Explosive power and asymmetry in leg muscle function in frequent fallers and non-fallers aged over 65

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Abstract

Background: although low strength is a risk factor for falls, lower limb explosive power is more predictive of functional difficulties than strength. Power may be more predictive of a future fall than strength per se.

Objective: to compare leg muscle strength and explosive power and asymmetry of leg strength and power of women aged 65 or over living at home, with and without a history of falls.

Design: a case controlled study of self-reported 'fallers' versus 'non-fallers'.

Subjects: twenty women, aged 65 or over, with a history of at least three falls in the previous year were age matched with 15 women with no history of falls in the previous year.

Methods: lower limb explosive power, isometric strength of the quadriceps and hamstrings, isokinetic concentric strength (100°/sec) of the quadriceps, hamstrings, ankle plantar- and dorsi-flexors and quadriceps eccentric strength (100°/sec). Habitual physical activity was assessed using the self-completed Habitual Activity Profile Questionnaire.

Results: the women with a history of falls were less active but were not significantly weaker in any of the strength measurements, apart from ankle dorsiflexion adjusted for body weight. Both groups had significant asymmetry in all the leg muscles for both strength and power. Although both groups were asymmetrical in their lower limb power, the fallers demonstrated a significantly greater asymmetry. When the least powerful legs were compared, the women with a history of falls were 24% less powerful for their weight than those who did not fall (P=0.04).

Conclusions: weakness and asymmetry is prevalent in women aged 65 and over, with and without a history of falls. Poor lower limb explosive power combined with asymmetry between limbs may be more predictive of future falls than more traditional measurements of strength in older women who live independently.

Keywords: aged, asymmetry, explosive power, falls, muscle strength

Introduction

Falls, and injuries due to falls, often lead to fear and consequent limiting of activity that can lead to further falls, a vicious cycle of inactivity-related disability [2]. Fractures, mostly due to falling, cost the UK National Health Service nearly £1 billion every year [3]. The number of older people in the population will rise and it is thought that the rate of falls is increasing faster than can be accounted for by the increasing numbers of older people [4]. There have been many research trials that have considered possible risk factors for falls [for review: 5 and 6].

Physical fitness is especially important in old age, in order to cope with everyday tasks and any unforeseen demands such as hills, uneven ground, trips etc., on the ageing body [7]. Low muscle strength has been identified as a risk factor for falls since nursing home fallers were shown to be much weaker than their non-falling counterparts [8]. Reduced ankle dorsiflexion (60°/sec and 120°/sec), quadriceps strength (isometric, 60°/sec and 120°/sec) and short-term power (assessed on a dynamometer) have all been shown to predict falls and indicate fear of falling [9]. To the authors’ knowledge, no study to date has considered eccentric, isometric, and concentric strength, as well as explosive
power, in community dwelling fallers and non-fallers. In addition, no studies have investigated whether there is a difference between the two lower limbs within older individuals for strength or power.

Explosive muscle power (the product of force and the speed at which force is produced, in the first 0.3 s of a movement) is more predictive of functional difficulties than muscle strength per se [10, 11]. It seems likely that leg muscle power is important in correcting a displacement or movement error; to prevent a fall, an individual must have sufficient lower limb muscle power in the stabilising leg to counteract the kinetic energy of the unbalanced individual. One of the reported risk factors for falls is an increased difficulty with everyday tasks [6]. Explosive power is also strongly related to ability to perform everyday tasks [10, 11]. Explosive power in elderly women who had surgery to repair a hip fracture was 70% less, in the uninjured leg, than their healthy counterparts [12]. To the authors’ knowledge, explosive muscle power has not been assessed in a specific group of fallers without hip fractures.

The aim of this study was to consider differences in leg muscle strength, leg muscle power, asymmetry and activity between age-matched community dwelling women, aged 65 and over, who do and do not have a history of falls.

**Subjects and methods**

**Subjects**

All subjects gave written informed consent and the protocol was approved by the local ethical committee.

**Fallers**

Twenty women living at home, with a history of falls in the past year, were recruited from local and national newspapers, voluntary organisations and word of mouth. They had all had three or more falls (where part of their body inadvertently met the ground or some lower object) in the last twelve months. All aged over 65.

**Non-fallers**

Fifteen age-matched community dwelling women, with no history of falls in the past year, who were recruited from an existing database of volunteers.

**Exclusions for both groups**

Acute rheumatoid arthritis; uncontrolled heart failure or hypertension; marked cognitive impairment; multiple sclerosis; Parkinson’s disease; previously diagnosed osteoporosis. These conditions were chosen as they preclude safe or reliable strength and power testing.

Confirmation of their health status was received from the subjects’ GPs.

**Measurements**

We measured height, weight and body fat (4 skin fold sites). We recorded the number of prescribed medications. Subjects completed a modified version of the 94 question Human Activity Profile [13]. From this questionnaire, a Maximal Activity Score (MAS) and an Adjusted Activity Score (AAS) can be quantified.

**Lower limb explosive power**

The explosive power of the legs was measured using the Nottingham Leg Extensor Power-Rig, designed for use in older people [14]. The subject was seated, with arms folded. One leg was measured at a time and the free leg was rested on the floor. They were asked to push the pedal down as hard and fast as possible, accelerating a flywheel attached to an A-D converter. Their power was recorded for each push until they reached a plateau of power (at least 6 pushes per leg). We recorded the best power for each leg. The coefficient of variation of repeated tests on different days was < 8%.

**Muscle strength**

We measured the strength of the leg muscles using a KIN-COM Isokinetic Dynamometer (Chettecx Corp, Chattanooga, TN). The muscles tested were: quadriceps, hamstrings, plantarflexors and dorsiflexors. The coefficient of variation of repeated tests on different days was < 10% for all tests.

**Quadriceps and hamstrings strength**

The subject was seated with the strain gauge positioned just above the ankle, the lever arm aligned to the centre of rotation of the knee and the knee angle fixed at 90°. Subjects then performed maximum isometric contractions of the quadriceps and hamstrings. Each contraction was held for 3–4 s and the peak force measured. Following this, the range of movement of the lever arm was set between 90 and 20 degrees of flexion. Subjects performed 3 consecutive isokinetic concentric extension/flexion movements at 100°/sec, then a submaximal extension of the leg, followed by a maximal eccentric contraction of the quadriceps at 100°/sec. This protocol was then repeated for the other leg. We corrected all measurements for the weight of the lower segment of the lower limb.

**Plantarflexor and dorsiflexor strength**

The subject lay supine with the foot securely strapped in a footplate, a pillow underneath the slightly flexed knee to prevent full extension and a mid-thigh strap to remove the influence of the quadriceps or hamstrings on
the measurements. The foot began in the dorsiflexed position and the subject was asked to push their foot down and then pull back as hard and as fast as possible. The speed was set at 100°/sec. Again, the movement was repeated three times for each ankle.

Prospective fall history

The fallers were part of a larger trial [15] and completed two-weekly diaries of any trips or falls they had over 12 months. The non-fallers were asked to contact the laboratory if they had a fall in the next 12 months and were telephoned on three occasions during the 12 months for confirmation.

Statistical Analysis

Data were analysed for the weakest/strongest and average leg strength and power. Between-group comparisons were made using Student's unpaired t-tests. Individual differences between legs was analysed using Student’s paired t-tests. We used regression analysis to consider changes of strength and power with age. We used Confidence Interval Analysis to consider differences between regression slopes and intercepts (95% CI).

Results

Group details

There were no statistical group differences for age or body dimensions (Table 1). The non-fallers had significantly higher adjusted activity scores ($P<0.02$, Mann–Whitney $U$ test) but the difference in their maximal activity score did not reach statistical significance (Table 1). The fallers took more prescribed medications than the non-fallers ($P<0.01$). On collection of information from the fall diaries and telephone follow up, the fallers had a median of 2 (range 0–10) falls over the following year and one non-faller had a fall.

Lower limb explosive power

Fallers and non-fallers were not significantly different in their absolute weakest/strongest or average power output. However, the fallers’ least powerful leg was significantly weaker than the non-fallers’ least powerful leg, when normalised for body weight (W/kg) ($P=0.04$, Table 2).

Both groups had significant differences in power between legs (Figure 1, $P<0.001$ for fallers and $P<0.05$ for non-fallers). The fallers, however, were significantly more asymmetric (the difference between legs as a percentage of most powerful leg) than the non-fallers ($P<0.007$, Table 2, Figure 1). Thirteen percent of non-fallers and 60% of fallers had asymmetry between legs greater than 10%. This asymmetry did not increase significantly with age in either ‘fallers’ ($r=0.23$) or ‘non-fallers’ ($r=−0.21$) (Figure 2).

Table 1. Subject characteristics

<table>
<thead>
<tr>
<th></th>
<th>Fallers</th>
<th>Non fallers</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Age (years)</td>
<td>74.5±5.7</td>
<td>74.0±6.3</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.55±0.06</td>
<td>1.58±0.03</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>66.5±10.1</td>
<td>64.5±9.7</td>
</tr>
<tr>
<td>Body mass index (kg.m⁻²)</td>
<td>27.5±3.1</td>
<td>25.9±3.6</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>38.3±6.3</td>
<td>36.6±6.1</td>
</tr>
<tr>
<td>Maximal activity score*</td>
<td>69 (57–82)</td>
<td>75 (62–86)</td>
</tr>
<tr>
<td>Actual activity score</td>
<td>62 (48–76)</td>
<td>74 (56–85)</td>
</tr>
<tr>
<td>No. of medications</td>
<td>2.5 (0–5)</td>
<td>0 (0–3)</td>
</tr>
</tbody>
</table>

Means ± SD except where indicated.
*a as median (range).
*b difference between fallers and non fallers significant at $P<0.05$.

Table 2. Average and weakest leg strength and power in fallers and non-fallers

<table>
<thead>
<tr>
<th></th>
<th>Average of both legs (mean SD)</th>
<th>Weakest leg mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fallers</td>
<td>Non Fallers</td>
</tr>
<tr>
<td>IsoM quadriceps (N)</td>
<td>214.5±56.6</td>
<td>236.6±56.2</td>
</tr>
<tr>
<td>IsoM hamstrings (N)</td>
<td>84.6±20.9</td>
<td>95.5±16.7</td>
</tr>
<tr>
<td>Conc quadriceps* (N)</td>
<td>147.5±49.0</td>
<td>175.8±46.8</td>
</tr>
<tr>
<td>Conc hamstrings* (N)</td>
<td>158.0±50.4</td>
<td>149.8±41.9</td>
</tr>
<tr>
<td>Eccn quadriceps* (N)</td>
<td>299.4±81.3</td>
<td>331.4±80.1</td>
</tr>
<tr>
<td>Conc ankle plantarflexion* (N)</td>
<td>59.6±22.9</td>
<td>61.5±15.0</td>
</tr>
<tr>
<td>Conc ankle dorsiflexion* (N)</td>
<td>160.0±81.7</td>
<td>200.1±56.3</td>
</tr>
<tr>
<td>Conc ankle dorsiflexion/kg² (N/kg)</td>
<td>2.4±1.0</td>
<td>3.1±0.8</td>
</tr>
<tr>
<td>Lower limb explosive power (W)</td>
<td>90.3±36.3</td>
<td>107.8±38.5</td>
</tr>
<tr>
<td>Lower limb explosive power (W/kg)</td>
<td>1.35±0.5</td>
<td>1.70±0.6</td>
</tr>
</tbody>
</table>

IsoM, Isometric; Conc, Concentric; Eccn, Eccentric.
* measured at a constant velocity of 100°/sec.
$P$ = group differences; $n=20$ for fallers and $n=15$ for non-fallers all measurements except eccentric quadriceps ($n=19$, $n=15$ respectively).
In this cross-sectional comparison, the fallers had a lower baseline muscle power than non-fallers in early old age as the intercepts are significantly different (95% CI = −0.05 to −0.73 W/kg) (Figure 3a). Although the fallers ‘appear’ to lose power at a slower rate with increasing age than non-fallers (8.7% vs 18.6% per decade) the slopes are not significantly different from one another (95% CI = −0.03 to 0.09 W/kg/year).
Muscle strength

Although fallers tended to be weaker on most strength tests, both absolute and standardised for body weight, than the non-fallers, only ankle dorsiflexor strength (normalised for body weight) was significantly weaker (Table 2). As with power, there was significant asymmetry between legs for all of the muscle strength measurements in both fallers and non-fallers (P<0.05, Figure 1). However, the strength asymmetry was not significantly greater in the fallers than the non-fallers, as it was with lower limb power. The asymmetry did not follow the dominance pattern of the limbs, nor were the weaknesses consistent to one side of the body. Fallers and non-fallers living at home appear to lose quadriceps strength at a similar rate and the intercepts of the slopes are not different (Figure 3b).

Discussion

Explosive muscle power declines faster with increasing age than isometric quadriceps strength [10, 16]. The decline in strength and power has been strongly implicated in the frailty of old age and, in particular, in an increased risk of falls [1, 6, 9].

In the current study, the fallers were about 24% less powerful for their weight than the non-fallers, when the least powerful leg was compared. The fallers’ mean power, 1.35 W/kg, is less than the proposed functional threshold of 1.5 W/kg that has been suggested as a minimum required to confidently step onto a 30 cm step [12, 16]. 26% of the non-fallers, but 65% of the fallers, have power below this suggested threshold. Certainly in this cross-sectional study, the fallers appear to be less powerful than non-fallers in their early old age.

Although there was a tendency for these fallers to be weaker in most of the strength tests, there were no significant differences between these women and the non-fallers apart from ankle dorsiflexion normalised for body weight. This differs from the significant differences seen in knee peak flexion and extension torque in fallers and non-fallers living in a nursing home [8].

Fallers are not only less powerful but they are also more asymmetric between limbs. Although the current study was not designed with the power to detect differences in fall rates between the groups, the degree of asymmetry in the fallers did not appear to correlate with the subsequent reported number of falls. Perhaps once a significant level of asymmetry is present, the degree of asymmetry is not important. Maybe one weak leg is enough to precipitate a fall or to have too little power to stabilise the body after a trip. Many falls may be related to an environmental hazard. At some point a ‘tripper’ may become a ‘faller’ because of insufficient strength or power in a lower limb.

In healthy, uninjured younger people there is no difference in dominant vs non-dominant leg strength [17]. In younger people who have sustained a unilateral leg injury, significant long-term decrements in quadriceps strength and balance remain, leading to asymmetry [17]. To our knowledge, this is the first description of asymmetry in older people and the differences between fallers and non-fallers. It is possible that these asymmetries are a result of previous injuries.

Eccentric strength is known to be less affected by age than either isometric or concentric strength [18]. Younger people are unable to produce eccentric forces much greater than isometric [19], yet older people can. For the current study, both groups were able to generate about 40% more force during eccentric contractions compared to isometric contractions. This confirms the previous findings [18] and is the first time that it has been demonstrated in people with a history of falls.

It may be that the fallers in this study are still living in their own home only because they have not yet crossed a functionally important threshold of strength.

![Figure 3](image-url)
that would make it impossible to live an independent life. In this study, the fallers did fewer activities of daily living and were less active than the non-fallers. This functional inactivity may be one of the causes of the tendency for weaker muscles and the significant difference seen in the more functionally relevant explosive muscle power—though it could also be argued that the falls preceded the weakness. The fallers also took more medications than the non-fallers, but only two took more than four medications a day, the amount implicated with a higher risk of falls [5, 6].

It appears that power is more predictive of risk of falls than strength alone in these older women. It may be that there is a disproportionate loss of Type 2 fibres in the fallers compared with their non-falling counterparts. This could be as a result of inactivity—or perhaps fallers have preferential loss of type 2 fibres. To the authors’ knowledge, there have been no biopsy studies of muscles from fallers.

This lower and asymmetrical power may be particularly important in cold weather. Some older peoples houses are cold in the winter [20]. In younger people, cooling the muscles down to a temperature expected in cold older peoples’ muscles, led to a 20% decrease in muscle power [21]. If a faller is 24% less powerful than a non-faller and then in cold weather experiences an additional 20% short term loss of power, they put themselves at high risk of being unable to correct even the most minor stumble.

Low power can be improved with tailored, progressive exercise, even to advanced ages [22]. It has yet to be demonstrated whether the same is true for asymmetry. Exercise has many advantages in the preventative battle against the increasing number of falls and injuries in older people [5, 23], by improving power and strength, but also co-ordination, reaction time, gait and balance, all of which are risks factors for future falls [5, 6]. Individual assessment could detect those who have a marked degree of asymmetry and who would likely benefit most from tailored strength and power training.

Conclusions

In conclusion, we have demonstrated for the first time, that older women at home are asymmetrical in their lower limb strength and power. This asymmetry is greater for power in women with a history of falls. Weight-adjusted leg power was also significantly lower in fallers than non-fallers. Perhaps surprisingly, there were no differences in leg strength between fallers and non-fallers, apart from weight adjusted ankle dorsiflexion strength. Future work, therefore, should aim to determine the mechanisms behind reduction in power, rather than strength, in fallers and investigate the causes of significant levels of asymmetry in older women. Potential mechanisms may include the role of selective type 2 atrophy or altered neural control, possibly as a result of previous injury.

Key points

- Older women living at home are asymmetrical in their lower limb strength and power.
- Fallers are more asymmetrical in lower limb explosive power than non-fallers.
- Fallers are weaker in ankle dorsiflexion and lower limb explosive power, when normalised for body weight, compared to non-fallers.
- Older women who fall are less habitually active and take more medications than non-fallers.

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The data presented in this paper has been published as an abstract [1].

References

Asymmetry in strength and power in older female fallers and non-fallers


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