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Accumulated versus continuous exercise for health benefit: a review of empirical studies

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Abstract

Current physical activity guidelines endorse the notion that the recommended amount of daily physical activity can be accumulated in short bouts performed over the course of a day. Although intuitively appealing, the evidence for the efficacy of accumulated exercise is not plentiful. The purpose of this review was to compare the effects of similar amounts of exercise performed in either one continuous or two or more accumulated bouts on a range of health outcomes.

Sixteen studies met the selection criteria for inclusion in the review, in which at least one outcome known to affect health was measured before and after continuous and accumulated exercise training interventions. Where improvements in cardiovascular fitness were noted, most studies reported no difference in the alterations between accumulated and continuous patterns of exercise. In the few studies where a normalization of blood pressure was observed from baseline to post-intervention, there appear to be no differences between accumulated and continuous exercise in the magnitude of this effect. For other health outcomes such as adiposity, blood lipids and psychological well-being, there is insufficient evidence to determine whether accumulated exercise is as effective as the more traditional continuous approach.

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Seven short-term studies in which at least one health-related outcome was measured during the 0- to 48-hour period after a single continuous bout of exercise and a number of short bouts of equivalent total duration were included in the review. Many of the studies of such short-term effects considered the plasma triglyceride response to a meal following either accumulated short or continuous bouts of exercise. Collectively, these studies suggest that accumulated exercise may be as effective at reducing postprandial lipaemia. Further research is required to determine if even shorter bouts of accumulated exercise (<10 minutes) confer a health benefit and whether an accumulated approach to physical activity increases adherence among the sedentary population at whom this pattern of exercise is targeted.

Since 1995, physical activity guidelines have embraced the notion that for gaining health benefits, exercise or physical activity may be accumulated in bouts spread over the course of the day.[1] Given that a lack of time is a frequently cited barrier to physical activity,[2] a recommendation that allows individuals to perform short bouts of activity throughout the day rather than having to put aside a continuous time-slot in a busy schedule, is intuitively appealing. Theoretically, such a recommendation should make it easier for individuals to adhere to recommended amounts of physical activity. At the time of publication of the 1995 guidelines,[1] only two empirical studies had compared the effects of performing short bouts of exercise over the course of a day with completing a similar amount of activity in one continuous bout.[3,4] Although both studies indicated that accumulating short bouts of exercise was effective in improving fitness and favourably altering a number of health outcomes, the endorsement of accumulated exercise was advanced primarily on the basis of epidemiological evidence suggesting a dose-response relationship between physical activity volume and health. A review by Hardman[5] identified a further three studies that made direct comparisons of equal amounts of physical activity performed in a single continuous bout or accumulated in shorter bouts over the course of the day.[6-8] Since that review, several authors have conducted intervention studies to investigate the effects of bouts of physical activity accumulated over the course of a day.

It is well established that at least some of the health benefits of regular physical activity are likely to be due, in part, to the short-term changes that occur in the hours and days following a bout of activity.[9] Benefits such as reduced resting blood pressure, improved glucose control, favourable alterations in lipids[10] and enhancement of mood[11] have all been demonstrated in the post-exercise period. Whether such immediate beneficial effects of exercise are retained when a single continuous bout is split into shorter bouts accumulated over the course of the day has been the focus of number of recent studies.

The purpose of this article is to review the empirical studies that have compared the effects of physical activity on a range of health outcomes for activity performed in a single continuous bout or short accumulated bouts of the same total duration. The article includes two categories of studies: (i) studies that compared the long-term response to training using accumulated versus continuous exercise; and (ii) short-term studies that compared the effects of accumulated and continuous exercise during the 48-hour period following the last exercise bout.

1. Methods

1.1 Literature Search Strategy

A search was made through MEDLINE using the following terms: ‘accumulated AND exercise’, ‘accumulated AND physical activity’, ‘short bouts AND exercise’, ‘short bouts AND physical activity’. The search incorporated any article published in English that included any of these combinations in the title, keywords or abstract. This search was crosschecked and supplemented using the authors' personal libraries. Over 340 articles were identified through this search method. In several instances, the publications identified referred to short intermittent bouts of repeated very high-intensity activity performed with short recovery within a single training session. This type of intermittent exercise is normally undertaken by individuals training for multiple sprint sports and was therefore outside the scope of this review. The search also identified several studies of 'lifestyle physical activity' where individuals are encouraged to accumulate additional physical activity over the course of the day by incorporating planned or opportunistic activities of daily living into their routine. These studies were not designed to provide a direct comparison between accumulated and continuous exercise. Moreover, this 'lifestyle' approach has previously been reviewed and therefore is not included in this review.[12-14]

1.2 Selection Criteria

The following criteria were used to select studies included in the review:

1. Studies were designed to compare the effects of 'equal' amounts of exercise performed in either one continuous or two or more accumulated bouts.
2. The duration of physical activity bouts was prescribed by the researcher with no opportunity for the participant to self-select bout duration.
3. The continuous or accumulated exercise was the primary intervention or where an additional intervention (e.g. weight loss programme) was included, this was applied equally to both exercise conditions.

In addition, studies selected had to meet one of the following criteria depending on which category of study was being considered:

4. For the training studies, at least one outcome known to affect health was measured before and after continuous and accumulated exercise interventions of at least 4 weeks' duration.
5. For the short-term studies, at least one health-related outcome was measured during the 0- to 48-hour period after a single continuous bout of exercise and a number of short bouts of equivalent total duration.

These criteria were independently applied to all studies by two authors (MM and EM), with any discrepancies resolved by consensus.

2. Findings

2.1 Characteristics of the Training Studies

Using the search strategy and inclusion criteria described above, 16 training studies were identified. Walking was the predominant mode of exercise in 12 studies with two studies using jogging or running,[3,4] and one study employing aerobic dance as the exercise modality.[15] Collectively, these studies involved 836 subjects, predominantly females (n = 630). Although the physical activity status of subjects varied between studies, no subjects were meeting the current physical activity guidelines at the start of the study. The majority of interventions were short, ranging in duration from 4 to 20 weeks and involved total daily exercise durations of between 20 and 40 minutes on 3–5 days per week. The intensity of exercise prescribed in the studies ranged from 50% to 80% of maximum oxygen uptake (VO2max). For subjects assigned to the accumulated exercise groups, this was prescribed in 2, 3 or 4 bouts of between 10 and 15 minutes, with half of the studies (n = 8) requiring participants to separate the accumulated exercise bouts by at least 2 hours.[4,7,15-20] More than half of the studies (n = 9) employed a non-exercise control group.[7,15-17,19,21-23] Table I provides a summary of the design and findings of the intervention studies included in the review.

2.2 Long-Term Training Responses

2.2.1 Fitness

Most of the selected intervention studies reported measures of fitness before and after the exercise interventions. With the exception of two studies,[15,29] all others reported significant improvements in at least one measure of cardiovascular fitness following training. Only three studies [4, 18, 27] reported a significant difference between accumulated and continuous exercise groups for improvements in VO2max. De Busk and colleagues [4] noted greater improvements in VO2max in the continuous group compared with the control group. Murphy and co-workers[27] . reported greater increase in VO2max in the accumulated group compared with the continuous group. Quinn et al.[18] also noted an increase in VO2max in the accumulated group with no change in VO2max among the continuous exercisers.

2.2.2 Body Composition

Body Mass

Of the nine studies that reported body mass measurements before and after the exercise intervention, five noted significant reductions in body mass following accumulated or continuous exercise training compared with controls.[7,16,22,24,25] However, three of these studies included caloric restriction as part of the intervention.[22,24,25] Four of the studies reporting weight loss noted similar reductions following accumulated and continuous exercise training,[16,22,24,25] while Murphy and Hardman[7] noted a significant weight loss

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from pre- to post-intervention in the accumulated group compared with controls, but not the continuous exercise group.

Adiposity

Six studies reported percentage body fat.[3,17,21,25,26,28] Three of these[3,21,26] reported no changes in any exercise group. Another two studies [25,28] reported significantly reduced body fat in all exercise groups, but no significant differences between the continuous and accumulated conditions. Osei-Tutu and Campagna [17] noted a decrease in percentage body fat in the continuous exercise group only.

Four authors recorded sum of skinfolds at pre- and post-intervention.[7,22,27,29] Three of these studies[7,22,27] noted a reduction in skinfold thickness in all exercise groups; however, there was no significant difference between groups. Altena and colleagues [29] noted no alteration in skinfolds following either exercise pattern.

Waist and Hip Circumference

Five studies reported waist and hip circumferences before and after the exercise intervention. Murtagh et al.[21] and Quinn et al.[18] found no changes in these measures. A significant reduction in waist circumference was recorded by the accumulated exercise group, but not the continuous group in the study by Murphy and Hardman,[7] while Murphy et al.[27] noted significant reductions in waist and hip circumferences for both exercise conditions. Similarly, Jakicic and colleagues[25] recorded changes over time for waist girth and waist-to-hip ratio. No study noted a significant difference for changes in waist and hip circumferences between continuous and accumulated exercise interventions.

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Table I. Training studies comparing the effects of accumulated and continuous exercise on a range of health outcomes

Study	Subjects; age	Intervention	Patterns	Control	Duration	Outcome measures	Changes over time
Ebisu[21]	53 M; 21 y	3- to 6 mile (4.8–9.6 km) run 80% HR_{max} 3 d/wk	a. 1 bout b. 2 bouts c. 3 bouts	Yes	10 wk	$\dot{V}O_{2max}$ 1.5-mile (2.4-km) run time HDL TC/TG/LDL/VLDL	a. +6.9%[a] b. +9.8%[a] c. +8.4%[a] (nsd between groups) a. −10.2%[a] b. −10.8%[a] c. −12.7%[a] (nsd between groups) a. +3.4% b. +4.7% c. +9.6%[a] nsd
DeBusk et al.[14]	36 M; 40–60y	Jogging 65–75% HR_{peak} 5 d/wk	a. 1 × 30 min b. 3 × 10 min	No	8 wk	$\dot{V}O_2$ Exercise test duration HR during submax test Body mass	a. +13.9%[a] b. +7.6%[a] (a sig > b) a. +12.4%[a] b. 10.4%[a] a. −6.6%[a] b. −6.3%[a] nsd
Jakicic et al.[34]	56 F OW; 25–50 y	20–40 min walking 70% HRR 5 d/wk Caloric restriction	a. 1 bout b. multiple 10-min bouts	No	20 wk	Body mass Time to 80% HRR $\dot{V}O_2$ at HR_{peak} $\dot{V}O_2$ at HR = 110 bpm $\dot{V}O_2$ at HR = 125 bpm SBP DBP Resting HR	a. −7.2%[a] b. −9.7%[a] a. +7.2%[a] b. +7.8%[a] (nsd between groups) a.+ 5.8%[a] b. +5.5%[a] (nsd between groups) a. +9.9%[a] b. +21.2%[a] (nsd between groups) a. +7.6%[a] b. +14.5%[a] (nsd between groups) a. −3.3%[a] b. −2.3%[a] (nsd between groups) a. −5.1%[a] b. −6.5%[a] (nsd between group) a. −6.2%[a] b. −6.7%[a] (nsd between groups)
Murphy and Hardman[7]	47 F; 44.4 ± 6.2 y (mean ± SD)	Walking 70–80% HR_{max} 5 d/wk	a. 1 × 30 min b. 3 × 10 min	Yes	10 wk	$\dot{V}O_{2max}$ $\dot{V}O_2$ at 2 mmol/L blood La Body mass Skinfolds Waist circumference SBP	a. +8.5%[a] b. +8.3%[a] (nsd between groups) a. +18.1%[a] b. +13.8%[a] (nsd between groups) a. −1.3% b. −2.6%[a] (nsd between groups) a. −4.2%[a] b. −4.6%[a] (nsd between groups) a. −2.3% b. −3.8%[a] (nsd between groups) nsd
Woolf-May et al.[19]	49 (21 F); 40–71 y	20–40 min walking 73% HR_{max} Progressive from 60 to 200 min/wk	a. 1 bout b. 10–15 min bouts	Yes	18 wk	HR_{peak} during submax test Recovery HR Blood lactate TC/LDL/HDL Apolipoproteins	a. −4.3%[a] b. −4.9%[a] (nsd between groups) nsd nsd nsd Increase in control group only
Jakicic et al.[35]	115 F OW; 36.7 ± 5.6 y (mean ± SD)	20–40 min exercise 5 d/wk Weight-loss programme	a. 1 × 20–40 min b. 2–4 × 10 min c. 2–4 × 10 min + treadmill	No	18 mo	Body mass Body fat percentage Waist : hip Bone mineral content Predicted $\dot{V}O_2$ peak	a. −11.4%[a] b. −10.3%[a] c. −11.7%[a] (nsd between groups) a. −6.5%[a] b. −3.6%[a] c. −9.4%[a] (c sig > b) nsd nsd a. +9.9%[a] b. +6.3%[a] c. +11.5%[a] (nsd between groups)
Coleman et al.[36]	21 (18 F); 18–55 y	30 min walking 60–70% HR_{max} 6 d/wk	a. 1 × 30 min b. 3 × 10 min[b]	No	16 wk	Predicted $\dot{V}O_{2max}$ Body fat percentage Body mass SBP DBP	a. +7.8%[a] b. +6.4%[a] (nsd between groups) nsd nsd a. −4.7%[a] b. −2.1%[a] (nsd between groups) nsd

Study	Subjects; age	Intervention	Patterns	Control	Duration	Outcome measures	Changes over time
Woolf-May et al.[20]	56 (37 F) 50.1 ± 6.3 y (mean ± SD)	60–200 min walking/wk 70–75% $\dot{V}O_{2max}$	a. 20–40 min bout b. 10–15 min bouts c. 5–10 min bouts	Yes	18 wk	Predicted $\dot{V}O_{2max}$ HR_{peak} during submax test Lactate during submax test LDL TC/TG Apolipoprotein A-II	nsd nsd a. −45.5%[a] b. −33.3%[a] c. −46.2% (nsd between groups) a. −5.9%[a] b. −8.3%[a] c. −2.6% nsd a. −10.9%[a] b. −4.4%[a] c. +2.5%
Schmidt et al.[22]	38 F OW; 18–21 y	30 min walking 75% HRR 3–5 d/wk Caloric restriction	a. 1 × 30 min b. 2 × 15 min c. 3 × 10 min	Yes	12 wk	$\dot{V}O_{2max}$ Skinfolds Body mass BMI Sum of circumferences	sig increase all groups (nsd between groups) sig decrease all groups (nsd between groups) a. −3.3%[a] b. −3.5%[a] c. −5.0%[a] (nsd between groups) a. −3.5%[a] b. −3.6%[a] c. −4.9%[a] (nsd between groups) sig decrease in all groups (nsd between groups)
Murphy et al.[27]	21 (14 F); 44.5 ± 6.1 y (mean ± SD)	30 min walking 70–80% HR_{max} 5 d/wk	a. 1 × 30 min b. 3 × 10 min	No	2 × 6 wk crossover	Predicted $\dot{V}O_{2max}$ Waist circumference Hip circumference Sum of 4 skinfolds Body mass SBP DBP TC HDL TG Mood State POMS Self-efficacy Barriers to exercise	a. +3.8%[a] b. +14.2%[a] (b sig > a) a. −1.2%[a] b. −0.3%[a] (nsd between groups) a. −0.6%[a] b. −0.9%[a] (nsd between groups) a. −3.3%[a] b. −1.6%[a] (nsd between groups) nsd nsd a. −1.9%[a] b. −1.7%[a] (nsd between groups) a. −7.1%[a] b. −5.1%[a] (nsd between groups) a. +9.2%[a] b. +5.4%[a] (nsd between groups) a. −10.8%[a] b. −9.3%[a] (nsd between groups) Similar decreases in tension/anxiety in both groups nsd for walking, b increased efficacy for other activities[a] a. decreased health barrier[a] b. decreased effort barrier[a]
Asikainen[28]	130 F; 48–63 y	Walking 1500 kcal/wk 65% $\dot{V}O_{2max}$ 5 d/wk	a. 1 bout b. 2 bouts	Yes	15 wk	$\dot{V}O_{2max}$ Submax HR response Body mass Body fat percentage	a. +12.5%[a] b. +12.7%[a] (nsd between groups) nsd a. −1.0%[a] b. −1.0%[a] (nsd between groups) a. −6.8%[a] b. −5.6%[a] (nsd between groups)
Schachter et al.[illegible]	143 F FM; 20–55 y	Progressive to 30 min 'aerobic dance' 65–75% HRR 3–5 d/wk	a. 1 bout b. 2 bouts	Yes	16 wk	Peak $\dot{V}O_2$ Treadmill test duration Physical function Symptom severity/pain Self-efficacy Well-being	nsd nsd nsd b. decreased disease severity[a] b. increased[a] nsd

Study	Subjects; age	Intervention	Patterns	Control	Duration	Outcome measures	Changes over time
Murtagh et al.[24]	48 (31 F); 45.7 ± 9.4 (mean ± SD)	20 min walking ~73% HR_{max} 3 d/wk	a. 1 × 20 min b. 2 × 10 min	Yes	12 wk	$\dot{V}O_2$ during submax test HR during submax test RPE during submax test Body mass Body fat percentage Waist and hip circumference SBP DBP TC/TG/HDL/LDL	nsd decrease in both groups (a sig > b) a. −15%[a] b. −11.2%[a] (nsd between groups) nsd nsd nsd nsd nsd nsd
Osei-Tutu and Campagna[37]	40 (21 F); 20–40 y	30 min walking 60–79% HR_{max}	a. 1 × 30 min b. 3 × 10 min	Yes	8 wk	$\dot{V}O_{2max}$ Body fat percentage POMS	a. +6.7%[a] b. +7.2% (nsd between groups) a. −6.7%[a] (a sig > b) Increase in vigour activity[a] and decrease in total mood disturbance[a] in both groups a. decreased tension-anxiety[a] and decreased depression-dejection[a]
Quinn et al.[18]	37 (20 F); 48.8 ± 9.0 y (mean ± SD)	30 min aerobic exercise (various modalities) 70–80% HRR 4 d/wk	a. 1 × 30 min b. 2 × 15 min	No	2 × 12 wk crossover	$\dot{V}O_{2max}$ HR during submax test $\dot{V}O_2$ during submax test Treadmill test duration Treadmill test SBP Treadmill test DBP HDL TC/LDL/TG	a. +4.5% b. +8.7%[a] a. −4.7% b. −9.0%[a] a. −4.1% b. −14.7%[a] a. +12.0%[a] b. +21.2%[a] a. −9.2% b. −11.6%[a] a. −13.7%[a] b. −8.4%[a] a. nsd b. +6.4%[a] nsd
Altena et al.[38]	18 (11 F); 18–45 y	30 min jogging 60% $\dot{V}O_{2max}$ 5 d/wk	a. 1 × 30 min b. 3 × 10 min	No	4 wk	$\dot{V}O_{2max}$ Waist and hip circumference Sum of 3 skinfolds TC HDL LDL TG AUC TG peak	nsd nsd nsd a. −4.7%[a] b. −11.3%[a] (nsd between groups) nsd nsd nsd nsd

a Significant change from pre- to post-intervention.

b Study also included a third group who could self-select bout duration (these subjects are not included in the table).

AUC = area under the concentration-time curve; BMI = body mass index; bpm = beats/min; DBP = diastolic blood pressure; F = female; FM = subjects with fibromyalgia; HDL = high density lipoprotein cholesterol; HR = heart rate; HR_{max} = maximum heart rate; HR_{peak} = peak heart rate; HRR = heart rate reserve; LDL = low density lipoprotein cholesterol; M = male; nsd = no significant difference; OW = overweight; POMS = profile of mood states; RPE = rate of perceived exertion; SBP = systolic blood pressure; sig = significantly; sig > = significantly greater than; TC = total cholesterol; TG = triacylglycerol; VLDL = very low density lipoprotein cholesterol; $\dot{V}O_2$ = oxygen uptake; $\dot{V}O_{2max}$ = maximal oxygen uptake.

Blood Pressure

Six of the selected studies reported resting systolic and diastolic blood pressure before and after the exercise interventions.[7,18,24,26,27,30] Two of these studies found a significant decrease in both systolic and diastolic blood pressure following training with no differences between the two patterns of exercise.[24,26] Quinn and colleagues[18] also measured ambulatory blood pressure during treadmill walking before and after training. During exercise, diastolic blood pressure decreased following 12 weeks of accumulated or continuous exercise and systolic blood pressure, during exercise, decreased following the accumulated exercise training.

Blood Lipids

Seven studies included assessment of fasting blood lipid profiles before and after the intervention.[3,18-21,27,29] Three studies reported an increase in high-density lipoprotein (HDL) cholesterol.[3,18,27] One found an increase following accumulated[18] exercise training and two found an increase in both exercise groups[3,27] from pre to post-intervention. There were no consistent observations of alterations in total cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides or other lipid parameters measured in the studies. One study that compared the postprandial response to a high-fat meal before and after 4 weeks of training found no differences between continuous and accumulated conditions.[29]

2.2.3 Other Health Outcomes

One study compared the effects of accumulated and continuous sessions of low impact aerobics on signs and symptoms of fibromyalgia.[15] Small improvements in self-efficacy and disease severity following both exercise conditions were observed with no difference between the two exercise patterns.

2.2.4 Psychological Outcomes

Three studies reported measures of psychological health before and after training. Murphy and colleagues[27] noted that both accumulated and continuous exercise conditions resulted in similar decreases in tension and anxiety. However, Osei-Tutu and Campagna[17] found a positive effect on mood in the continuous exercise group only, although they note that a definite trend in the direction of positive mood was evident for the accumulated exercise group. Schachter and co-workers[15] observed that improvements in psychological well-being were evident in the continuous exercise group at mid-test, but not after 16 weeks of training.

2.3 Characteristics of Short-Term Studies

Seven studies meeting the selection criteria compared the effects of continuous and accumulated exercise in the 48 hours following physical activity.[31-37] Study designs included measurement of lipids, insulin, glucose, substrate oxidation, metabolic rate and/or enzyme activity at baseline. Several studies considered responses to a standardized high-fat meal,[31,34] mixed meals[36,37] and an oral glucose load[32] following accumulated and continuous exercise bouts. Two studies considered fasting lipid responses at baseline, 24 and 48 hours following the two patterns of exercise.[33,35] Six studies employed a no exercise control condition.[31,32,34-37] Subject numbers were consistently low in these studies (n = 10–18) with a total of 96 participants (56 males, 40 females). Exercise modality consisted of running or walking with total duration varying from 30 to 90 minutes. Table II summarizes the design and findings of the short-term studies included in this review.

2.4 Short-Term Responses

2.4.1 Fasting Blood Lipids

Fasting blood lipids in the 48-hour period following accumulated and continuous exercise bouts were measured in five studies.[31,33-36] No differences were observed in triglyceride or total cholesterol levels between exercise and control or between accumulated and continuous exercise conditions. Two studies reported an increase in fasting HDL cholesterol in the 48 hours after exercise compared with baseline.[33,35] Campbell et al.[33] reported no difference between accumulated and continuous conditions, whereas Mestek et al.[35] report greater increases in HDL cholesterol following accumulated compared with continuous exercise of equivalent total energy expenditure. Only one study determined the activity of enzymes involved in lipid metabolism in response to different patterns of exercise. Campbell and colleagues[33] noted an increase in the activity of the HDL cholesterol-forming enzyme lecithin-cholesterol acyl transferase (LCATa) in the 24–48 hours following continuous and accumulated exercise.

2.4.2 Postprandial Lipaemia

All four studies that compared the effects of exercise on the lipid responses to high-fat or mixed meal ingestion reported a decrease in postprandial triglycerides compared with controls.[31,34,36,37] Three studies reported no difference in the pattern of this response between accumulated and continuous exercise conditions[34,36,37] with one study noting a lower triglyceride response compared to controls following the accumulated, but not the continuous exercise.[31]

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2.4.3 Fasting Glucose and Insulin

Three studies determined fasting glucose and insulin levels the morning after accumulated and continuous exercise compared with controls.[32,34,36] Two of these studies noted no differences in fasting glucose between exercise and control conditions nor between the accumulated and continuous exercise trials.[32,34] The study by Miyashita and colleagues[36] showed lower fasting glucose on the morning following accumulated exercise compared with controls with no difference between continuous and control trials. None of the three studies noted any alterations in fasting insulin following exercise trials.

3. Discussion

The notion that the recommended daily amounts of physical activity required for good health can be accumulated through several separate episodes of activity interspersed throughout the day is persistent in recent public health guidelines.[38,39] Given the multiple demands upon individuals' time, the flexibility afforded by an accumulated approach may help to increase the proportion of the population meeting physical activity recommendations. However, the empirical evidence to support splitting a continuous bout of activity into several shorter bouts is not extensive or unequivocal. If accumulated exercise is to be recommended at a population level, there are two major issues to be considered. The first of these is whether or not continuous and intermittent exercise of comparable doses will produce similar health benefits. A second important issue is to determine if the flexibility and convenience of splitting an exercise dose into several bouts increases adoption and maintenance of regular physical activity for previously sedentary persons. This article focuses on the first of these questions, and considers both short- and long-term effects of the two approaches to on a range of fitness and health parameters.

Table II. Studies comparing the acute effects (0–48 h) of accumulated and continuous exercise on a range of health outcomes

Study	n	Interventions	Patterns	Control	Timing of measures	Outcome measure	Reported change
Gill et al.[illegible]	18 M 30.6 ± 9.0 y (mean ± SD)	90-min run at 60% $\dot{V}O_{2max}$	a. 90 min continuous b. 3 × 30 min run >3 h between bouts	Yes	12 h post-exercise 2, 3, 6 h post-high-fat meal	Triglycerides	No difference in fasting levels pp response 18.1% lower in continuous 17.7% lower in accumulated compared with control (nsd between exercise pattern)
						Non-esterified fatty acids	Fasting levels 30.3% higher in continuous compared with control No difference in pp response
						Insulin	No difference in fasting levels pp response 22.4% lower in accumulated compared to control
						Glucose	No difference in fasting levels No difference in pp response
Murphy et al.[illegible]	10 (7 F) 34–66 y	30-min walk at 60% $\dot{V}O_{2max}$	a. 30-min continuous b. 3 × 10 min >3 h between bouts	Yes	Baseline 1, 2, 3 h After breakfast, lunch and dinner	Metabolic rate	No difference in fasting or pp response
						Triglycerides	No difference in fasting levels pp response lower in both exercise patterns compared to control (nsd between exercise pattern)
						Insulin	No difference in fasting or pp response
						Non-esterified fatty acids	No difference in fasting or pp response
						Glucose	No difference in fasting or pp response
Altena et al.[illegible]	18 (11 F) 25 ± 1.8 y	30-min run at 60% $\dot{V}O_{2max}$	a. 30-min continuous b. 3 × 10 min 20 min between bouts	Yes	Baseline and 2, 4, 6, 8 h After high-fat meal	Triglycerides	pp response 26.9% lower in accumulated pattern compared with control
						Total cholesterol	No difference in fasting or pp response
						HDL	No difference fasting or pp response
Baynard et al.[illegible]	15 F[a] 42–60 y	30-min walk at 60–65% $\dot{V}O_{2max}$	a. 30 min continuous b. 3 × 10 min >3.5 h between bouts	Yes	Baseline + every 30 min for 4 h After 75 g oral glucose load	Glucose	No difference
						Insulin	No difference
Miyashita et al.[illegible]	10 M 21–32 y	30-min run At 70% $\dot{V}O_{2max}$	a. 30 min continuous b. 10 × 3 min 30 min between bouts	Yes	Baseline and 1, 2 and 3 h	Triglycerides	pp response 24% lower in continuous 22% lower in accumulated compared with control (nsd between exercise pattern)
					After breakfast and lunch	Insulin	pp response lower in accumulated compared to control
						Glucose	No difference
Mestek et al.[illegible]	9 M 25 ± 4 y (mean ± SD)	500 kcal walk/jog at 70% $\dot{V}O_{2max}$	a. 500 kcal in single bout b. 3 bouts of 167 kcal 4 h between bouts	No	24 h before	Triglycerides	No difference
					Baseline, 24 and 48 h post-exercise	Total cholesterol	No difference 10.2% increase at 24 h post and 14.3% increase at 48 h post-accumulated
						HDL	4% increase at 48 h post-continuous accumulated significantly higher than continuous at 48 h post-exercise
Campbell et al.[illegible]	16 M 22 ± 2 y (mean ± SD)	450 kcal Treadmill running at 65% $\dot{V}O_{2max}$	a. 450 kcal in single run b. 2 × 225 kcal >4 h between bouts c. 3 × 150 kcal >4 h between bouts	No	Baseline, Post-exercise: 0, 24 and 48 h	Triglycerides	No difference
						Cholesterol	Increase in HDL subfraction cholesterol 13–15% in all 3 exercise trials (nsd between exercise pattern)
						Enzymes	Increase in lecithin cholesterol acyl transferase activity for all three exercise trials (nsd between exercise groups)

a Nine subjects with type 2 diabetes mellitus.

F = females; **HDL** = high-density lipoprotein cholesterol; **M** = males; nsd = no significant difference; pp = postprandial; $\dot{V}O_2$ = oxygen consumption; $\dot{V}O_{2max}$ = maximum oxygen consumption.

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3.1 Long-Term Effects

Cardiovascular fitness is recognized as an independent risk factor for cardiovascular disease.[40] The majority of studies included in this article demonstrate increases in fitness following exercise interventions ranging in volume from as little as 60 minutes per week to those that meet or surpass current physical activity guidelines. The magnitude of the increase in VO2max ranged from 3.8%[27] to 13.9%.[4] Where no measurable alterations in fitness were noted, this can be attributed to the very short duration of the exercise intervention[29] or the use of cardiovascular fitness measures that did not reflect the mode of activity used in the intervention.[15] Among the studies that identified improvements in fitness following the exercise intervention, the majority of studies noted no difference between accumulated and continuous approaches to exercise in the magnitude of this improvement. Where differential responses were noted, there appears to be no clear pattern in the findings with a few studies suggesting that continuous exercise results in greater fitness enhancement,[4,25] while others report greater improvements using the accumulated approach.[18,21,37] Most studies used multiple indices of cardiovascular fitness including VO2max, heart rate and blood lactate response to exercise and field fitness tests. In studies that found differences between continuous and accumulated exercise, these were often not consistently observed in all of the fitness measures employed. The available evidence suggests that there is no difference between accumulated and continuous exercise of the same total duration on improvements in cardiovascular fitness.

The majority of the intervention studies included in the review measured body mass, body composition or fat distribution before and after training. Although eight studies noted positive alterations in body composition[4,16-18,22,24,27,28] following training, there is little consistency in the comparisons between the two exercise patterns. Four studies noted similar favourable alterations in body composition in both patterns,[4,22,24,27] whereas three studies noted greater improvements following the accumulated exercise[16,18,24] and one study reported greater improvement following the continuous approach.[17]

Despite the increased energy expenditure, which is likely to have occurred with the exercise intervention, four studies noted no alteration in body composition.[3,21,26,29] Such equivocal findings reflect the difficulty in using body composition measures in exercise intervention studies with free-living individuals. Aside from the weight-loss intervention, which was applied to subjects in three of the training studies,[22,24,25] deliberate alterations in exercise habits may result in conscious or unconscious alterations in energy intake. These alterations may contribute to changes in body composition noted following an exercise intervention. Theoretically, at least, it seems likely that a given quantity and quality of exercise would induce similar changes whether it is performed in single daily bouts or accumulated in shorter bouts of equal total duration. Where increased weight loss has been noted following accumulated exercise, this has been attributed to reduced energy intake, increased total exercise volume or even the small increases in metabolism that occur following each exercise bout; however, none of these explanations have been fully empirically tested.

Normalization of resting blood pressure following exercise training is well documented,[41] although the benefit is not always observed.[42] Only six of the training studies included in this review used resting blood pressure as an outcome measure.[7,18,21,24,26,27] Where reductions in resting systolic or diastolic blood pressure were noted, these tended to be among subjects who had elevated blood pressure levels at baseline.

Although there are insufficient data to allow a comparison of the effects of accumulated and continuous patterns of exercise on blood pressure, all but one of the reviewed studies[18] that found decreases in blood pressure following exercise reported that these reductions were

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similar following accumulated or continuous patterns of exercise.[24,26,27] The proposed mechanisms for exercise-induced blood pressure reduction include decreased peripheral resistance resulting from increased lumen diameter, decreased vasoconstriction or greater vasodilation.[43] It is perhaps not surprising, therefore, that exercise of a given mode, intensity and total duration produces similar long-term effects irrespective of whether it is accumulated or performed in a continuous bout.

Only seven of the intervention studies in the review considered the effect of continuous and accumulated exercise on fasting blood lipid profiles.[3,18-21,27,29] Collectively, these studies suggest that 60–200 minutes of moderate-intensity exercise expending approximately 300–1000 kcal per week whether performed in a continuous or intermittent manner is insufficient to alter blood lipids in normolipidaemic individuals. This is consistent with suggestions that such favourable blood lipid alterations require a training threshold of 1200–2200 kcal per week.[44] In the studies that noted an alteration in one or more lipid parameters, this may be attributable to pre-intervention lipid profile.[18,20,27]

There is an insufficient number of studies in the review (n = 3) that have compared the effects of the two approaches to exercise on psychological parameters to allow reliable conclusions to be advanced.[15,17,27] Although no alterations in selfefficacy or well-being were noted in a patient population following 16 weeks of accumulated or continuous aerobic exercise,[15] in normal populations, similar improvements in mood state were observed following continuous and accumulated exercise interventions.[17,27] Given the importance of such enhancements in psychological attributes to exercise adherence, this may represent an important area for future comparisons of accumulated and continuous exercise.[11]

The data included in the current review derive from studies where subjects were predominantly middle-aged females with relatively low baseline levels of cardiovascular fitness. Whether our conclusions hold true for males or females with average or above-average fitness levels and indeed other populations, such as ethnic minorities, children and older people, cannot be determined at this stage.

3.2 Short-Term Effects

Cardiovascular fitness is recognized as an independent risk factor for cardiovascular disease.[40] The majority of studies included in this article demonstrate increases in fitness following exercise interventions ranging in volume from as little as 60 minutes per week to those that meet or surpass current physical activity guidelines. The magnitude of the increase in VO2max ranged from 3.8%[27] to 13.9%.[4] Where no measurable alterations in fitness were noted, this can be attributed to the very short duration of the exercise intervention[29] or the use of cardiovascular fitness measures that did not reflect the mode of activity used in the intervention.[15] Among the studies that identified improvements in fitness following the exercise intervention, the majority of studies noted no difference between accumulated and continuous approaches to exercise in the magnitude of this improvement. Where differential responses were noted, there appears to be no clear pattern in the findings with a few studies suggesting that continuous exercise results in greater fitness enhancement,[4,25] while others report greater improvements using the accumulated approach.[18,21,37] Most studies used multiple indices of cardiovascular fitness including VO2max, heart rate and blood lactate response to exercise and field fitness tests. In studies that found differences between continuous and accumulated exercise, these were often not consistently observed in all of the fitness measures employed. The available evidence suggests that there is no difference between accumulated and continuous exercise of the same total duration on improvements in cardiovascular fitness.

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3.2 Short-Term Effects

In addition to the effect of regular exercise on fitness and a range of health outcomes, it is now accepted that a single episode of exercise results in a number of short-term physiological alterations that may benefit health. These short-term effects are attributable to the last bout of exercise. Such last bout effects are thought to contribute to the health-enhancing effects of near daily exercise. The second element to this review focuses upon the small number of studies that have compared the short-term responses to accumulated and continuous exercise. Two of these studies compared the effects of continuous and accumulated exercise on fasting blood lipids 24 and 48 hours after the exercise was completed.[33,35] Both studies report modest increases in HDL cholesterol or a HDL subfraction following exercise, which is consistent with previous reports from continuous exercise studies.[44] Although Mestek and colleagues[35] demonstrate more favourable alterations following accumulated exercise, there is insufficient evidence at this time to support the conclusion that accumulated exercise is superior in this regard.

In recent years, how an individual metabolizes dietary fat has emerged as a risk factor for cardiovascular disease and it has been established that a single exercise session can result in a reduction in postprandial lipaemia.[45] Four of the seven studies included in this review focused on whether splitting the session of exercise into several smaller bouts alters this beneficial effect of exercise.[31,34,36,37] The range of study designs, including duration of exercise, meal content and timing, and post-exercise blood sampling schedule make it difficult to draw sound conclusions.

While three of these studies suggest that splitting exercise into shorter accumulated bouts has no effect on its capacity to alter postprandial lipaemia,[34,36,37] one study suggests that accumulated bouts of exercise may provide greater reductions in plasma triglycerides than a single exercise session.[31]

Collectively, the short-term studies included in this review provide tentative support for the notion that splitting a bout of continuous exercise into shorter bouts accumulated over the course of day does not alter its ability to elicit modest reduction in fasting or postprandial lipaemia. Although a small number of studies have reported greater short-term benefits following accumulated exercise, at this stage such suggestions should be regarded as speculative. There is currently a dearth of research comparing the short-term effects of moderate-intensity exercise performed in a continuous and accumulated pattern.

4. Recommendations for Future Research

Most of the training studies included in this review used accumulated bouts of 10 minutes or longer in duration. In a real-life setting, however, individuals attempting to accumulate ‡30 minutes of physical activity in line with current recommendations may opt for even shorter bouts performed more frequently. Jakicic et al.[24] have shown that subjects attempting to meet a daily 30-minute exercise target selected bouts that were <10 minutes in duration. Furthermore, Miyashita and colleagues[36] observed similar reductions in postprandial lipaemia on the day after subjects performed either one 30-minute run or ten 3- minute runs with 30 minutes between bouts. From a practical research perspective, it may be difficult to investigate the efficacy of very short bouts (<5 minutes) of moderate-intensity exercise in free-living individuals as the boundaries between ‘accumulated bouts’ of activity and ‘lifestyle’ physical activities such as walking for personal transport become blurred.[14] However, the use of objective monitoring devices such as accelerometers may make such studies feasible, and it would be useful to know if accumulating the exercise in very short bouts is beneficial.

Accumulating exercise in such very short bouts has, however, been investigated using the vigorous-intensity exercise of stair-climbing. Recent studies have demonstrated that five to eight 2-minute bouts of stair-climbing accumulated over the course of a day conferred health benefits including increases in cardiovascular fitness compared with non-exercising controls.[46-48] Of the short-term studies included in this review, only one compared very short bouts of <10 minutes in duration.[36] The alterations in lipid clearance observed the day after 30 minutes of running or three 10-minute runs are likely to be due to increased activity of key enzymes involved in lipid metabolism and increased energy expenditure.

Given the high levels of inactivity in most developed countries, an important consideration is whether an accumulated exercise is more palatable and easier to maintain. Future studies should examine whether the continuous or accumulated pattern of activity results in increased adoption and maintenance of regular exercise for previously sedentary persons. Such information is crucial to shaping future public health campaigns aimed at the sedentary majority.

A number of limitations of the studies included in this review have been identified, which should be considered in future study design by researchers. Seven of the training studies included in this review did not have a control group limiting the degree to which alterations in health outcomes can be attributed entirely to the exercise intervention.[4,18,24-27,29] The majority of the training studies rely on self-report of exercise bouts. More objective measures of exercise duration, intensity and timing may be warranted to ensure reliable comparisons.

In general, the studies included in this review involved low subject numbers. This probably reflects the practical difficulties encountered by researchers attempting to recruit sedentary participants and encourage them to undertake exercise that is somewhat rigidly prescribed in terms of intensity, duration and bout length. With a few exceptions, the studies included in this review. involved fewer than 60 subjects assigned to two or more intervention groups. Inevitably, therefore, some of these studies may have been insufficiently powered to detect alterations in some of the outcome measures selected.

5. Conclusion

The available evidence suggests that at least for fitness, accumulated and continuous patterns of exercise training of the same total duration confer similar benefits. For the effects of continuous and accumulated training on the other health outcomes identified and the short-term effects of continuous and accumulated exercise, firm conclusions are difficult to draw.

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