Effect of exercise on balance, strength and reaction time in older people

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Twenty subjects enrolled to take part in an exercise programme (mean age = 62.5 years) and 20 control subjects (mean age = 65.5 years) underwent assessments of strength, reaction time, neuro-muscular control and body sway. The exercisers participated in one hour exercise sessions comprising a cardiorespiratory (walking) component and a gentle exercise component twice weekly for 20 weeks. All subjects were then re-tested for the same measures after the completion of the programme. The exercisers showed improved quadriceps strength, reaction time and reduced body sway when compared with the control group; the exercise group showing continued improvement throughout the programme in tests of body sway. The findings suggest that exercise can improve physical function in older people.

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The decline in physical functioning that is associated with ageing may, at least in part, be due to a decrease in, or lack of, physical activity (Nichols et al 1993). While regular exercise is often recommended as a means of improving physical function in older persons, the effects of exercise on various functional systems has not been adequately shown (Buchner et al 1992).

Several studies have found that adherence to a regular exercise programme can significantly improve muscle strength (Aniansson et al 1984, Charlette et al 1991, Fiatarone et al 1990, Frontera et al 1988, Morey et al 1991, Nichols et al 1993) and in two studies, a significant improvement in reaction time following regular exercise programmes has been found. (Dustman et al 1984, Rudisill and Toole 1992).

However, studies that have measured the effects of exercise trials on balance control have produced conflicting results. Era (1988) and Johansson and Jarnlo (1991) have reported significant improvements in measures of postural sway following exercise trials, whilst Crilly et al (1989), Lichtenstein et al (1989) and McMurdo and Rennie (1993) have reported weak to negligible effects of exercise training on body sway. One study (Parsons et al 1992) which assessed the effect of exercise training on balance when tested on stable and moving platforms, found significant improvement post exercise in the test on the moving platform only.

Most of these trials have been of a pilot nature with small sample sizes. Although the existing evidence is sufficient to suggest that older people should exercise, further studies are required, particularly with regard to exercise type, intensity, frequency and duration, to elucidate the role exercise can play in improving sensori-motor function in older people. Such research has important practical implications, as it has been found that impaired strength, reaction time and stability are associated with falls in older persons (Brocklehurst et al 1982, Lord et al 1991a, Whipple et al 1987).

This paper examines the effect of a pilot 20-week programme of exercise (comprising cardiorespiratory and gentle exercise components) on muscle strength, neuromuscular control, reaction time and body sway in a group of 20 older persons, comparing these outcomes with 20 control subjects of similar age.

Method

The exercise subjects were drawn from 44 persons aged 50 to 75 years (mean age 62.4 years) who commenced exercise programmes and underwent baseline sensori-motor assessments at the Lewisham Sports Medicine Clinic. All of these exercise subjects were living independently in the community. The control group was drawn from women who had taken part in the Randwick Falls and Fractures study – a study aimed at

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assessing physiological factors associated with falls and fractures in older community-dwelling women (Lord et al 1993). The 20 youngest women from this study, who were not taking part in any organised exercise programme, and who had completed sensori-motor assessments on two occasions 22 weeks apart, comprised the controls. These women were aged 59-70 years (mean = 65.5, SD=2.8). The exercise and control groups were similar across a number of health and lifestyle measures. Table 1 shows the numbers and proportions in each group who reported medical conditions, medication use, falls in the past year and participation in physical activities.

Table 1.
Number and proportion of subjects who reported medical conditions, drug use and participation in physical activities.

	Exercisers		Controls	
	N	(%)	N	(%)
Medical conditions				
Osteoarthritis	9	(45)	7	(35)
High blood pressure	5	(25)	5	(25)
Stroke/Heart problems	1	(5)	1	(5)
1+ falls in past year	4	(20)	4	(20)
Drug use				
3+ drugs	2	(10)	4	(20)
CVS drugs	3	(15)	5	(25)
CNS drugs	2	(10)	4	(20)
NSAIDS	1	(5)	4	(20)
Activity				
1+ planned walks/week[1]	11	(55)	11	(55)
Activities[2]	6	(30)	5	(25)

1 – planned walks for exercise.
2 – participation in one or more of the following on a weekly basis: bowls, golf, tennis, swimming, dancing.

The exercise programme

The exercisers participated in approximately one hour exercise sessions twice weekly for two 10 week sessions (with an inter-term two week break). The classes were divided into four sections: a warm up period, a cardiorespiratory (walking) component, a flexibility and muscular strength (gentle exercise) component and a cool down period.

The cardiorespiratory component consisted of an outdoor walking programme graded in terms of both duration and intensity. The flexibility and muscular strength component was a modified aerobics programme in which all joints and major muscle groups were exercised. Specific graded muscle group strengthening exercises were undertaken, with an increased number of repetitions per session. Muscle groups targeted included ankle dorsiflexors, knee extensors, hip abductors and hip side-flexors. Balance exercises were undertaken using equipment such as chairs, sticks and mini-trampolines. Ball games assisted in co-ordination exercises and exercise bikes were used in some circuit training (a series of exercises undertaken in rotation). The exercises were undertaken as group activities, with a major emphasis on social interaction and enjoyment. Most of the activities were done with the accompaniment of music.

The programme timetable for Term 1, which outlines how the stimulus was increased to maintain the workload and the number of exercise repetitions in each class is shown in Figure 1. The second 10 week term comprised a maintenance programme with the workload and number of exercise repetitions maintained at the level reached in week 10 of Term 1. Attendance at the classes was monitored throughout the exercise period.

Sensori-motor function assessments

The assessment included tests of muscle strength, reaction time, neuromuscular control and body sway. Each full assessment took approximately 20 minutes.

Quadriceps strength was measured by placing a strap around the subject's dominant leg, ie the right leg in a right-handed person and the left leg in a left-handed person. The strap was connected to a fixation point behind a chair so that when the subject (seated on the chair) attempted to extend the leg, a spring gauge was extended giving a measure of maximal quadriceps strength. The subject had three experimental trials and the greatest force measured by the spring gauge was recorded in kilograms.

Reaction time was assessed using a simple reaction time paradigm, using a light as the stimulus and depression of a switch (by the foot) as the response. Subjects were given 10 practice trials and 10 experimental trials. The mean score of the 10 experimental trials was taken as the measure of reaction time.

Neuromuscular control was measured using a device that measured the subject's ability to press and depress a switch with the foot as many times as

Figure 1.
Modified Aerobics Programme - Term 1.
[10 weeks - two sessions per week]

Week	Warm up	Cardiorespiratory endurance (Walking)	Flexibility and Strength (Gentle exercise - 30 mins)	Cool down
1	10 mins	10 mins	MGJE	10 mins
2	10 mins	10 mins – inc pace	MGJE	10 mins
3	10 mins	10 mins – inc pace	MGJE, SMG (x5)	10 mins
4	10 mins	15 mins	MGJE, SMG (x10)	10 mins
5	10 mins	15 mins – inc pace	MGJE, SMG (x15)	10 mins
6	10 mins	15 mins – inc pace	MGJE, SMG (x20)	10 mins
7	10 mins	20 mins	MGJE, Pair activities, SMG (x25)	10 mins
8	10 mins	20 mins – inc pace	MGJE, Group activities, SMG (x30)	10 mins
9	10 mins	20 mins – inc pace	MGJE, Circuits, apparatus, SMG (x30)	10 mins
10	10 mins	20 mins – maximal pace	MGJE, Group activities, SMG (x30)	10 mins

MGJE – Major muscle group and joint exercises – modified aerobics program.
SMG – Specific muscle groups: ankle dorsiflexors, knee extensors, hip abductors, hip side-flexors.

possible in a period of eight seconds. The seated subject placed the dominant foot on a foot rest which was hinged to a base plate. A switch recorded how many times the foot rest was depressed. The subject had a number of practice trials with the device, and then attempted to press and depress the foot as quickly as possible for eight seconds. Two experimental trials were performed, with the higher number of foot depressions taken as the measure of neuromuscular control.

Body sway was measured using a sway meter that measured displacements of the body at the level of the waist. The device consisted of a rod attached to the subject at the waist level by a firm belt. A pen attached to the end of the rod recorded the movements of the subject on a sheet of graph paper (with a millimetre square grid) which was fastened to the top of an adjustable height table. The subject was instructed to stand with feet together on a firm base as motionless as possible for a period of 30 seconds while fixating a point at eye level at a distance of three metres. The test procedure was then repeated under a further three conditions: standing on a firm base with the eyes closed; standing on high density foam rubber (70cm by 62cm by 15cm thick) with the eyes open; and standing on the foam rubber with the eyes closed. The foam was used to reduce proprioceptive input from the ankles so that subjects were required to rely on visual and/or vestibular cues to maintain a steady stance (Lord et al 1991b). Total sway (number of square millimetre squares traversed) in the 30 second period was recorded for the four test conditions, providing a measure of the length of the sway path.

Exercise subjects were tested prior to commencement of the trial, re-assessed at the end of the first 10 week term and then again at the end of the programme (22 weeks). The control subjects were tested for the same measures on two occasions 22 weeks apart. Exercisers and controls performed similarly in the tests of quadriceps strength, reaction time and neuromuscular control at initial testing, although sway scores were significantly higher in the exercise subjects at this time.

Full descriptions of the apparatus and procedures, along with test-retest reliability scores for the test measures have been reported elsewhere (Lord et al, 1991b, Lord et al, 1993).

Statistical analysis

Chi square tests for cross-tabulation tables and student *t*-tests were used to compare the prevalence of health and lifestyle factors and the means of the test measures of the exercise and control groups at initial assessment. Paired *t*-tests were used to examine any changes in test performance at the end of the program within each group, whilst student *t*-tests were used to compare any differences in performance between the exercise and control groups, where differences between initial assessment and retest were measured in absolute terms and percentage change. As the test measures had right skewed distributions, logarithms of the variables were calculated and examined in the analyses. Multiple analysis of variance with repeated measures was

Table 2.
Mean values (SDs) for the test measures at pre- and post-tests.

	Exercisers (n=20)			Controls (n=20)		
	Pre-test	Post-test	% change	Pre-test	Post-test	% change
Quadriceps strength (kg force)	28.6 (15.3)	32.4 (14.9)	15.2**	28.4 (9.0)	27.4 (7.9)	-1.0
Reaction time (msecs)	273 (65)	253 (30)	-4.9*	272 (35)	280 (28)	3.8
Neuromusc control (taps/8 secs)	33.1 (6.6)	34.8 (6.2)	6.5	32.0 (6.7)	32.9 (5.2)	5.3
Sway (mm squares traversed in 30 secs)						
Eyes open (floor)	84 (38)	60 (26)	-20.4*	57 (18)	54 (22)	-1.7
Eyes closed (floor)	108 (53)	74 (36)	-22.9**	63 (27)	70 (29)	23.1
Eyes open (foam)	129 (33)	91 (29)	-27.2**	90 (38)	89 (32)	10.0
Eyes closed (foam)	183 (61)	124 (41)	-29.8**	142 (51)	146 (54)	7.5

Increases in the tests of strength and neuromuscular control, and decreases in the tests of reaction time and sway indicate improvements.

Percentage change expressed as ([test 2 score - test 1 score] / test 1 score) x 100

* $p<0.05$

** $p<0.01$

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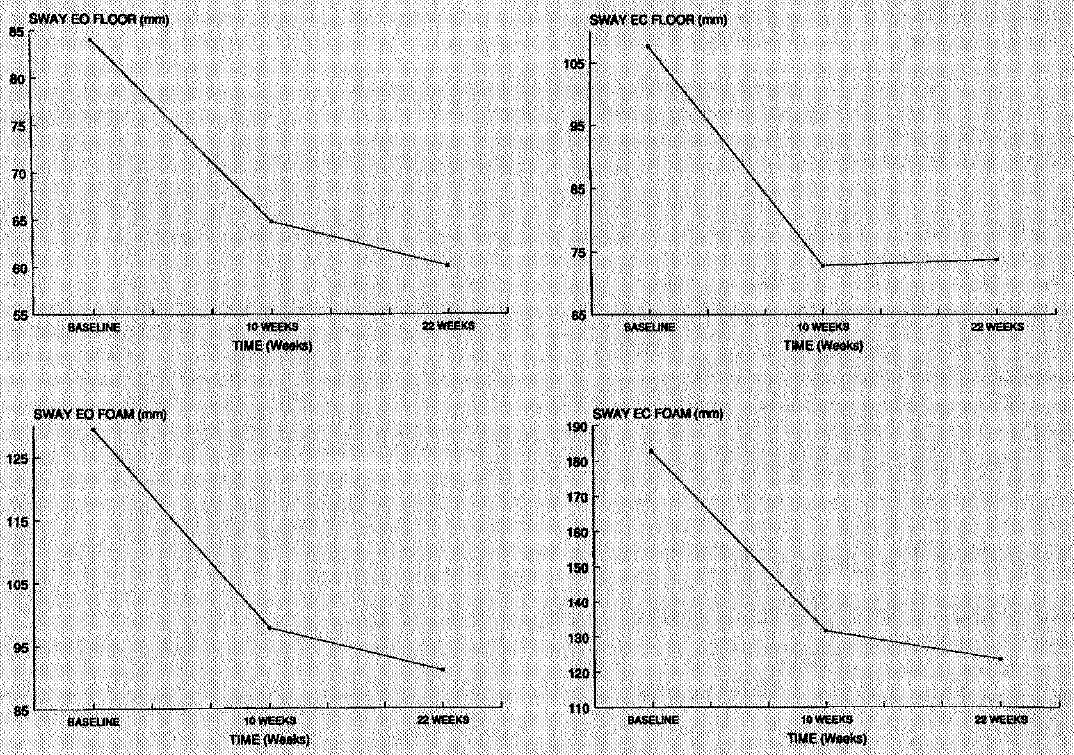
used to examine whether there were improvements in the test measures over the 22 week period in the exercise group. In these analyses, polynomial contrasts were selected, giving measures of linear and quadratic (ie non-linear or asymptotic) trends (Norusis, 1990). A significant linear contrast indicates that there is an overall improvement throughout the trial, whilst a significant quadratic contrast indicates that there is a change in the rate of improvement during the trial. The alpha level was set at 0.05. The data were analysed using the SPSS computer package (SPSS Inc. 1990).

Results

Twenty-eight of the 44 subjects (63.7 per cent) who commenced the programme were still attending at the end of the second 10 week term, but eight of these were unavailable for retest. Of those no longer exercising, five subjects stopped due to poor health (eg heart problems, stroke, incontinence), one stopped because of her husband's illness, three moved from the area and seven discontinued because they were no longer interested. The mean number of classes attended for the 20 subjects (eight men and 12 women) available for retest was 35.1 (SD = 2.8). The range was from 28-39 classes (72-100 per cent).

Mean values, plus standard deviations for the test measures at baseline and at completion of the trial for the 20 exercisers available for retest and the 20 controls are shown in Table 2. At the 22 week retest, the exercise subjects showed significantly decreased sway in all four conditions compared with baseline results: sway on floor eyes open, ($t_{(19)} = 3.22, p<0.01$); sway on floor eyes closed, ($t_{(19)} = 3.62, p<0.01$); sway on foam eyes open, ($t_{(19)} = 5.06, p<0.01$); and sway on foam eyes closed, ($t_{(19)} = 5.62, p<0.01$). Exercisers also showed improvements in the other test measures: quadriceps strength ($t_{(18)} = 1.75, p = 0.10$), reaction time ($t_{(19)} = 1.67, p = 0.11$) and neuromuscular control ($t_{(19)} = 1.66, p = 0.11$), although the differences were not statistically significant. In contrast, the control subjects' retest results were very similar to their baseline results for all test measures. When comparing baseline retest changes in performance between the groups (expressed either in absolute terms or percentage change), the exercise subjects showed significantly improved quadriceps strength, reaction time and body sway under all four test conditions, but not neuromuscular control.

Figure 2 shows the average scores in the sway tests for the exercise group at baseline, 10 weeks and 22 weeks. The multiple analysis of variance in which length of the sway path was the dependent variable revealed that the exercise group showed continued improvement throughout the programme in the sway tests with the eyes open on both the floor and foam as indicated by significant linear contrasts and non-significant quadratic contrasts. Overall improvement was also evident in the sway tests with the eyes closed (linear contrasts significant at $p<0.01$), although the quadratic contrasts were also significant, indicating that the amount of improvement in the second period was less than in the initial period.



Legend:

Sway EO Floor:
linear contrast $F_{(1,19)}=10.35, p<0.01$
quadratic contrast $F_{(1,19)}=3.27, p=0.09$

Sway EC Floor:
linear contrast $F_{(1,19)}=13.13, p<0.01$
quadratic contrast $F_{(1,19)}=5.90, p=0.03$

Sway EO Foam:
linear contrast $F_{(1,19)}=25.61, p<0.01$
quadratic contrast $F_{(1,19)}=3.16, p=0.09$

Sway EC Foam:
linear contrast $F_{(1,19)}=31.54, p<0.01$
quadratic contrast $F_{(1,19)}=5.67, p=0.03$

Figure 2.
Mean sway scores in exercisers at baseline, 10 weeks and 22 weeks.

Discussion

The exercise group showed significant improvements in the tests of strength and body sway following the programme, compared with the control group of non-exercisers. The increase in strength in those undertaking exercise is in accord with published studies of exercise trials that have mostly included heavy resistance (weight) training of short duration (Buchner et al 1992). The current trial differed in that it was based on aerobics and walking components, which may be more acceptable to older people over a long period than resistance training. The subjects reported that they enjoyed the programme and most of those who withdrew did so because of health problems, or because they moved from the study area. For those still participating at the end of two terms, attendance was high throughout the programme.

The findings of significant improvements in body sway measures following the exercise programme are in accord with studies by Era (1988) and Johansson and Jarnlo (1991) and in contrast to the findings of the studies by Crilly et al (1989), Lichtenstein et al (1989) and McMurdo and Rennie (1993). The inconsistent findings may be due to differences in intensity and duration of the exercise programmes, compliance and sample differences. The present study group (mean age = 63 years) was considerably younger than those in the studies where no significant effect of exercise was noted, ie Lichtenstein et al (mean age = 77 years), Crilly et al (mean age = 82 years) and McMurdo and Rennie (mean age = 82 years). The importance of the duration of an exercise programme is made apparent by the maintained or continued improvement in the sway measures at the end of the second 10 week term. Further, the greatest improvements in body sway were evident in the tests undertaken on the compliant surface, which indicates that exercise may be particularly

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helpful in situations that stress or reduce stability. The findings of Parsons et al (1992), who reported that after an exercise programme, subjects showed improved sway when standing on a moving platform, are consistent with this claim.

At the end of the programme, reaction time in the exercise group improved by five per cent, whereas there was no change in the control group. This finding is consistent with studies by Dustman et al (1984) and Rudisill and Toole (1992) and supports the claim by Rudisill and Toole (1992) that older inactive persons can avoid or minimise increases in their central processing time without having had a lifetime of physical activity. The improvement in the test of neuromuscular control in the exercise group was little different from that found in the control group, indicating that the change may have been simply due to a practice effect.

One limitation of the study was that although the exercisers and controls were well matched for age and prevalence of diseases and disorders, there were some subject-control differences, in that the control group was made up entirely of women (whereas the exercise group comprised both men and women) and performed significantly better at baseline in the sway tests. Nonetheless, the improvements in the sway tests were considerable in the exercise group, so that on retest, the sway scores in the exercise group were in line with or better than the levels of the control group.

A further inherent limitation in a study of this type, is that the subjects cannot be blinded to their treatment condition. Thus the exercise subjects were aware that they were receiving the intervention, and it is possible that part of the improvement noted at retest in this group may have been due to increased motivation and effort expended in the tests of strength, reaction time and neuromuscular control. However, such a confounding factor is unlikely to have occurred in the sway tests, as these do not rely on maximal performance.

Conclusion

The findings suggest that exercise can offer older people a means of improving physical function measures such as body sway and strength. However, randomised controlled studies with large sample sizes are required to conclusively determine the role exercise may play in maintaining or improving sensori-motor function in older persons.

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