et al. (1990)
2.27	5.7-7.1	34-44	13-25.1	Waist to shoulder high arm swings with 90° angle at elbow	Miller & Stamford (1987)
0.45, 2.27	1-4	7-27	16-19	Arm pumps through vertical distance of 0.3m	Zarandona et al. (1986)

a Walking on an inclined treadmill.

Table II. The effect of handweight on the energy costs of running

Handweight (kg)	$\Delta\dot{V}O_2$ (ml/kg/min)	% increase over walk	Total $\dot{V}O_2$ (ml/kg/min)	Arm movement(s)	Reference
0.91	11.9-12.1	41	39.5-43.8	Arm pumps through vertical distance of 0.6m	Von Hofen et al. (1989)
0.91	0.12 L/min	5	2.59 L/min	Normal arm swing of run	Claremont & Hall (1988)
0.91, 1.82	2.7-4.4	9-14	33.7-35.4	Normal arm swing of run	Francis &Hoobler (1986)
0.45, 2.27	1-2	3-5	39-40	Normal arm swing of run	Zarandona et al. (1986)

ported costs for handweighted walk that were as much as 7.1 ml/kg/min or 44% greater than those of ordinary walk when using heavier 2.27kg handweights. Somewhat surprisingly, the largest increase in the energy costs of walk occurred when using handweights lighter than 2.27kg. In an investigation by Auble et al. (1987), the energy costs for using 0.45 to 1.36kg handweights were as much as 25.5 ml/kg/min or 155% greater than those of ordinary walk.

Results for running with and without handweights were as varied as those for walking (table II). The $\dot{V}O_2$ of running while using 0.45 to 2.27kg handweights ranged from the same as (Claremont & Hall 1988; Zarandona et al. 1986) to as much as 41% greater than (Von Hofen et al. 1989) costs for ordinary running at the same speed.

These seemingly ambiguous findings could in part be attributed to variations in the combination of walking or running speed and handweight used. Walking speeds ranged from 0.9 to 2.0 m/sec and running speeds from 2.2 to 3.1 m/sec. Handweights ranged from 0.45 to 2.27 kg. However, even when comparisons are limited to one speed and handweight combination, large differences persist (table III). Thus, factors other than speed and handweight must contribute to the widely divergent effect of handweights on the aerobic requirements of exercise.

1.1 Variations in Arm Movement Patterns

The magnitude of the effect of handweights on the energy costs of exercise is most closely related to variations in arm movement patterns. Two investigations demonstrate this effect. In one study, subjects walked at both 1.3 and 1.8 m/sec while using 0.91kg handweights (Auble et al. 1987). The arm swings used forced the arms upward from full extension at the side, while flexing them about the elbow (pumping). Pumps ended with the weights in line with the vertical axis of the body. Pump height was systematically increased in 0.15m increments from 0.61 to 1.07m. Within both walking speeds, the $\dot{V}O_2$ of handweighted walk increased with each incremental change in pump height (fig. 1). These increases were not trivial. For example, when walking 1.8 m/sec, an increase in pump height from 0.61 to 1.07m increased the $\dot{V}O_2$ of handweighted walk by 15.5 ml/kg/min (from 27.2 to 42.7 ml/kg/min). It is clear from these results that there is a positive and graded dose-response relationship between arm range of motion and the effect of handweight on the energy costs of walk.

A second study extends this conclusion to running (Von Hofen et al. 1989). When subjects ran while using 0.91kg handweights, the $\dot{V}O_2$ of running while pumping the hands shoulder high was 41% greater than that of ordinary running whereas this difference was an insignificant 5% when weights were simply carried. Even pumping unweighted arms increased the $\dot{V}O_2$ of ordinary running by 19%. Although these findings are specific to walking and running in combination with arm pumps, they strongly suggest that the effect of handweight on the energy costs of exercise is closely linked to the distance through which they are moved, regardless of arm stroke pattern or exercise modality.

One might therefore speculate that reported differences in the effect of handweights on the energy costs of exercise are primarily a function of differences in arm range of motion. Inspection of tables I and II supports this hypothesis. The effect of handweights on energy costs tends to increase with increasing arm range of motion. The smallest effect of handweights occurred in those studies in which they were either carried or swung through a vertical distance of 0.30m. The absolute and percentage increases in the $\dot{V}O_2$ of walk and run tended to be somewhat greater when handweights were swung to shoulder height ending with a 90° angle at the elbow. In turn, pumping handweights through vertical distances of 0.61 to 1.07m resulted in substantially greater increases in $\dot{V}O_2$.

It is probable that factors other than the vertical distance through which any given handweight travels may affect energy costs. Distances through which handweights are swung other than vertically probably affect energy costs (Maud et al. 1990). The effect of the same vertical distance may be dependent on anatomical differences between individuals. Leg stride frequencies were both freely selected (Francis & Hoobler 1986; Graves et al. 1987, 1988a,b; Makalous et al. 1988; Maud et al. 1990; Miller & Stamford 1987; Zarandona et al. 1986) and standardised (Auble et al. 1987) within specific walking speeds, possibly causing differences in energy costs due to variations in stride efficiency. Thus, although vertical distance is an important determinant of handweighted exercise energy costs, exercise prescriptions based on this criterion should be considered as approximations.

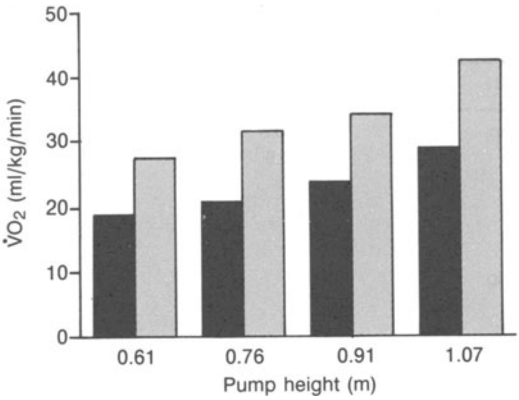

Fig. 1. The effect of arm range of motion on the aerobic requirements of walking at 1.34 (■) and 1.79 (□) m/sec while pumping 0.91kg handweights (adapted from Auble et al. 1987).

1.2 Interaction Between Arm Range of Motion and Change in Handweight

One would assume that the weight held in each hand is another key factor regulating the energy costs of walk. Indeed, more studies manipulated handweight (Auble et al. 1987; Claremont & Hall 1988; Francis & Hoobler 1986; Graves et al. 1987; Maud et al. 1990; Zarandona et al. 1986) than arm range of motion (Auble et al. 1987; Maud et al. 1990; Von Hofen et al. 1989). The effect of changes in handweight of 0.91kg on walk and run energy costs are presented in table IV. It is evident that changes in handweight can have a considerably varied effect on changes in $\dot{V}O_2$ and that this effect is a function of differences in arm range of motion. For example, Francis and Hoobler (1986) reported no difference in the energy costs of holding either

Table III. The effect of 0.45kg handweights on the energy costs of walking at approximately 1.57 m/sec

Speed (m/sec)	$\Delta\dot{V}O_2$ (ml/kg/min)	% increase	Reference
1.57	3.6-15.0	22-91	Auble et al. (1987)
1.52	1.0	7	Makalous et al. (1988)
1.66	1.9	8[a]	Graves et al. (1987)
1.57	1.0	6	Zarandona et al. (1986)

a Walking on an inclined treadmill.

Table IV. The effect of a 0.91kg increase in handweight on the energy costs of walking (approximately 1.57 m/sec) and running (2.2 m/sec)

Modality	$\Delta\dot{V}O_2$ (ml/kg/min)	Arm range of motion	Reference
Walking	3.2-3.3	0.61m pump height	Auble et al. (1987)
	9-10.5	1.07m pump height	Auble et al. (1987)
	0.4	Carried handweights	Francis & Hoobler (1986)
	1.4	Swung handweights from waist to shoulder height (90° at elbow)	Graves et al. (1987)
Running	1.8	Carried handweights	Francis & Hoobler (1986)
	1.8	Carried handweights	Von Hofen et al. (1989)
	7.0	0.60m pump height	Von Hofen et al. (1989)

0.45 or 1.82kg handweights when walking. By comparison, the same incremental change in handweight when walking while pumping the hands through a vertical distance of 0.61m increased the $\dot{V}O_2$ of walk by as much as 3.3 ml/kg/min (Auble et al. 1987). The effect was more dramatic when pumping handweights 1.07m high. Under this condition, the $\dot{V}O_2$ of walk and pump was boosted by as much as 10.5 ml/kg/min. A similar pattern occurs when running. An incremental change in handweight of 0.91kg increased the $\dot{V}O_2$ of running by 1.8 ml/kg/min or less when handweights were simply carried compared to an increase of 7.0 ml/kg/min when handweights were pumped shoulder high. Taken together, these findings suggest an interaction between changes in handweight and arm range of motion; the greater the distance through which handweights are moved, the greater the effect of changes in handweight on energy costs.

1.3 Exercise Prescription Implications of Handweighted Exercise Energy Costs

It is by now evident that the effect of handweights on the energy costs of exercise can be substantial. However, total energy costs should be considered when prescribing endurance training exercise. As might be expected, the total $\dot{V}O_2$ of handweighted walk and run is dependent on arm range of motion (table I). In those investigations in which 0.45 to 1.82kg handweights were carried, swung through a vertical distance of 0.30m or swung to shoulder height and ending with a 90° angle at the elbow, the $\dot{V}O_2$ of handweighted walk on a level treadmill was limited to 25 ml/kg/min or less, an appropriate endurance training stimulus for those with low to modest levels of aerobic fitness.

Handweighted walk costs can be much greater if handweights are used in combination with larger arm ranges of motion. Auble et al. (1987) reported energy costs of 31.5 ml/kg/min when fit young males pumped 0.45kg handweights through a vertical distance of 1.07m, a cost equivalent to that estimated for running 2.4 m/sec [American College of Sports Medicine (ACSM) 1986]. When these conditions were combined with 1.36kg handweights, the $\dot{V}O_2$ climbed to 42 ml/kg/min, an energy cost 2.5 times that of ordinary walk at the same speed and equivalent to estimated costs for running 3.2 m/sec (ACSM 1986). A similar pattern occurred when running (Von Hofen et al. 1989). When 0.45 or 0.91kg handweights were carried, the $\dot{V}O_2$ of handweighted running was not different than that of ordinary running. In contrast, in fit young men pumping 0.91kg handweights through a height of 0.61m increased the $\dot{V}O_2$ of unweighted jogging at 2.2 m/sec to costs approximating those of a 3.1 m/sec run (from 27.4 to 39.5 ml/kg/min).

Thus, one can progress to higher energy costs within an exercise modality through the addition of handweighted arm strokes instead of increases in walking or running speed. Conversely, prescribed walking and running speeds must be slowed when large range of motion handweighted arm movements are added if exercise intensities are to remain unchanged.

Handweighted walk costs can be manipulated further by adding leg stride variations. Cyclic leg flexion/extension movements or 'dips' combined with arm pumps to the top of the head while holding 1.36kg handweights can generate energy costs 513% of those of ordinary walk, costs equivalent to running 3.7 m/sec (Auble & Schwartz 1988). In practical terms, these research findings alter the prescription limits of walking. Walkers can progress to higher energy costs without the need to run by adding handweighted arm strokes or leg stride variations. The latter means of progression may be preferred by those who would rather walk than run or who may be susceptible to lower extremity injuries caused by the higher impact forces of run.

Is there an upper limit to handweighted exercise energy costs? Certainly, limb range of motion within a given movement pattern is limited. However, the amount of weight and the frequency of limb movements is not. Research suggests that handweighted exercises can be customised through modifications in walking or running speed, arm stroke and leg stride frequency, handweight and most importantly, limb range of motion to provide energy costs sufficient for the conditioning of individuals whose fitness ranges from poor to excellent (Auble et al. 1987). Thus, the energy costs of handweighted exercise are likely open-ended; limited only by one's level of fitness or possibly upper body orthopaedic limitations that preclude certain arm movement patterns.

2. *'Cross-Training' with Handweighted Exercise*

Endurance training modalities such as walking, running or cycling can improve both peak cardiovascular capacity and submaximal cardiovascular efficiency. However, these improvements tend to be specific to activities involving muscles of the lower body with little transfer of these effects to upper body activities (Franklin 1989). Yet, most occupational and recreational activities require combined upper and lower body work or, at times, upper body work alone. Moreover, these life functions often rely on upper body strength. Ideally, a single exercise modality should cross-train muscles in both the upper and lower body simultaneously for endurance and strength.

Handweighted aerobic exercise may provide such a stimulus. Vigorous arm swings increase upper body power output requirements and thereby the rate of upper body skeletal muscle oxygen consumption (Auble et al. 1987; Goss et al. 1987). The contribution of the upper body to the total $\dot{V}O_2$ of handweighted exercise is difficult to determine. However, it can be estimated as the difference between the $\dot{V}O_2$ of handweighted and nonhandweighted aerobic exercise or $\Delta\dot{V}O_2$ (Goss et al. 1987), or the relative contribution of upper body to total body $\dot{V}O_2$ can be expressed as the ratio of $\Delta\dot{V}O_2$ to total $\dot{V}O_2$ of handweighted exercise.

The estimated upper body contribution to $\dot{V}O_2$ for each handweighted walk and run investigation in which 0.45 to 1.82kg handweights were used is summarised in table V. The contribution ranges from 3 to 61% of the total body $\dot{V}O_2$. Within those investigations that used small to modest arm swings ranging from carrying to swinging handweights to shoulder height, the upper body contribution is 31% or less. In contrast, it is as much as 61% when pumping handweights through vertical distances of 0.61 to 1.07m. The findings of Auble et al. (1987) demonstrate graded relationships between both arm range of motion and handweight and upper body contribution (fig. 2).

Even though these upper body contribution values are estimates, they indicate that handweighted arm movements can effectively convert leg-dominated exercises to regimens that cross-train both the upper and lower body simultaneously. Moreover, since each arm swing is resisted by the combined weight of the arm and handweight, handweighted exercise may stimulate a unique combination of both strength and endurance adaptations. We suspect that along this strength-endurance continuum, the use of heavier handweights may emphasise strength and lighter handweights speed and endurance adaptations. However, this hypothesis remains to be tested.

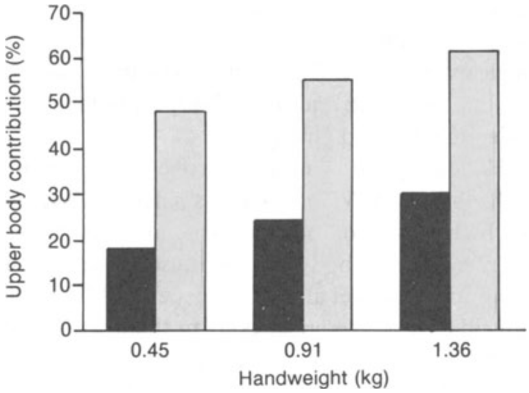

Fig. 2. The relative contribution of the upper body (UB) to the energy costs of handweighted walking with arm pumps through a vertical distance of 0.6m (■) and 1.07m (□) [calculated from Auble et al. 1987].

3. *Physiological and Perceptual Responses to Handweighted Exercise*

Handweighted exercise research has focused on whether the use of handweights induces a pressor response due to gripping. Hand grip forces superimposed on dynamic exercise cause isometric contractions that result in a pressor reflex characterised by heart rate (HR), blood pressure (BP) and cardiac output (Q) responses disproportionately greater than those of dynamic exercise alone (Kiblom & Persson 1981; Lind & McNicol 1967; Mitchell et al. 1981; Nelson et al. 1974). Such elevations are indicative of an increase in myocardial oxygen demand and therefore cardiovascular strain, a potentially undesirable outcome for those with left ventricular complications or in whom increased afterloads are contraindicated. In this section, physiological responses to handweighted exercise, possible contributing mechanism to these responses, an evaluation of cardiovascular risks related to the use of handweights, and perceptions of exertion during handweighted exercise are considered.

3.1 Physiological Responses to Handweighted Exercise

Differences between physiological responses to handweighted and nonhandweighted exercise at submaximal intensities have been inconsistent. Among normotensives or subjects of unspecified blood pressure status, heart rates during handweighted walking (Graves et al. 1987, 1988b; Zarandona et al. 1986) and handweighted bench stepping (Goss et al. 1987) were the same as those of ordinary walk at a given $\dot{V}O_2$. Moreover, Q and stroke volume (SV) were not different between handweighted bench stepping and ordinary walking (Goss et al. 1987).

Blood pressure and rate pressure product (RPP) responses for handweighted and unweighted walking at the same $\dot{V}O_2$ or HR were less consistent. Zarandona et al. (1986) found no differences between the systolic (SBP) and diastolic blood pressure (DBP) responses to handweighted and ordinary walking or running. Graves et al. (1987, 1988a,b) reported either an increase in SBP (+9mm Hg) or DBP (+5mm Hg) but not both during handweighted versus ordinary walk. RPP when using handweights was either unchanged or slightly elevated (Graves et al. 1987, 1988a,b).

Individual differences in BP responses between handweighted and unweighted walk were more marked. Among normotensives, SBP during handweighted walk ranged from 16mm Hg lower to 24mm Hg higher than during unweighted walk, with more subjects exhibiting increases than decreases (Graves et al. 1988b). Among hypertensive responders to exercise, the extremes were somewhat greater, ranging from −36 to +28mm Hg when using handweights (Graves et al. 1988a). Surprisingly, more subjects exhibited higher SBPs when walking without handweights than with handweights. The lack of a consistent elevation in either the average or individual heart rate, SBP, DBP, Q and RPP responses when using handweights suggests that if a pressor reflex occurred, it was small.

If gripping handweights during dynamic exercise does cause a pressor reflex, then it should occur when holding handweights but not when wearing them on the wrists. However, research findings are equivocal. Among normotensives, DBP (Graves et al. 1988b) or SBP, DBP and HR (Abadie 1990) were elevated compared to ordinary walk when holding handweights but not when wearing wrist weights, evidence in support of a pressor reflex. But, when hypertensive responders to exercise held handweights while walking (Graves et al. 1988a), the HR, SBP and DBP responses during both hand- and wristweighted conditions were elevated compared to walking without weights but were similar for the two weighted conditions, arguing against a pressor reflex mechanism.

That BP and HR responses when using handweights were elevated compared to unweighted or wristweighted exercise in some but not other studies may be due to variations in hand grip force. The more intense an isometric contraction, the greater the elevation in HR, SBP and DBP (Lind 1983). Since a strapped weight designed to minimize the need to grip was used in all investigations, grip forces should have been minimal. Nevertheless, some may still grip weights, particularly those unfamiliar with handweighted exercise. It is therefore possible that handweights were gripped more forcefully in those studies reporting elevations in HR, SBP and DBP relative to unweighted exercise or in those individuals with marked increases in these same responses. Moreover, some may elect to use handweights that do not include a strap. Under these conditions, handweights must be gripped, possibly more forcefully than when strapped weights are used. Consequently, a pressor reflex may be unavoidable and potentially more intense than reported thus far for using strapped weights.

Alternatively, reported variations in the effect of handweights on physiological responses may have been caused by differences in the relative contribution of the upper body to total body metabolic requirements. Physiological responses to combined arm and leg ergometry and leg alone cycling at a given submaximal $\dot{V}O_2$ are the same when upper body power outputs represent 60% or less of the total body power output (Toner et al. 1983). When the arms contribute 100% of the work the arm exercise HR, SBP, DBP and RPP are elevated (Bevegard et al. 1966; Stenberg et al. 1967). Moreover, the peak $\dot{V}O_2$ of combined arm and leg ergometry is highest when the arms contribute 10 to 30% of the total body power output (Bergh et al. 1976; Nagle et al. 1984). Peak $\dot{V}O_2$ is reduced when upper body power outputs exceed 30 or 40% of the total body power output.

The relative contribution of the upper body did vary between handweighted exercise studies (table V). However, it is estimated to have been 20% or less within those investigations that compared handweighted and non-handweighted exercise responses at a given intensity (Graves et al. 1987, 1988b; Goss et al. 1987; Zarandona et al. 1986). While these findings are of interest, upper body contribution to $\dot{V}O_2$ is estimated to be as much as 61% when using 0.45 to 1.36kg handweights (Auble et al. 1987) and would likely be even higher when using heavier weights. However, physiological responses to such handweighted exercise workload combinations are unknown. Combined arm and leg ergometry research suggests that most handweighted exercise movement combinations in which upper body contribution is 60% or less may not cause disproportionate increases in HR or BP. However, it may be inappropriate to generalise the findings of one combined exercise modality to another. Handweighted exercise research should shift its focus from the study of small and less metabolically effective arm movements toward the study of larger arm movement patterns that provide a greater challenge to the upper torso.

Submaximal physiological responses tend to be proportional to the relative intensity of exercise. If the peak oxygen consumption of handweighted exercise were less than that of ordinary walk, then differences in the relative intensity of these exercise modalities at a given $\dot{V}O_2$ might in part explain an elevation in responses when using handweights. However, in the only study of peak physiological responses to handweighted exercise, peak $\dot{V}O_2$ and other peak metabolic responses were the same during handweighted and ordinary walk (Graves et al. 1987). Thus, variations in hand grip force and/or the distribution of work between the upper and lower body seem more plausible mechanisms.

3.2 Risks Associated with Physiological Responses to Handweighted Exercise

Whatever the mechanism for reported elevations in HR, SBP or DBP when using handweights, it is important to consider whether such elevations

Table V. The relative contribution of the upper body (UB) to the energy costs of handweighted exercise

Modality	Handweight (kg)	UB (%)	Arm movement	Reference
Walking	0.45-1.36	18-61	Arm pumps through vertical distances of 0.6 to 1.07m	Auble et al. (1987)
	0.91, 1.82	4-10	Normal arm swing of walk	Francis & Hoobler (1986)
	0.45, 1.36	5-12[a]	Waist to shoulder high arm swings with 90° at elbow	Graves et al. (1987)
	1.36	13[a]	Waist to shoulder high arm swings with 90° at elbow	Graves et al. (1988b)
	0.45	7	Arm pumps through vertical distance of 0.30m	Makalous et al. (1988)
	1.36	31	Below the waist to shoulder high arm swings ending with 90° angle at elbow	Maud et al. (1990)
	0.45	6	Arm pumps through vertical distance of 0.30m	Zarandona et al. (1986)
Running	0.91	27-31	Arm pumps through vertical distance of 0.60m	Von Hofen et al. (1989)
	0.91, 1.82	8-12	Normal arm swing of run	Francis et al. (1986)
	0.45	3	Arm pumps through vertical distance of 0.30m	Zarandona et al. (1986)
Bench-stepping	0.91	20	Arm pumps through vertical distance of 0.61m	Goss et al. (1987)

a Walking on an inclined treadmill.

pose a clinical risk particularly for those with coronary artery disease. Elevations in one or more of these responses may be indicative of greater myocardial oxygen demand at a given exercise intensity and therefore an increase in cardiovascular strain. Since SBP, DBP and HR may be elevated in some cases when using handweights compared to unweighted or wristweighted exercise (Abadie 1990; Graves et al. 1987, 1988a,b), the use of handweights is often qualified with statements of caution for those with left ventricular complications or in whom an increased afterload is contraindicated (Abadie 1990; Franklin et al. 1989; Graves et al. 1987, 1988a,b; Makalous et al. 1988).

These cautions may on average be unwarranted. The SBP of handweighted walking was either the same as (Graves et al. 1988a,b; Zarandona et al. 1986) or within 9.0mm Hg of (Abadie 1990; Graves et al. 1987) unweighted walking. When the SBP of handweighted walking exceeded that of unweighted walking (Abadie 1990; Graves et al. 1987), the absolute pressure was 182mm Hg or less (table VI). The DBP of handweighted walking was either the same as (Graves et al. 1987; Zarandona et al. 1986) or within 7.0mm Hg of (Abadie 1990; Graves et al. 1988a,b) unweighted walking. When the DBP of handweighted walking exceeded that of unweighted walking (Abadie 1990; Graves et al. 1988a,b), the absolute pressure was either less than 90mm Hg or less than resting DBP (table VI). Thus, although the SBP and DBP of handweighted walking were in some investigations greater than those of unweighted walking, differences were on average small and of little physiological concern (Graves et al. 1988a).

The findings of Niederberger et al. (1974) support this conclusion. Physiological responses of cardiac patients to stationary cycling, a commonly prescribed exercise modality, and walking on a treadmill were compared. When exercising at 75%

of $\dot{V}O_{2max}$, the predicted mean arterial pressure (MAP) for cycling averaged approximately 12 to 13mm Hg more than that for walking. In contrast, differences between the MAP of handweighted and unweighted walking have averaged 5mm Hg or less (table VII).

But, what of the wider variation in individual responses reported when using handweights? In a study by Graves et al. (1988a), some hypertensive responders to exercise exhibited SBP responses during handweighted walking as much as 28mm Hg higher than those of unweighted walking. These findings have led to the conclusion that handweighted walking should be prescribed with caution, particularly for those with left ventricular complications. However, the same study demonstrated that others exhibit the opposite response pattern. The SBP of handweighted walking in one subject was 36mm Hg higher during unweighted walking than it was when using handweights. Moreover, most subjects exhibited the latter tendency. These case reports suggest that it may be as risky to prescribe walking without handweights for some as it would be to prescribe handweighted walk for others.

In this context, it may be that modest differences in BP responses between exercise modalities may not accurately represent cardiovascular strain during exercise. Blood pressure guidelines exist for the termination of maximal graded exercise testing (ACSM 1986). However, none exist for regular exercise. Furthermore, static or static-dynamic contractions during exercise may not necessarily cause undue cardiovascular strain. Research demonstrates that the incidence of ischaemic responses (ST segment depression, angina or arrhythmias) in cardiac patients when weight-training, walking while carrying weighted boxes, or intentionally gripping while walking are similar to or less than those of dynamic exercise (DeBusk et al. 1978; Kelemen et al. 1986; Kerber et al. 1975; Hung et al. 1982; Shedahl et al. 1983; Stewart et al. 1988). The attenuation of ischaemic responses may be attributable to enhanced myocardial perfusion caused by elevations in DBP (Kerber et al. 1975).

Many work and recreational functions include the upper body and include gripping (e.g. gripping tennis rackets, carrying bags and boxes, using house and garden tools, using oars when rowing or poles when skiing). It may be more prudent to prescribe total body exercises that mimic these situations during conditioning rather than avoiding them. Handweighted walking may be a convenient training modality for this purpose. Taken together, research suggests that on average handweighted walking can be safely prescribed. However, for some individuals, wide variations in blood pressure responses between handweighted and unweighted walking may suggest the use of one method over the other for training. Thus, handweighted walking should be prescribed using precautions similar to those used when implementing any new unweighted exercise regimen, particularly among those with known or suspected cardiovascular disease.

Finally, subjects used in handweighted exercise research had not trained with handweights. Physiological responses during either submaximal or peak handweighted exercise in trained subjects are unknown. Training, whether of the arms or legs, tends to attenuate HR, SBP, DBP and RPP re-

Table VI. Systolic and diastolic blood pressure responses during handweighted walk

Subject BP characteristics	Resting BP (mm Hg)		Handweighted walking BP (mm Hg)			Reference
	SBP	DBP	intensity	SBP	DBP	
Unknown	128	84	Unknown	182	89	Abadie (1990)
Normotensives	128	87	75% HRR_{max}	160	78	Graves et al. (1987)
Hypertensive responders	145	96	75% HRR_{max}	201	91	Graves et al. (1988a)
Normotensives	122	84	75% HRR_{max}	182	74	Graves et al. (1988b)

Abbreviations: BP = blood pressure; SBP = systolic blood pressure; DBP = diastolic blood pressure; HRR_{max} = heart rate reserve.

sponses at a given submaximal power output. These adaptations are specific to the muscles used during chronic exercise (Franklin 1989). One might therefore expect a diminution or possible reversal of the differences reported by some between handweighted and unweighted exercise responses consequent to training. Research into the chronic effects of handweighted training on physiological responses is needed to test these hypotheses.

Table VII. Comparisons of mean arterial pressures (MAP) [calculated from SBP and DBP responses] between handweighted and ordinary walk at 75% HRR_{max}

MAP (mm Hg)			References
unweighted	handweighted	Δ MAP	
100	105	+5	Graves et al. (1987)
130	128	−2	Graves et al. (1988a)
106	110	+4	Graves et al. (1988b)

3.3 Perceptions of Exertion During Handweighted Exercise

The work of combined arm and leg exercise may be perceived to be easier than leg alone exercise. Graves et al. (1988b) reported ratings of perceived exertion (RPE) that were the same for handweighted and ordinary walk even though the $\dot{V}O_2$ of the former was 14% higher. These findings were consistent with those of Gutin et al. (1988). RPEs for combined arm crank and leg cycle exercise were the same in spite of energy costs that were 10% higher during combined exercise. Others have reported a tendency to tolerate combined arm and leg exercise more readily than leg only exercise at both peak (Åstrand 1977) and submaximal intensities (Franklin 1989). The sense of relative ease during combined arm and leg exercise has been attributed to spreading the metabolic workload across a greater mass of muscle during combined arm and leg versus leg alone exercise, thereby reducing the metabolic demand on any one group of muscles (Åstrand 1977; Gutin 1988). Thus, combined upper and lower body exercise modalities such as handweighted exercise may enable one to work more intensely, thereby enhancing both the cardiovascular conditioning and weight control benefits of exercise (Gutin et al. 1988).

4. Adaptations to Handweighted Exercise Training

Few studies regarding the effect of handweights on physiological adaptations to exercise have been conducted. Ewing et al. (1987) reported no effect of training by running with or without handweights on either $\dot{V}O_{2max}$ or shoulder/elbow strength. Blessing et al. (1987) found no effect of aerobic dance training with or without handweights on the $\dot{V}O_{2max}$. Together, these findings suggest that the addition of handweights to aerobic exercise training regimens may not enhance either upper body strength or cardiovascular function beyond that possible by exercising without handweights.

However, these conclusions may not be applicable to all handweighted training regimens. In the study by Ewing et al. (1987), handweights were carried. This limited range of arm motion likely offered the aerobic stimulus to the muscles of the upper body. Moreover, the handweight used was relatively light, progressing from 0.45 to 1.36kg across an 8-week training period. Only the final 3 weeks were spent carrying 1.36kg in each hand. Thus, the stimulus for strength changes was probably small. Furthermore, the Bruce protocol was used to measure changes in endurance capacity. Although an appropriate test to assess overall changes in cardiovascular fitness, additional tests would have been required to detect possible differences between the groups in upper body endurance capacity.

The aerobic dance study by Blessing et al. (1987) may also have limited the training stimulus to the upper body. The handweights used were light (0.45kg) and the handweighted exercise time per training session was limited to 20 minutes or less of the 45-minute exercise period (the rest was dancing without handweights). Moreover, the same arm and leg movement choreography was used by both training groups. Since exercise heart rates were the same with or without handweights, the handweighted group may have maintained metabolic activity levels similar to those of the unweighted group by using less extensive arm and leg movements (Blessing et al. 1987). And again, the use of a standard uphill walking/jogging maximal graded exercise test precluded the detection of potential differences between the groups in upper body endurance capacity.

The design of handweighted exercise training studies should be modified if we are to determine whether or not handweights can be of benefit. First, evidence exists to show that handweights are of little benefit when carried. Training studies should now incorporate large arm range of motion movements that effectively challenge the muscles of both the upper and lower body simultaneously. Second, combined arm and leg movement patterns should be carefully defined, controlled, measured and reported to provide a context for interpretation and comparison of results. Finally, standard tests using uphill walking/jogging protocols should be augmented by tests specifically designed to examine the combined upper and lower body, strength-endurance, cross-training adaptations that may occur consequent to handweighted exercise training. Without these methodological changes, conclusions regarding the potential value of handweighted training will be severely limited.

5. *Conclusions*

The energy costs of handweighted exercise can greatly exceed that of unweighted exercise. The aerobic requirements of handweighted walk or run increase with increasing speed, handweight and most importantly, arm range of motion. The greater the distance through which handweights are swung, the greater the effect of any given handweight or change in handweight on total body $\dot{V}O_2$. Moreover, the addition of such handweighted arm swings to walking or running can convert these exercise modalities from leg dominated to combined upper and lower body cross-training regimens.

The use of handweights may elevate HR and BP responses compared to unweighted exercise at a given exercise intensity. However, such elevations have not been consistently reproduced and when they occurred, were on average small. Individual blood pressure responses for handweighted walking have been shown to vary more widely, ranging from 36mm Hg less than to 28mm Hg more than those of unweighted walking. Thus, evidence suggests that handweighted exercise is safe for most individuals. However, it should be prescribed using precautions similar to those used when implementing any new exercise modality, particularly among those with cardiovascular complications. Handweighted exercise training studies using carefully documented, large range of motion arm movements and methods to test potential strength and endurance cross-training adaptations related to such movements remain to be conducted.

References

Abadie BR. Physiological responses to grade walking with wrist and hand-held weights. Research Quarterly 61: 93-95, 1990

American College of Sports Medicine. Resource manual for guidelines for exercise testing and prescription, Lea & Febiger, pp. 126, 128, Philadelphia, 1988

American College of Sports Medicine. Guidelines for graded exercise testing and prescription, 3rd ed., pp. 20, 33-36, 40-42, 171, Philadelphia, 1986

Åstrand PO, Rodahl K. Textbook of physiology – physiological bases of exercise, 2nd ed., pp. 306, McGraw-Hill Book Co., New York, 1977

Auble TE, Schwartz L. Speed and frequency effects on handweighted walk energy costs. Presented at the American College of Sports Medicine Annual Meeting, 1988

Auble TE, Schwartz L, Robertson RJ. Aerobic requirements for moving handweights through various ranges of motion while walking. Physician and Sportsmedicine 15: 133-140, 1987

Bergh U, Kanstrup I-L, Ekblom B. Maximal oxygen uptake during exercise with various combinations of arm and leg work. Journal of Applied Physiology 41: 191-196, 1976

Bevegard S, Freyschuss U, Strandell T. Circulatory adaptation to arm and leg exercise in supine and sitting position. Journal of Applied Physiology 21: 37-46, 1966

Blessing DL, Wilson GD, Puckett JR, Ford HT. The physiologic effects of eight weeks of aerobic dance with and without handheld weights. American Journal of Sports Medicine 15: 508-510, 1987

Claremont AD, Hall SJ. Effects of extremity loading upon energy expenditure and running mechanics. Medicine and Science in Sports and Exercise 20: 167-171, 1988

DeBusk R, Valdez R, Houston N, Haskell W. Cardiovascular responses to dynamic static effort soon after myocardial infarction: application to occupational work assessment. Circulation 58: 368-375, 1978

Ewing A, Vandeputte H, Francis K. Effects of exercise with light hand weights on strength. Journal of Orthopaedic and Sports Physical Therapy 8: 533-536, 1987

Francis K, Hoobler T. Changes in oxygen consumption associated with treadmill walking and running with light hand-carried weights. Ergonomics 29: 999-1004, 1986

Franklin BA. Aerobic exercise training programs for the upper body. Medicine and Science in Sports and Exercise 21: S141-S148, 1989

Goss FL, Robertson RJ, Spina RJ, Auble TE, Cassinelli DA, et al. Are treadmill-based exercise prescriptions generalizable to combined arm and leg exercise? Journal of Cardiopulmonary Rehabilitation 7: 551-555, 1987

Graves JE, Martin AD, Miltenberger JL, Pollock ML. Physiological responses to walking with hand weights, wrist weights, and ankle weights. Medicine and Science in Sports and Exercise 20: 265-271, 1988b

Graves JE, Pollock ML, Montain SJ, Jackson AS, O'Keefe JM. The effect of hand-held weights on the physiological responses to walking exercise. Medicine and Science in Sports and Exercise 19: 260-275, 1987

Graves JE, Sagiv M, Pollock ML, Miltenberger LA. Effect of hand-held weights and wrist weights on the metabolic and hemodynamic responses to submaximal exercise in hypertensive responders. Journal of Cardiopulmonary Rehabilitation 8: 134-140, 1988a

Gutin B, Ang KE, Torrey K. Cardiorespiratory and subjective responses to incremental and constant load ergometry with arms and legs. Archives of Physical Medicine and Rehabilitation 69: 510-513, 1988

Hung J, McKillip J, Savin W, Magder S, Kraus R, et al. Comparison of cardiovascular response to combined static-dynamic effort, postprandial dynamic effort and dynamic effort alone in patients with chronic ischemic heart disease. Circulation 65: 1411-1419, 1982

Kelemen MH, Stewart KJ, Gillilan RE, Ewart CK, Valenti SA, et al. Circuit weight training in cardiac patients. Journal of the American College of Cardiology 7: 38-42, 1986

Kerber RE, Miller RA, Najjar SM. Myocardial ischemic effects of isometric, dynamic and combined exercise in coronary artery disease. Chest 67: 388-394, 1975

Kiblom A, Persson J. Cardiovascular response to combined dynamic and static exercise. Clinical Research (Suppl. I) 38: 93-97, 1981

Lind AR. Cardiovascular adjustments to isometric contractions: static effort. In Handbook of physiology: the cardiovascular system, peripheral circulation and organ blood flow. sec. 2, vol III, pp. 957-960, American Physiological Society, Bethesda, 1983

Lind AR, McNicol GW. Circulatory response to sustained hand-grip contractions performed during other exercise, both rhythmic and static. Journal of Physiology 192: 595-607, 1967

Makalous SL, Araujo J, Thomas TR. Energy expenditure during walking with hand weights. Physician and Sportsmedicine 16: 139-148, 1988

Maud PJ, Stokes GD, Stokes LR. Stride frequency, perceived exertion and oxygen cost response to walking with variations in arm swing and hand-held weight. Journal of Cardiopulmonary Rehabilitation 10: 294-299, 1990

Miller JF, Stamford BA. Intensity and energy cost of weighted walking vs running for men and women. Journal of Applied Physiology 62: 1497-1451, 1987

Mitchell JH, Schibye B, Payne FC, Saltin B. Response of arterial blood pressure to static exercise in relation to muscle mass, force development, and electromyographic activity. Circulation Research (Suppl. I) 48: 70-75, 1981

Nagle FJ, Richie JP, Giese MD. $\dot{V}O_{2max}$ responses in separate and combined arm and leg air-braked ergometer exercise. Medicine and Science in Sports Exercise 16: 563-566, 1984

Niederberger M, Bruce RA, Kusumi F, Whitkanack S. Disparities in ventilatory and circulatory responses to bicycle and treadmill exercise. British Heart Journal 36: 377-382, 1974

Nelson RR, Gobel FL, Jorgensen CR, Wang K, Taylor HL. Hemodynamic predictors of myocardial oxygen consumption during static and dynamic exercise. Circulation 50: 1179-1188, 1974

Schwartz L. Heavyhands: the ultimate exercise, Warner Books Inc, New York, 1982

Schwartz L. The heavyhands walking book, Panaerobics Press Inc., Pittsburgh, 1989

Shedahl LM, Wilke NA, Tristani FE, Kalbfleisch JH. Response of patients after myocardial infarction to carrying a graded set of weightloads. American Journal of Cardiology 52: 698-703, 1983

Stenberg J, Åstrand PO, Ekblom B. Haemodynamic response to work with different muscle groups, sitting or supine. Journal of Applied Physiology 22: 61-70, 1967

Stewart KJ, Mason JM, Kelemen MH. Three-year participation in circuit weight training improves muscular strength and self-efficacy in cardiac patients. Journal of Cardiopulmonary Rehabilitation 8: 292-296, 1988

Toner MM, Sawka MN, Levine L, Pandolf KB. Cardiorespiratory responses to exercise distributed between the upper and lower body. Journal of Applied Physiology 54: 1403-1408, 1983

Von Hofen D, Auble TE, Schwartz L. Aerobic requirements for pumping versus carrying .91kg handweights while running. Medicine and Science in Sports and Exercise (Suppl. 2) 21: S7, 1989

Zarandona JE, Nelson AG, Conlee RK, Fisher AG. Physiological responses to hand-carried weights. Physician Sportsmedicine 14: 113-120, 1987

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