//Information for health and exercise professionals

This working paper aims to inform people involved in the planning and delivery of exercise after stroke about recent research developments and to give an overview of the wider research context. This is not an exhaustive review of the literature but a starting point for further investigation and discussion. We would be very interested to receive your views and ideas on the future direction of research in this area and on any other aspect of this paper. Please email cbest@staffmail.ed.ac.uk with your feedback.

Impact of stroke

Stroke is the largest single cause of severe disability in Scotland. Around 2.5% of men and 2.8% of women in Scotland are stroke survivors (Scottish Health Survey 2008, section 8.3 http://www.scotland.gov.uk/Publications/2009/09/28102003/90). The majority of stroke survivors are left with some degree of on-going disability. In addition to this, around one sixth of people who have had a stroke are likely to experience another stroke within 5 years [1].

These two areas:

- on-going disability after stroke.
- and the high incidence of secondary strokes in stroke survivors

have enormous public health implications. Exercise interventions have potential to reduce this disease burden and improve quality of life for people after stroke.

As suggested by Deplanque and Bordet [2] ‘the famous Latin sentence *mens sana in corpore sano* …may be of greater neurological importance than previously expected’.

We will discuss the existing research evidence on Exercise after Stroke in more detail covering: the role of physical activity in stroke prevention, the evidence that stroke survivors can improve their physical fitness and function through training and general issues in recent research on exercise after stroke.

Physical activity levels can help prevent first ever stroke

Older adults

Willey et al. [3] conducted a prospective cohort study on the effects of physical activity on risk of ischaemic stroke. Just over 3000 participants (mean age 69.2 ± 10.3) completed a questionnaire on leisure-time physical activity. The questionnaire (adapted from the National Health Interview Survey of the National Center for Health Statistics) asked about the type and duration of physical activity over the previous two weeks and from this, METs equivalents (intensity of exercise) and energy expenditure were calculated. This revealed that a large proportion of the sample were physically inactive (40.5%). After completion of the questionnaires, participants were followed up for a mean of 9.1 years and within this period, there were 238 incident ischemic strokes. The key finding from the study was that men who engaged in moderate to heavy physical activity were much less likely to have an ischemic stroke (fully adjusted hazard ratio 0.37, 95% CI 0.18-0.77). This was not the case for women in the study, although the authors note that high level of inactivity amongst women may have reduced power to detect benefits.

Younger adults

Willey's study [2] was the first to look at stroke risk and physical activity in older adults, most research evidence to date has been from samples ascertained in middle age. Wendel-vos [4] conducted a meta-analysis of these observational studies of physical activity and stroke. Thirty-one studies were included and approximately 440,000 participants. The meta-analysis found that high-level physical activity versus low-level physical activity reduced the risk of stroke. This was for both leisure time and occupational physical activity. They explored potential sources of heterogeneity in the data and found that gender had a borderline significant effect on risk of haemorrhagic stroke. The only other potential source of heterogeneity was country of origin with studies conducted in Europe showing larger effects of physical activity than studies in the US. The authors suggest that this is because levels of physical activity are inconsistently defined and there may be less difference between low and high levels of physical activity in studies conducted in the US due to lower overall levels of physical activity in this population.

Men and Women

There is an indication from some of these studies that the effects of physical activity on stroke risk are influenced by gender. Willey et al [3] in the Northern Manhattan study (c.3,000 people) found an effect of physical activity only for men, Kiely and colleagues [5] analysing data from the Framington heart study (c. 4, 000 people) also found, that high levels of physical activity were protective in men but not women. However Hu [6], in a very large prospective cohort study (c. 72, 000 participants, the Nurses Health study) found protective effects of activity in women - including benefits from moderate level activity such as walking. So it is likely that physical activity is protective against overall stroke risk for both men and women. Hu found these effects were associated mainly with ischemic stroke but there were low numbers of other stroke types in the sample and this is a general problem in that because hemorrhagic strokes account for only 10% of all incident strokes there are generally low numbers of hemorrhagic strokes even in the largest studies.

Dose-response relationship

There is also the question of the dose response relationship between physical activity and risk of stroke. Overall, it seems that even moderate levels of activity lower the risk of stroke in adults: with effects for not only high levels of physical activity but also moderate levels of activity found in large studies.

There is also the question of whether there is a limit to this relationship i.e. is there a point at which taking more exercise does not produce greater benefits? Williams et al's [6] analysis of data from the National Runner's Health study found that people who exceeded the physical activity recommendations of the American Heart Association that is, ran more the 2 kilometres per day, further reduced their risk of stroke. This study found no evidence of a ceiling on the benefits of physical activity when examining the outcomes for people who far exceeded the physical activity recommendations.

Across the lifespan

Grau et al. [7] in a retrospective case-controlled study of lifetime sports participation found little protective effect of participation in sports in young adulthood if this was not continued through the lifespan. Either continued participation in sports or taking up sports in later life reduced stroke risk.

How does physical activity help prevent strokes?

There are a number of established risk factors for stroke that are modified by exercise We know that increasing physical activity:

- Reduces blood pressure [8]
- Increases high-density lipoprotein cholesterol concentration [9].
- Reduces plasma fibrinogen level and platelet aggregation [10]
- Facilitates weight loss and weight maintenance [11]
- Increases insulin sensitivity because of increased number and activity of glucose transporters, both in muscle and adipose tissue [12].

Lee et al [13] in their study of the impact of physical activity on stroke risk in male physicians found that the impact of physical activity was mediated through effects on body mass, blood pressure, serum cholesterol, and glucose tolerance. The reduction in risk was not completely explained by reduction in vascular risk factors however. There are theories that exercise has direct effects that reduce stroke risk. A plausible molecular mechanism is via nitric oxide levels. Exercise of small and large muscle groups improves NO-vasodilator function in humans [14] and increases the expression of endothelial nitric oxide synthase (eNOS). Nitric oxide is a vasodilator and prevents platelet aggregation (anti-clotting effects). Endres et al [15] found that mice exposed to voluntary or forced exercise had increased levels of eNOS, increased vasodilation and reduced infarct size after left middle cerebral artery occlusion than mice that did not have the opportunity to exercise. Mice that have had the gene for eNOS removed (eNOS knockout mice (knockout mice link=http://www.genome.gov/12514551#al-1) did not experience the same protective effects from exercise.

At present, there is no *direct* evidence that exercise reduces the risk of recurrent stroke and other vascular events in people who have had a stroke. There is strong evidence that exercise reduces the risk of first ever stroke and it seems highly plausible that the same mechanisms will be effective in preventing subsequent as well as first-ever strokes.

Effects of physical activity on stroke severity

Studies have also shown that people who are physically active have less severe strokes and recover faster than people who are inactive. Krarup and colleagues [16], using data from the ExStroke trial, used a retrospective Physical Activity Scale for the Elderly (PASE) questionnaire in people who had just had a stroke. They found that people in the top quartile for physical activity prior to their stroke presented with less severe strokes (by Scandinavian Stroke Scale) and had better functional outcome at 2 years (modified Rankin Scale). Stroud and colleagues also found that levels of pre-stroke physical activity were associated with a higher Barthel score just after stroke and this effect remained at 3-month follow up.

We do not know exactly how physical activity helps the brain recover from stroke but animal studies have shown that exercise increases expression of excitatory neurotransmitter receptors. Up-regulation of NDMA receptors (subtype of glutamate =excitatory receptors) produces increases in neurotrophic factors (BDNF) involved in neuronal plasticity [17, 18]. Increased physical activity has been shown in animal models to have broad beneficial effects on blood supply to the brain, neurogensis and synaptic plasticity [19].

Benefits of physical activity in general

Physical activity is associated with a roughly 30% reduction in cardiac risk [20] in the general population. Individuals with better cardiovascular fitness (Maximum Aerobic Capacity >7.9METS) are at substantially lower risk of all-cause mortality [21]. Exercise has beneficial effects on mental health and has been shown to be effective in reducing the symptoms of clinical depression [22, although there are issues with the methodological quality of many studies in this area].

Exercise has beneficial effects on cognitive performance in unaffected older populations. Quaney et al [23] found that aerobic exercise improved stroke survivors' motor learning on the serial reaction time task.

We now know that exercise is beneficial -but what exactly do we mean by exercise and physical activity? And how much is enough to gain these benefits?

Physical fitness terms and their definitions

Definition of key terms.

The terms in this field are often employed interchangeably in the literature. Back in 1985 Caspersen et al [24] wrote a paper offering key definitions and asking for greater consistency in the use of exercise and fitness related terms.

The definition of physical activity offered by Casparsen is identical to that currently employed by the World Health Organisation:

- **Physical activity** is 'any bodily movement produced by skeletal muscles that requires energy expenditure'. http://www.who.int/topics/physical_activity/en/

In the research literature, physical activity is often subdivided into occupational and leisure time physical activity and also graded into low medium and high levels of physical activity. For example 'Lets get Scotland more active' (http://www.scotland.gov.uk/Publications/2003/02/16324/17897) recommends that adults should accumulate 30 minutes of moderate intensity exercise per day. Moderate intensity is defined as using about five to seven calories a minute - the equivalent of brisk walking. Moderate-intensity physical activity is also described as activity that raises the heart rate and makes the participant feel warm and slightly out of breath. The 'talk test' is often used as a guide to exercise intensity. If the participant can still hold a normal conversation -but not laugh- then they are engaging in moderate intensity physical activity. At vigorous intensity, they would only be able to speak a few works without pausing for breath.

In moderate intensity physical activity the body's metabolism is working at 3-6 times the resting level (3-6 MET 's) [25] and for vigorous intensity it works at more than 6 times the resting level..

Caspersen also notes that physical activity is positively correlated with physical fitness.

- **Physical fitness** is a set of attributes that people have or achieve that relates to the ability to perform physical activity.

Casparsen subdivides physical fitness into health related and skill related physical fitness. Health related physical fitness includes cardiorespiratory fitness, muscular endurance, muscular strength, body composition, flexibility. Skill related fitness includes agility, balance, coordination, speed, power, and reaction time.

- **Physical fitness training** is a structured regimen designed to improve any or all of these aspects physical fitness. This entails progressive increments in the training schedule. Physical fitness programmes can be formulated to improve cardio-respiratory fitness, muscular strength, flexibility, co-ordination and balance and ideally include activities aimed at improving all of these components.
- The term '**exercise**' is more difficult to define. Caspersen defines exercise in a way that it is almost interchangeable with the definition of physical fitness training given above, - 'Exercise is physical activity that is planned, structured, repetitive, and purposive in the sense that improvement or maintenance of one or more components of physical fitness is an objective'. However, Winter and Fowler (2009) [64] in their attempt to improve the scientific precision of terms used in exercise and sport science reject this definition. This is on the grounds that Caspersen's distinction between physical activity and exercise relies on assumptions about the intention of the person doing the activity -whether they intend improving their fitness or not. Instead, Winter and Fowler suggest a refined version of the American College of Sports Medicine definition. They define exercise as**–'** a potential disruption to homeostasis by muscle activity that is either exclusively or in combination, concentric, isometric or eccentric'. This recognises that exercise does not necessarily imply movement as it can have isometric components. The Winter and Fowler definition of exercise is very close to the WHO definition of physical activity. The WHO definition of physical activity focuses on energy expenditure above the resting rate and Winter and Fowler's definition of exercise focuses on the need for the body to adjust to the effects of muscle contraction and the accompanying metabolic disturbances (the need for extra oxygen etc) which in practice will be difficult to distinguish.

When encountering the term 'exercise' it is necessary to determine whether it is being used in the sense of physical fitness training (Caspersen, Wikipedia http://en.wikipedia.org/wiki/Physical_exercise , DoH http://www.nhs.uk/Conditions/Exercise/Pages/Introduction.aspx) or physical activity (American College of Sports Medicine) some organisations even seem to use both (see NHS Direct patient info leaflet http://www.cks.nhs.uk/patient_information_leaflet/exercise/definition) or neither (see http://www.bbc.co.uk/science/humanbody/body/articles/muscles/exercise.shtml). Others focus on the 'planned, structured, repetitive' element of Caspersen's definition and use 'exercise' to differentiate planned structured physical activity such as aerobics classes or gym sessions from unstructured activity such as stair climbing and walking. We will use 'exercise' after stroke to imply the physical activity sense of the definition -a disruption to homeostasis -as many community exercise after stroke classes do not have the progressive element necessary to systematically improve physical fitness in participants. Exercise after stroke services are structured, planned, repetitive interventions designed to directly increase physical activity levels. They may or may not include a planned progressive element designed to increase physical fitness in stroke survivors.

Stroke survivors are less physically fit than their age-matched counterparts

Stroke survivors often exhibit significant physical deconditioning. Studies of peak aerobic fitness of hemiparetic stroke survivors have found mean VO_2 peak values of 11.5-17.7 mLs/Kg. Age matched controls in their mid 60s who are not physically active but have no long-term health conditions have peak VO_2s in the range between 25 and 30 mLs/Kg [26]. This illustrates the large difference in physical fitness between people who had a stroke and the unaffected older population.

The reasons that stroke survivors are not physically fit is die to a combination of deconditioning due to low levels of physical activity after (and possibly before) having and stroke coupled with direct effects of stroke on physical fitness. These direct effects leading to loss of physical fitness after stroke are described below.

<u>Biological mechanisms for low physical fitness after stroke</u>

Ivey and colleagues in their 2006 paper outline some mechanisms for low physical fitness after stroke. These are:

- Reduced central drive secondary to brain damage
- Gross tissue changes

  In people who have hemiparesis after stroke, there is a change in the tissue composition of large muscles on the paretic side. There is a proportional decrease in slow myosin heavy chain (muscle fibre composition link=http://neuromuscular.wustl.edu/mother/myosin.htm) and an increase in fast myosin heavy chain isoform in paretic skeletal muscle [27]. In individuals without stroke, the proportions of slow and fast Myosin Heavy Chain are about equal. A shift to more fast Mysosin Heavy Chain is associated with increases in fatigue and increased insulin resistance.
- Inflammatory pathway activation

  Expression of the inflammatory cytokine TNF-α is associated with sarcopenia in advancing age and to diabetes. Studies have shown increased transcription of TNF-α in the paretic limb muscles of stroke survivors [27].
- Hemodynamic changes after stroke

  There is impaired blood flow in muscle on the paretic side in stroke survivors with hemiparesis.

<u>Implications of the loss of physical fitness</u>

The amount of work required to perform a physical task can be estimated in Metabolic Equivalents or METS. An average person at rest uses one MET -approximately 3.5 ml 0_2/kg/min. The physical requirements of other physical activities can be estimated in multiples of resting oxygen consumption. It is calculated that light Activities of Daily

Living require 3 METS and that heavy work requires 5 METs. Based on this estimation, many stroke survivors do not have the physical fitness necessary to perform many of the activities of daily living such a hoovering and shopping [28].

The average stroke survivor is unable to walk fast enough to cross the road safely or far enough to go shopping [Hill in 29].

Stroke survivors who have hemiparesis often have an inefficient gait and so use much more energy when walking than unaffected people [65]. People with hemiparesis use almost twice as much energy to walk an equivalent distance. The fact that activity can involve higher energy costs than in age matched counterparts plus the physical deconditioning present in stroke survivors combine to increase overall disability and dependence.

Stroke survivors are also much less active than age matched controls. Moore et al [30] notes that chronic stroke survivors take much fewer steps per day (2500 to 3500 steps/d) compared to sedentary older adults (5000 to 6000 steps/d). The authors attribute this to reduced balance, metabolic capacity and efficiency of the stroke survivors.

Life after stroke

Having a stroke has considerable impact on a person's self-image and stroke survivors need to go through a phase of reconstruction of the self [45]. Part of this process is often developing self-confidence to go outside the home. Many people who have had a stroke have a fear of falling. Restrictions on mobility and lack of confidence may in combination reduce opportunities for physical activity and social contact.

This lack of activity creates a negative feedback loop leading to further reductions in physical fitness and increase in cardiac risk factors. We will now consider whether this reduction in physical fitness can be addressed through structured interventions.

Evidence that physical fitness training is effective for stroke

The Cochrane systematic review of physical fitness training for stroke patients is available on line and is open-access.

http://www.mrw.interscience.wiley.com/cochrane/clsysrev/articles/CD003316/frame.html

The review included 24 trials, involving 1147 participants, comprising cardiorespiratory (11 trials, 692 participants), strength (four trials, 158 participants) and mixed training interventions (nine trials, 360 participants). However, the variety of outcome measures used by trialists made combing studies for meta-analysis difficult. The main finding of the review was that physical fitness training in stroke survivors produces benefits to walking speed, independence and endurance.

Wevers et al.[31] conducted a systematic review of task-orientated circuit training for people after stroke. This review included 6 studies and 307 participants. Their main finding was that task orientated circuit training had beneficial effects on walking speed and distance and on the ability to rise from a sitting position.

This is a rapidly expanding area of research. An update to the Cochrane systematic review on physical fitness training in stroke will be undertaken in the next year.

Cochrane systematic reviews have very clear criteria for included studies and the Cochrnae review of physical fitness training for stroke survivors includes only randomised controlled trials and thoroughly evaluates the methodological quality of trials. Here we will present an overview of issues arising from recent research in Exercise after Stroke. This will include studies that do not meet the inclusion criteria for the Cochrane review either because they do not meet criteria for physical fitness training or because they employ research methods other than randomised controlled trials. This provides a broader perspective on research in this field but this is not a systematic review and readers are referred to the Cochrane review for the most robust evaluation of effectiveness of physical fitness training for stroke.

Recent research into exercise after stroke

As in the Cochrane review, subsequent studies have found effects of cardiovascular or mixed training for stroke survivors on walking outcomes: [32] endurance, [30]O_2 for 12min walk; [33] gait and 6 min walk; [34] muscle strength and walking velocity. Other outcomes that have been positively influenced include physical integration and quality of life [35].

These studies vary regarding the point in the patient pathway at which the intervention is applied. The patient pathway is also relevant in differentiating exercise after stroke from rehabilitation.

Differentiating exercise after stroke from rehabilitation

Exercise after stroke is aimed primarily at increasing physical activity levels and/or physical fitness (link to definition of physical fitness). In contrast, rehabilitation by a physiotherapist focuses primarily on return of function and on ability to perform activities of daily living. Studies of the optimum methods for rehabilitation after stroke or interventions for exercise very early after stroke are outside the scope of this paper. We will focus on studies after the acute phase of treatment. Even after this point, there are a number of points in the patient pathway at which the effectiveness of exercise after stroke can be studied.

Intervention points

Post- acute phase

The first point is immediately after the acute phase (e.g. Mudge et al 2009 [32]). These interventions are typically delivered by physiotherapists in rehabilitation settings and study whether group exercise is a useful adjunct to conventional physiotherapy. For example in Mudge et al [32] participants (n=58) had been discharged from inpatient physiotherapy. The intervention group were given 12 circuit based exercise sessions and they found that intervention participants improved gait endurance relative to controls. The control group received educational and social activities. An on-going trial by Van der Port (the FIT-stroke trial) is investigating the effectiveness of task-orientated circuit class on the mobility section of the Stroke Impact Scale and on Quality of life. The intervention will be delivered twice a week for twelve weeks. They are also assessing cost effectiveness. This study is to enrol people who have been discharged from inpatient rehabilitation but the intervention is to be delivered in a rehabilitation hospital and the control group will receive outpatient physiotherapy.

Screening for cardiac risk factors

The issue that studies in this area have yet to examine is the potential role of these interventions in screening participants for underlying cardiac risk factors that would prevent them exercising in the community. There is considerable co- morbidity between stroke and cardiac disease. It is estimated that between 20-40% of patients with stroke will test positive for silent cardiac ischaemia [36] Atherosclerotic vascular disease is the main cause of exercise related deaths in adults, in people with known coronary heart disease the primary cause of death after exercise is ventricular fibrillation. The overall risk from exercise is low, even in people with coronary disease, as in cardiac rehabilitation programs, cardiac arrests occur at a rate of 1 in 12 000 to 15 000 in people with known cardiac disease [37]. Although exercise has been shown to have great benefits as the main form of cardiac rehabilitation (27% reduction in mortality [38], Cochrane review) the greatest risk is when previously inactive people start exercising. Allowing participants to exercise in a highly supportive medical environment with a very gradual increment in physical activity would allow for the uncovering of any significant cardiac contraindications for exercise. Another possible role for interventions at this point is for participants to learn how to exercise and become accustomed to exercise. This would be supported by qualified physiotherapists before participants go on to continued activity in the community. These are two areas for further research at this point:

The prevalence of adverse events and the detection of cardiac problems by these interventions

The effect of these interventions on knowledge about exercise. Knowledge of exercise has two aspects

1. physical self- knowledge=knowledge of what it feels like to be exercising at the correct intensity and knowledge of the kind of exercises that will help the individual to reach their personal goals, and
2. factual knowledge about exercise = knowledge about the general benefits of exercise and physical activity.

After discharge from physiotherapy

Another potential point of intervention is when participants have been discharged from outpatient physiotherapy. Moore et al. 2009 [30] were interested in whether intensive locomotor training could improve walking after the 'plateau' stage of 'no further improvement from traditional physiotherapy' had been reached. The intervention was 4 weeks of locomotor training (the participants walked on a treadmill at the 'highest tolerable speed http://stroke.ahajournals.org.ezproxy.webfeat.lib.ed.ac.uk/cgi/content/full/41/1/129 - R7-563247#R7-563247 with velocity increased in 0.5-kmph increments until subjects' heart rate reached 80% to 85% of age-predicted maximum or until the subjects' Rating of Perceived Exertion increased to 17 on the Borg scale' Moore et al. 2009). The additional 4 weeks of locomotor training significantly reduced the O_2 cost of the twelve minute walk in the intervention group. The study was a cross over design. It is interesting to note that even while the participants were in the four-week delay before receiving the intervention they still improved on many of the outcome measures. This is important as stroke survivors taking part in studies after a greater time has elapsed after their stroke might be expected to experience a deterioration in their physical capacity in the absence of intervention [as found by 39].

Long term
The remainder of studies then fall into the ‘chronic stroke’ category and enrol participants who have been discharged from hospital for a longer period of time. Many of these studies include exercise interventions delivered by exercise professionals (supported in many cases by physiotherapy advice) and are delivered in community locations such as leisure centres [e.g. 34, 35, 39]. It was thought at one time that all potential for recovery from stroke was achieved during the first few months. We now know that there is potential for improvement long after this, as these and other studies have demonstrated . We know that the physical fitness of stroke survivors can be improved by training. What is less clear is the frequency and intensity of exercise required to produce health improvements.

Types of intervention

Effect of duration/intensity
Studies of exercise after stroke vary considerably in the intensity, frequency and duration of the interventions applied. To our knowledge only one study has attempted to directly compare different exercise regimes (discounting studies of exercise versus usual physiotherapy, or treadmill versus overground training). This was the study by Rimmer et al (2009)[66]which aimed to compare the effects of 3 different exercise regimens on cardio respiratory fitness and coronary risk factor reduction in stroke survivors. They compared intense and short duration sessions, with longer but less intense exercise sessions and a therapeutic exercise session – consisting of strength and balance exercises. All groups exercised three times a week. Both the exercise training regimens produced reduction in cardiac risk factors compared to the therapeutic exercise condition: the short intense sessions produced reduced blood pressure and cholesterol and triglycerides and the longer less intense exercise sessions reduced triglycerides.
Further research is required to test the duration and intensity of exercise necessary to improve the functional outcomes and morbidity and mortality of stroke survivors.

Content
There is currently no evidence regarding the optimum exercise prescription for stroke. The clearest evidence is that cardiovascular training should include plenty of walking practice [54].
Below are some examples of circuit-based interventions that have been included in meta-analyses demonstrating effectiveness in improving gait speed and endurance and improvements on timed up and go [55]. The exception is Stuart et al 2009 [60] which is more recent and has yet to be included in a review. This study did find significant improvement across a range of outcome s in the intervention groups.
Dean et al 2000 [56]: 10 minutes participating in walking relays and races .Workstations: sitting at a table and reaching; sit-to-stand; stepping forward, backward, and sideways onto blocks of various heights; standing heel lifts; standing

reaching; kinetron; standing up from a chair and walking; treadmill; walking over various surfaces and obstacles; walking over slopes and stairs

Salbach et al 2004 [57]; stepups; balance beam; kicking ball; standup and walk; obstacle course; treadmill; walk and carry; speed walk; walk backwards; stair walking

Pang et al 2005 [58]: brisk walking, sit-to-stand, alternate stepping onto low risers; walking in different directions, tandem walking, walking an obstacle course, sudden stops and

turns during walking, walking on different surfaces standing on different surfaces, standing with one foot in front of the other, kicking ball

with either foot; partial squats, toe rises; resistance band exercises for shoulder;

other small muscle strength exercises.

Mead et al 2007 [59] Each session started with a warm-up to enhance circulation and mobility (15–20 minutes). The total duration of the exercise training increased from 15 minutes at Week 1 to 40 minutes by Week 12. The endurance component began in Week 1 as a circuit of cycle ergometry, raising and lowering a 1.4-kg, 55-cm exercise ball, shuttle walking, and standing chest press performed consecutively. Between each circuit station, patients walked or marched in place to ensure continuous movement. A stair climbing and descending exercise was added in Week 4. The circuit duration increased from 9 minutes to 21 minutes by Week 12. Cycling intensity was increased weekly by small increments in pedaling resistance, cadence or both while maintaining perceived rate of exertion in the range of 13 to 16.

Staurt et al 2009 [60] At beginning of class walk round room for 6 min, at end of class walk around ropes placed on floor for 6 minutes. Seated exercises included sit to stand, trunk twists, shoulder lifts, arm rolls, and neck stretches. Exercise at bar include weight shifting, mezzo squats, stretches and leg/trunk flexion and extensions.

Maintaining the benefits

There is evidence that the benefits of exercise after stroke are lost in the months after a discrete intervention finishes [40]. It is thought that on-going physical activity is required to retain improvements. It is generally recognised that to benefit from physical activity requires long term behaviour change. There are two principal ways to approach long-term behaviour change to a more active lifestyle –the first is to have an

on-going long term intervention- for example, there are two studies of fairly long term interventions: Michael et al [33] conducted a small, uncontrolled study of adaptive physical activity. Seven people took part and engaged in exercise sessions three times a week for six months. They found improvements in balance, gait, and fitness. The other example is Stuart [39] who examined an existing exercise scheme that was not time limited. The other method is:

to see whether short-term interventions can increase general levels of activity once the intervention is complete. A way to measure this is through pedometers or accelerometers. Pedometers measure steps taken and accelerometers measure the amount of physical activity. Mudge et al [61] did not find an increase in usual walking activity at home despite improvements in gait endurance in their intervention group. Moore 2009 did find that locomotor training increased the number of steps per day in the intervention group. Michael et al [33} did not find any effect of their intervention on daily step monitoring. The step monitoring was a count of the steps taken in the community or at home outside the exercise sessions. Rand et al. (2009) [67]found that stroke survivor's ability on the 6 min walk test did not correspond to their levels of activity at home and many had the potential to be more active. It requires further research to determine why improvements made during many of these interventions do not translate to increased activity outside the study. This may be to do with confidence, fear of falling or aspects of the environment.

Theoretical basis of intervention design

Exercise after stroke is often delivered as part of a broader complex intervention. For example, Harrington et al. [68]conducted a randomised controlled trial of a community based exercise and education scheme for stroke survivors. The intervention was influenced by the peer educator model. Compared to the control group who received standard care, the intervention group had much better physical integration at follow up. Physical integration was measured using the SIPSO which asks participants to rate (on a 4 point scale) how difficult they find it to –get dressed, move around their home, perform ADLs at home, move around neighbourhood and go shopping. They also found a significant improvement on the WHOQol-bref at six months. The intervention was quite intensive with two hours twice a week (1 hour exercise , 1 hr education) but only lasted for 8 weeks. After the intervention participants were encouraged to explore other options for continued exercise. The accompanying qualitative study found that stroke survivors valued the exercise component because it gave the opportunity to work towards defined goals, participate in meaningful activity and gain social support.

Cardiac rehabilitation model

The coupling of exercise and education is similar to the cardiac rehabilitation model model. Cardiac rehabilitation is defined in SIGN guideline 57 as ʻ the process by which patients with cardiac disease, in partnership with a multidisciplinary team of health professionals, are encouraged and supported to achieve and maintain optimal physical and psychosocial health' http://www.sign.ac.uk/guidelines/fulltext/57/section1.html There is good evidence of effectiveness the exercise component of cardiac rehabilitation [38]. Tang et al [62] have argued that cardiac rehabilitation should be widened to include stroke survivors because of the high levels of comorbidity between the two disorders and common risk factors. Tang et al surveyed cardiac rehab services in the Ontario area of Canada to find out whether people with stroke could access the schemes. They found that around 60 % of services accepted people with stroke but only around 5% of participants in these classes were stroke survivors. The study compared the outcomes of users who had primary stroke diagnosis and cardiac diagnoses, primary cardiac and stroke or just cardiac and all three groups had similar benefits from the program in improving peak oxygen capacity. The CRAFT s study by Lennon et al [41] is an on-going trial of the adaptation of cardiac rehab to stroke.

Falls prevention model

In addition to cardiac rehab, another example of existing models of exercise for older people that has been applied to stroke, is falls prevention. In an on-going trial in Australia, Dean and colleagues [42] are looking at the effects of a group exercise program on balance and mobility in stroke survivors. Stroke survivors are more likely to have falls and fractures than unaffected community dwelling older people. In the Dean et al study participants are randomised to either a lower limb or upper limb intervention. The lower limb intervention is the one hypothesised to influence balance and mobility the upper limb intervention are seated exercises to improve function in affected upper limbs. Both interventions are conducted in groups. They hope to recruit 350 stroke survivors. Outcomes will be collected at entry and 12 month follow up and the main outcome measures are 10m and 6min walk tests.

Batchelor et al [43] in another on-going trial, the FLASSH study, are also looking at the effects of a complex intervention, including exercise, on the rate of falls in community stroke survivors.

Types of outcome

Considering measurement of impact on long-term activity levels brings us to the range of potential outcomes that are considered in exercise after stroke research. The WHO International Classification of Functioning, Disability and Health (ICF) define three types of outcomes body structure/ function, activity and participation (http://www.who.int/classifications/icf/en/). Under these domains, the outcomes available for study in exercise after stroke include:

Body structure/function: structure: muscle composition, expression of NO in muscles, lipid levels, blood pressure, whole body composition, and body mass; function would include physical fitness (peak VO_2), depression, fatigue and anxiety.

Activities : balance, walking ability, sit to stand, and activities of daily living

Participation: shopping (iADLs), attending groups, visiting friends, employment, leisure activities and quality of life.

Salter and colleagues found that there are more than twenty stroke-specific standardised measurement tools that can be used for the above ICF outcomes. This makes the selection of outcome measures important so that results of studies are directly comparable.

Macko and Hidler (2008) (http://www.rehab.research.va.gov/jour/08/45/2/pdf/pagevii.pdf) suggest that exercise for stroke should be seen as 'a multisystems model' that encompasses adaptations in

- the central nervous system through neuroplasticity and motor learning;
- cardiovascular metabolic health; and
- body composition, including bone health and muscle maintenance

and that these in combination improve health and function outcomes.

Long term outcomes have rarely been examined such as the impact of exercise after stroke on long-term morbidity and mortality.

Psychosocial outcomes

Exercise classes can be a safe environment in which stroke survivors can regain their physical ability to move around independently outside the home [45]. This will theoretically improve their ability to access local services and maintain social contacts. It has also been reported that stroke survivors find the ending of physiotherapy difficult. They often disagree with the conclusion that they have no further scope for improvement and feel abandoned [46]. The benefit of exercise is that it allows participants to engage in continued purposeful activity to aid their recovery [45].

Effectiveness of existing community programs

There is only one published study of an existing community Exercise after Stroke program, that is, one that was not organised for research purposes. Stuart et al [39] have evaluated the adaptive physical activity program used in the Empoli health authority area, Italy. They performed a controlled study with 40 participants in the intervention group. The programme was intense in comparison to other existing community programs that we are aware of in Scotland, consisting of three hours exercise per week. At 6 months follow up, the intervention group improved whereas controls declined on 6 min walk test, balance, Short Physical Performance Battery, and Stroke Impact Scale-social participation domains. People in the intervention group who were depressed (by Hamilton Rating scale) on entry improved by follow up whereas the controls did not.

Efficacy of strength training.

Most of the above studies considered cardiovascular or mixed training. Some studies employ just strength training alone. In their meta-analysis Harris and Eng found that upper limb strength training had significant effects on grip strength and upper limb function but did not improve ADLs. The authors suggest that this may be because ADLs require complex movements and all elements of this may need to be trained in order to see improvements. They also found that upper limb strength training did not increase tone or pain in participants. Lee also found that progressive resistance training was effective in increasing strength, peak power and endurance in paretic and non-paretic limbs.

Balance training

Onigbinde found, in a small study, that wobble board training significantly improved dynamic and static (eyes closed) balance in stroke survivors.

Other types of exercise – e.g. tai chi, yoga, Pilates

There is very little research evidence about the application of tai chi and yoga to stroke. Some very small studies have found some evidence of potential benefits. For Tai chi [69]; and for Tai Chi on balance [70] but this requires further exploration through larger more methodologically robust trials.

Barriers and motivators to exercise.

We know that many stroke survivors are very inactive. To gain benefits from physical activity long term behaviour change to a more active lifestyle is required. There is currently little information about the barriers to stroke survivors becoming more active. Three studies have used questionnaire measures to assess barriers and facilitators to exercise after stroke. Two of these studies were very small [47, 48] and recruited samples very different to the majority of community dwelling stroke survivors in the UK (Payne: inpatients, Rimmer: majority female African-Americans). Rimmer et al's study was a survey of unilateral stroke survivors (n=83) on barriers to exercise. They found that the financial cost of going to a fitness centre was the major barrier followed by lack of knowledge about where they could exercise and then by lack of transport. Payne et al's study of stroke inpatients found that feeling tired and poor general levels of health were the biggest barriers and most patients thought that the doctor telling them to exercise would be the best motivator. The one larger study [49] on exercise behaviour and self-efficacy found an association between current levels of activity and participants' beliefs that they could overcome barriers to exercise. This was a cross sectional study and the concurrent association between these beliefs and exercise behaviour lacks explanatory power. The single existing qualitative study on barriers to exercise in stroke survivors [50] referred to general exercise participation and not on the decision to attend an exercise class specific to stroke. They found that functional limitations due to stroke and environmental factors were significant barriers to physical activity.

Boysen et al [51] conducted a randomised controlled trial of repeated encouragement from health professionals to stroke survivors in the community to increase levels of physical activity. This was not found to be effective in increasing levels of activity.

Payne et al [48] (stroke survivors), and Crombie and colleagues [52] (older people) have found that there are good levels of awareness about the benefits of physical activity. Further research is required in order to explore the barriers that prevent stroke survivors acting on this knowledge to increase their physical activity levels.

Conclusions

There is growing evidence that exercise after stroke is of benefit as demonstrated by the Cochrane review.

Based on the existing research evidence, exercise after stroke services are being developed in Scotland and in other countries. The next stage is to test whether these services can be shown to benefit stroke survivors particularly in terms of long-term morbidity and mortality. In addition to measuring these health outcomes further qualitative exploration of stroke survivor's experience of community exercise participation is required. We also need to establish the health economics of delivering these services outside a research context. The final strand is that in order to ensure that stroke survivors get the benefit of the services being developed, that barriers and motivators to participation in exercise are further explored so that participation can be maximised [53].

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