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**ORIGINAL REPORT**

# CIRCUMSTANCES AND CONSEQUENCES OF FALLS IN POLIO SURVIVORS

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***Objectives:*** **Many polio survivors have symptoms that are known risk factors for falls in elderly people. This study aims to determine the: (*i*) frequency; (*ii*) consequences; (*iii*) circumstances; and (*iv*) factors associated with falls in polio survivors.**

***Methods:*** **A survey was conducted among 376 polio survivors. Participants completed a falls history questionnaire and additional information was obtained from their medical files.**

***Results:*** **Of the 305 respondents, 74% reported at least one fall in the past year and 60% two or more. Sixteen percent of fallers described a major injury after a fall in the last year and 69% reported fear of falling. One-third of fallers had reduced the amount they walked because of their fear of falling. Most reported falls in a familiar environment (86%), during ambulation (72%) and in the afternoon (50%). Quadriceps weakness of the weakest leg (Medical Research Council (MRC) ≤3), fear of falling and complaints of problems maintaining balance were independently associated with both falls and recurrent falls, while increasing age and medication use were not.**

***Conclusion:*** **The high rate of falls and consequences thereof, merit the implementation of fall intervention strategies. To maximize effect, they should be tailor-made and target the fall mechanisms specific to polio survivors.**

*Key words:* accidental falls; poliomyelitis; injuries; muscle weakness; post-polio syndrome.

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## INTRODUCTION

Falls are a clinically important, but underrated, problem for poliomyelitis survivors. There has been little research on the topic, despite the fact that an estimated 10–20 million people worldwide (1) and 15,000 in the Netherlands (2) are living with the consequences of polio. Many polio survivors have a variety of symptoms that are known risk factors for falls in elderly people and patients with neuromuscular diseases (NMD) (3–9). In particular, they often have extensive muscle weakness that exists either as a remnant of the primary infection or appears and progresses later in life as a part of post-polio syndrome (PPS) (10–12). In addition, other late symptoms such as muscle and joint pain, cold intolerance and fatigue, may contribute to the occurrence of falls (10).

Studies of fall frequency among polio survivors to date have confirmed the clinical observation that falling is a problem in this group, with 50–84% of participants reporting at least one fall each year (5, 11–14). This yearly fall incidence is considerably higher than that in elderly people, where it is 17–23% for people over 55 years of age (15, 16) and 32–42% for those over 75 years of age (17, 18). Figures pertaining to consequences of falls in polio survivors are equally alarming. One study found that 96% of an outpatient population had osteopaenia or osteoporosis and reported a fracture incidence of 38% over 5 years (14). Another study reported that 61% of 233 community-based participants had required medical attention at some point as a result of a past fall and 35% had sustained a fracture (13). In addition, more than three-quarters of participants described a fear of falling (77%) and many changed their lifestyle because of this fear (62%) (13). Another study reported an even higher frequency of fear of falling, i.e. 95% (12).

Among elderly people, targeted fall prevention programmes have been implemented successfully to reduce the number of falls in the population (3, 17). Whether these interventions are also effective in polio survivors depends on whether the circumstances of falls and associated factors are comparable. Muscle weakness, increasing age, female sex, living alone, increasing disease severity, use of high risk drugs or polypharmacy and fear of falling are some of the numerous risk factors for falls in elderly people (3, 6, 16, 18–24) and people with neuromuscular diseases (4, 8) that might potentially also be associated with falls in polio survivors. So far, only the first and last factors have been expressly studied in relation to falls in polio survivors (5, 12), while circumstances of falls have only been explored in a pilot study (11).

The aim of the current study was to determine: (*i*) the magnitude and severity of the problem of falling; and (*ii*) the circumstances of falls and associated factors among a large cohort of polio survivors in the Netherlands in a retrospective cross-sectional study. The questions we aimed to answer are:

- How frequently do polio survivors fall?
- What are the physical and psychological consequences of falls in polio survivors?
- Under what circumstances do polio survivors fall?
- Are patient characteristics that are known risk factors for falls in elderly people present and associated with falls in polio survivors?

## METHODS

### *Participants*

A total of 387 patients with a history of paralytic poliomyelitis visited the Department of Rehabilitation of the AMC between April 2003 and August 2009. Of these, 11 were excluded because they: had died ($n=3$), were younger than 18 years of age ($n=3$) or currently resided outside the Netherlands ($n=5$). The 376 patients who remained were invited to participate in the study. The hospital medical ethics committee waived the need for ethical approval.

### *Falls history and disability questionnaire*

Participants were asked to complete a questionnaire detailing their: current medical and physical condition, home environment, mobility, average fall frequency, number of falls in the past year, injuries sustained as a consequence of these, fear of falling, reduction in activities because of this fear, and the circumstances of the most recent fall. The questionnaire was based on that used in a previous study among community-dwelling elderly people (15) and also incorporated the Dutch 10-item Falls Efficacy Scale (FES-10). Derived from the original by Tinetti et al. (25), this FES-scale has previously been used as a measure of fear of falling in elderly people (24) and is advised for patients with Parkinson's disease (26). It allows people to denote how concerned they are about falling during each of 10 activities on a 4-point scale, ranging from "0: not at all concerned" to "3: very concerned". The maximum total score was 30. If a subject left one or two items unanswered the total score was divided by the number of answered items and multiplied by 10. For a subject who left more than two items unanswered a sum score was not made, following the advice of the ProFaNE group (27). Missing or unclear answers in the questionnaires were amended by telephone interviews where possible and analysed as missing if not.

### *Disease characteristics*

Information concerning the extent of paresis, types and number of medications used and the history of poliomyelitis was extracted from the medical file of each participant. The strength of ankle dorsal- and plantar-flexion; knee extension and flexion; and hip extension, flexion, ab- and adduction are routinely assessed during outpatient visits using manual muscle testing (MMT) and scored according to the Medical Research Council (MRC) scale (28). For this study, the sum of the most recent MRC-scores of all aforementioned lower extremity muscle groups was calculated for each participant and used as a measure of extent of paresis (29). If a patient had an arthrodesis, the muscle groups crossing that joint were scored as 0. The maximum possible score was 80 and incomplete sum scores were excluded from analysis. Information about the use of prescription medication taken from the questionnaires was supplemented with that extracted from the patient files where necessary. This allowed calculation of the number of drugs used by each subject and the frequency of use of certain classes of drugs that are potential risk factors for falls. Specifically, the use of sedatives and hypnotics (including benzodiazepines), antidepressants, antipsychotics and neuroleptics, anti-arrhythmetics, anticonvulsants, diuretics, digoxine and non-steroidal anti-inflammatory drugs (NSAIDs) was reviewed (18–20). When subjects did not report actual names of drugs or classes of drugs they used and information from medical files was insufficient, the data was considered missing. Multiple drug use was defined as the use of 4 or more prescription drugs (21). The history of poliomyelitis that was sought consisted of: age at the time of infection, the country in which the primary infection was contracted and initially treated, and whether or not the definitive diagnosis post-polio syndrome had been made.

### *Data analysis*

The main outcome measures were self-reported frequency of falls, injuries sustained during a fall, fear of falling, FES-scores and the circumstances of falls. Circumstances of falls were described in terms of location, time of day, activity, ground surface, footwear and distractions during the most recent fall. A faller was defined as someone who had fallen at least once and a recurrent faller as someone who had fallen at least twice in the last year. Frequencies, means, standard deviations (SD) and proportions were used to describe the population and the main outcome measures. Differences in the prevalence of factors associated with falls between (recurrent) fallers and non-(recurrent) fallers and participants and non-participants were investigated using the Student's *t*-test for continuous variables and the $\chi$-square test and Fisher's exact test for (dichotomous) nominal and ordinal variables. A logistic regression analysis was performed in order to create a model for the fall and recurrent fall risks of "walkers" using the following 4 steps: (*i*) the full-time wheelchair users were removed from the analysis; (*ii*) relevant continuous variables were dichotomized using the median of each as a cut-off point; (*iii*) odds ratios (OR) were calculated for each dichotomous variable that was associated with falls or recurrent falls in the previous analysis (at $p<0.10$); (*iv*) the independent contribution of each variable with a significant OR in univariate analysis, was investigated in forward stepwise binary logistic regression analysis, providing an OR and 95% confidence interval (CI) corrected for multiple testing. Significance was set at $p<0.05$.

## RESULTS

### *Population*

A total of 305 of the 376 polio survivors who were approached returned their completed questionnaires (response rate 81%). Non-participants were significantly younger than participants and significantly more first-generation immigrants did not participate, while differences in gender were not significant. Various other disease- and mobility-related characteristics of participants are summarized in Table I.

### *Falls*

*Frequency of falls.* A total of 73.8% of patients ($n=225$) reported at least one fall in the last year (i.e. are *fallers*) and 60.3% (i.e. 81.7% of fallers, $n=184$) at least two falls (i.e. are *recurrent fallers*) (Fig. 1). The reported average fall frequency was similar, with 75.4 % ($n=230$) reporting falling at least once yearly, 25.9% ($n=42$) monthly, 12.1% ($n=31$) weekly and 2% ($n=6$) daily.

*Consequences of falls: injuries and fear of falling.* Eighty percent of the fallers ($n=180$) had sustained at least one injury as a result of a fall in the past year. The majority (64%, $n=144$) had sustained only minor injuries, such as bruises, superficial cuts, scrapes and sprains or strains. However, 15.6% of fallers ($n=35$) described additional major injuries. 7.1% had a fracture ($n=16$), just under half of whom required hospital admission; 3.1% ($n=7$) required hospital admissions for injuries other than a fracture (14 admissions in total = 6.2%) and 5.3% ($n=12$) had one or multiple other serious injuries not requiring hospital admission. The last category included: 5 head injuries (concussions, loss of consciousness, broken teeth,) 3 dislocations (shoulder, knee) and a variety of 5 other thigh, knee and foot injuries with severe repercussions. Three people reported memory loss after the most recent fall without head trauma or loss of consciousness. As the extent of the loss was unknown they were not included in the category "serious injuries".

Table I. *Characteristics of participants and non-participants*

| Characteristics† | Participants ($n$=305) | Non-participants ($n$=71) |
|---|---|---|
| Age, mean years (SD) [range] | 57.4 (11.4) [18–85] | 47.1 (12.2) [21–88]* |
| Female, % ($n$) | 63.6 (194) | 52.1 (37) |
| Acute infection + initial treatment outside EU, % ($n$) | 13.4 (41) | 59.2 (42)* |
| Age at time of acute polio ($n$=298), mean years (SD) [range] | 3.7 (3.8) [0.04–26] | – |
| Duration since acute polio ($n$=298), mean years (SD) [range] | 54.6 (10.8) [17–82] | – |
| Definite diagnosis PPS, % ($n$) | 70.5 (215) | – |
| Sum score MMT lower limbs ($n$=267), mean (SD) | 59.8 (17.7) | – |
| Living alone, % ($n$) | 30.5 (93) | – |
| Walking ability ($n$=303), % ($n$) | | – |
| Never walk | 5.2 (16) | |
| Only walk indoors+around the house | 25.6 (78) | |
| Walk outside, short+long distance | 68.5 (209) | |
| Type of walking aid in-/outdoors ($n$=289), % ($n$)§ | | – |
| None | 46.0 (133) | |
| Manual aid in-/outdoors‡ | 23.2/48.1 (67/139) | |
| Wheelchair in-/outdoors | 5.5/5.5 (16/16) | |
| Orthopaedic shoes ($n$=289), % ($n$)§ | 51.9 (150) | – |
| Orthoses ($n$=289), % ($n$)§ | 42.6 (123) | – |
| Frequent physical complaints, % ($n$) | | |
| Pain in joints or muscles | 83 (253) | – |
| Tiredness | 80 (242) | – |
| Reduced exercise tolerance | 74 (226) | – |
| Rigidity joints or muscles | 71 (217) | – |
| Back pain | 63 (193) | – |
| Problems maintaining balance | 57 (173) | – |
| Swollen feet | 32 (98) | – |
| Reduced sensation legs | 27 (83) | – |
| Respiratory problems/shortness of breath | 24 (73) | – |
| Palpitations | 16 (50) | – |

*$p$<0.01.
†The number of participants for whom the information was available is noted behind each characteristic if it deviated from the total number of participants (i.e. 305); percentages were all calculated as a fraction of the real total (i.e. 305, exception see:§);
‡Manual walking aid: 1/2 cane(s), 1/2 crutch(es) or a walker;
§Those 16 who "never walk" excluded from total in the percentage calculation for this item (i.e. total $n$=289).
SD: standard deviation; PPS: post-polio syndrome (only includes those for whom the diagnosis is certain); MMT: manual muscle testing.

Sixty-three percent of responders answered positively to the question "are you afraid of falling" ($n$=193) and 22.6% ($n$=69) had reduced their walking activity due to this fear. The mean total FES-score was 7.1 (SD 6.7) among the 285 people who completed the scale. There was a significant difference in fear of falling, FES-scores and reduction in activities between (recurrent) fallers and non-(recurrent) fallers (see Table II). Four items of the FES scale were particularly worrying activities to many participants, i.e. "showering or bathing" (72% had a FES-score of ≥1), "de- or ascending stairs" (65.2%), "walking around the neighbourhood" (51.5%) and "food shopping" (48.2%). People were also more often "fairly" and "very concerned" during these activities than during the other 6.

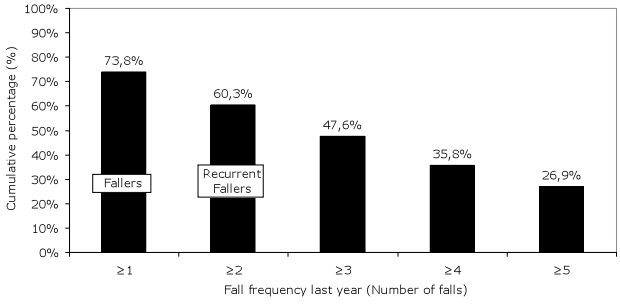


*Fig. 1.* Frequency of falls in the last year ($n$=305).

*Circumstances of falls.* The circumstances of participants' most recent fall are detailed in Table III. The majority of falls occurred in a familiar environment, more than half in or around the home. Four-fifths of all indoor falls occurred inside the home, while four-fifths of all outdoor falls occurred away from the home. With one exception, all falls occurred during daytime, approximately half of these in the afternoon. Almost three-quarters of the group fell while walking, descending and ascending stairs or during posture changes or transfers. Of those in the last category 72.4% (21/29) fell while attempting to get up from a seated position. In one-third of the cases the ground underfoot was noted as being either uneven or slippery. More than half of the fallers were wearing normal shoes when they fell and, interestingly, only 44% of the fallers who had orthopaedic shoes were wearing them at the time of the fall (51/116). One-third of people could not get up after a fall without assistance. Some 16.4% was distracted by an environ-

Table II. *Fear of falling and consequential decreased walking activity relative to fall status*

| | Faller ($n$=225/212†) | Non-faller ($n$=80/76) | $p$-value | Recurrent faller ($n$=184/174) | Non-recurrent faller ($n$=121/114) | $p$-value |
|---|---|---|---|---|---|---|
| Fear of falling, % ($n$) | 69.3 (156) | 46.2 (37) | **<0.001** | 70.7 (130) | 52.1 (63) | **0.001** |
| FES, mean (SD) (288‡) | 8.0 (6.3) | 4.7 (5.4) | **<0.001** | 8.6 (6.5) | 4.9 (5.1) | **<0.001** |
| FES Total ≥10, (%) (288‡) | 34.0 | 14.5 | **0.001** | 39.7 | 12.3 | **<0.001** |
| FES ≥1§, % | | | | | | |
| Cleaning the house (284) | 44.5 | 26.7 | **0.007** | 49.1 | 25.2 | **<0.001** |
| Getting (un-)dressed (291) | 36.7 | 22.4 | **0.022** | 39.3 | 23.0 | **0.004** |
| Preparing simple meals (287) | 24.1 | 8.0 | **0.003** | 25.7 | 10.7 | **0.002** |
| Taking a bath/shower (297) | 76.7 | 66.7 | 0.082 | 77.8 | 68.4 | **0.071** |
| Going to the shop (292) | 57.2 | 31.2 | **<0.001** | 59.0 | 36.8 | **<0.001** |
| Getting in/out of a chair (292) | 34.0 | 15.6 | **0.002** | 36.4 | 18.1 | **0.001** |
| Going up/down stairs (279) | 76.8 | 55.6 | **0.001** | 77.6 | 61.5 | **0.004** |
| Walk around neighbourhood (284) | 62.4 | 35.1 | **<0.001** | 65.3 | 39.6 | **<0.001** |
| Reaching down into cupboard (288) | 46.2 | 36.8 | 0.157 | 50.6 | 33.3 | **0.004** |
| Answering telephone (290) | 37.4 | 21.1 | **0.009** | 39.2 | 23.7 | **0.006** |
| Walk less due to fear of falling, % ($n$) | 27.2 (61) | 10 (8) | **0.003** | 29 | 13.2 | **0.002** |

All $p$-values are uncorrected. Significant values are shown in bold.
†The first number is the total number of fallers, the second the total number of fallers who completed the FES-scale.
‡Seventeen people did not fill in FES completely and were excluded from analyses involving total FES-score.
§The total number of people who scored a FES-item is noted between parentheses behind each item.
SD: standard deviation; FES: Falls Efficacy Scale.

mental factor just before the fall. Five people reported to have lost consciousness *before* the fall.

*Factors associated with falls.* The associations between fall status and factors potentially associated with falls can be seen in Tables II–IV. Both falls and recurrent falls were associated with significantly more weakness of knee extensors of the weakest leg; complaints of maintaining balance and reduced sensation in the legs; fear of falling (both in the answer to the question "are you afraid of falling", the total FES and 8 individual items of the FES-scale, Table II); and reduced ambulation due to this fear. In addition, single falls were also associated with more weakness of the lower limb in general (sum score); orthoses use and complaints of rigidity of joints and muscles, while recurrent falls were also associated with younger age and an extra item of the FES-scale.

Other patient characteristics, such as the diagnosis PPS, living alone and walking ability were not significantly associated with single or recurrent falls (Table IV). No form of prescription medication use was associated with fall frequency (not single or multiple drug use or the use of specific drug classes; Table IV). It should be noted, however, that the limited use of some of the evaluated "high-risk" prescription drugs made the groups too small for reliable statistical comparison.

The odds ratios for those variables significantly associated with falls or recurrent falls (walkers only, $n$=289) are shown Table V.

Stepwise binary logistic regression analysis revealed that fear of falling, an MRC-score of less than 3 for the knee extensors of the weakest leg and complaints of problems maintaining balance were independently associated with both falls and recurrent falls. Non-independently associated variables were removed from the regression model in order to reduce the number of missing cases (i.e. sum MRC: 31 missing, FES: 16 missing) and allow more accurate calculation of odds ratios (Table VI).

Table III. *Detailed circumstances of the most recent fall*

| Circumstance ($n$)† | | Frequency, % ($n$)‡ | |
|---|---|---|---|
| Location, familiar (220) | | 86.2 (194) | |
| Location, subdivided (216) | | | |
| Inside | Outside | 49.8 (112) | 46.2 (104) |
| Home | Home | 39.6 (89) | 10.2 (23) |
| Away from home§ | Away from home§ | 10.2 (23) | 36 (81) |
| Familiar | Familiar | 6.7 (15) | 28 (63) |
| Unfamiliar | Unfamiliar | 3.6 (8) | 8 (18) |
| Time of fall (198) | | | |
| Morning | | 22.7 (51) | |
| Afternoon | | 44.9 (101) | |
| Evening | | 20 (45) | |
| Night | | 0.4 (1) | |
| Activity prior to falling (212) | | | |
| Walking | | 54.7 (123) | |
| Transfer/change of posture | | 12.9 (29) | |
| De-/ascending stairs | | 4 (9) | |
| Various tasks in and around house¶ | | 22.7 (51) | |
| Type of ground underfoot (217) | | | |
| Uneven surface | | 20.9 (47) | |
| Slippery surface | | 11.1 (25) | |
| Other | | 63.6 (143) | |
| Shoes worn at time of fall (212)Ω | | | |
| Normal | | 54.8 (119) | |
| Orthopaedic | | 23.5 (51) | |
| Open-backed shoes/slippers | | 9.7 (21) | |
| None | | 9.7 (21) | |
| Need help to get up after fall (222) | | 33.8 (76) | |

†The total number of fallers (maximum 225) who reported the circumstance is noted after each item.
‡Percentages were calculated as a fraction of total number of fallers (i.e. 225, exception see Ω).
§Including among others: "on the street", "in the snow", "at a swimming pool", "in a shop", "at work" and "at the sports club".
¶These included more complex tasks such as "doing the washing", "gardening" and "cleaning".
ΩThe 8 full-time wheelchair users who are fallers were excluded from footwear analysis (i.e. total $n$=217).

Table IV. *Factors potentially associated with falls, stratified by fall status*

| Potentially associated factors | Faller ($n=225$) | Non-faller ($n=80$) | $p$-value | Recurrent faller ($n=184$) | Non-recurrent faller ($n=121$) | $p$-value |
|---|---|---|---|---|---|---|
| Age, years, mean (SD) | 57.1 (11.8) | 58.5 (9.9) | 0.316 | 56.3 (12.2) | 59.2 (9.7) | **0.022** |
| Female, % | 62.7 | 66.2 | 0.567 | 60.3 | 68.6 | 0.142 |
| Acute infection and treatment outside EU, % | 15.1 | 8.8 | 0.152 | 16.3 | 9.1 | 0.071 |
| Definite diagnosis PPS, % | 71.7 | 68.8 | 0.612 | 70.3 | 71.9 | 0.768 |
| MMT lower limbs, mean (SD)† | | | | | | |
| Sum score (267) | 59.6 (15.8) | 65.8 (16.2) | **0.007** | 59.6 (15.9) | 63.5 (16.2) | 0.056 |
| Hip flexion weakest leg (283) | 3.2 (1.7) | 3.5 (1.8) | 0.157 | 3.2 (1.7) | 3.4 (1.7) | 0.307 |
| Knee extension weakest leg (281) | 2.7 (1.9) | 3.2 (2.0) | **0.031** | 2.6 (1.9) | 3.1 (1.9) | **0.041** |
| Ankle dorsal flexion weakest leg (282) | 2.0 (1.9) | 2.5 (2.1) | 0.120 | 2.0 (2.0) | 2.4 (2.1) | 0.133 |
| Living alone, % | 32.4 | 25.0 | 0.214 | 32.6 | 27.3 | 0.322 |
| Walking ability % | | | | | | |
| Never walk | 3.6 | 10.1 | 0.081 | 3.8 | 7.5 | 0.358 |
| Only walk indoors + around the house | 26.3 | 24.1 | = | 26.8 | 24.2 | = |
| Walk outside, short + long distance | 70.1 | 65.8 | = | 69.4 | 68.3 | = |
| Walking aid, % | 24.4/51.7 | 19.4/48.5 | 0.39/0.65 | 24.3/50.6 | 21.4/51.4 | 0.57/0.89 |
| Manual aid‡ in-/outdoors† | 3.6/8.0 | 10.0/17.5 | | 3.8/8.7 | 7.4/13.2 | |
| Wheelchair in-/outdoors | | | | | | |
| Orthopaedic shoes, %† | 53.4 | 47.2 | 0.359 | 54.8 | 47.3 | 0.215 |
| Orthosis, %† | 47.0 | 29.2 | **0.008** | 46.9 | 35.7 | 0.061 |
| Frequent physical complaints, % | | | | | | |
| Pain in joints or muscles | 83.1 | 82.5 | 0.901 | 83.7 | 81.8 | 0.670 |
| Tiredness | 81.3 | 73.8 | 0.150 | 82.1 | 75.2 | 0.148 |
| Reduced exercise tolerance | 73.3 | 76.2 | 0.609 | 73.4 | 75.2 | 0.720 |
| Rigidity joints or muscles | 74.2 | 62.5 | **0.047** | 73.4 | 67.8 | 0.291 |
| Back pain | 66.2 | 55 | 0.074 | 67.4 | 57.0 | 0.066 |
| Problems maintaining balance | 64.4 | 35 | **<0.001** | 67.4 | 40.5 | **<0.001** |
| Swollen feet | 33.3 | 28.7 | 0.451 | 33.2 | 30.6 | 0.638 |
| Reduced sensation legs | 30.7 | 17.5 | **0.023** | 31.5 | 20.7 | **0.037** |
| Respiratory problems | 23.1 | 26.2 | 0.572 | 21.7 | 27.3 | 0.268 |
| Palpitations | 14.7 | 21.2 | 0.172 | 14.7 | 19.0 | 0.317 |
| ≥1 medication, % ($n$) (280)§ | 56.0 (116) | 52.1 (38) | 0.556 | 55.7 (93) | 54.0 (61) | 0.778 |
| ≥4 medications, % ($n$) (280)§ | 14.5 (30) | 19.2 (14) | 0.344 | 13.8 (23) | 18.6 (21) | 0.278 |
| Types of medications, % ($n$)§ | | | | | | |
| Benzodiazepines/hypnotics | 5.3 (11) | 9.6 (7) | 0.200 | 6 (10) | 7.1 (8) | 0.715 |
| Antidepressants | 4.8 (10) | 5.5 (4) | 0.519 | 5.4 (9) | 4.4 (5) | 0.716 |
| Anti-arrhythmics (all classes) | 1 (2) | 2.7 (2) | 0.279¶ | 0.6 (1) | 2.7(3) | 0.182§ |
| Digoxine | 1 (2) | 0 (0) | 0.546¶ | 0.6 (1) | 0.9 (1) | 0.645§ |
| NSAIDs | 19.3 (40) | 23.3 (17) | 0.470 | 19.8 (33) | 21.3 (24) | 0.763 |
| Diuretics | 11.1 (23) | 8.2 (6) | 0.486 | 10.2 (17) | 10.6 (12) | 0.906 |

All $p$-values are uncorrected. Significant values are shown in bold.

†Sixteen full-time wheelchair users removed from "walking aid indoors", "orthopaedic shoes", "orthosis" and "MMT lower limbs" categories; 32 full-time outdoor wheelchair users removed from "walking aid outdoors" category. ‡i.e. cane(s), crutch(es) or walker. §for 25 people accurate information on which and how many prescription drugs they used was not available, these people were excluded from this analysis (i.e. total $n=280$), ¶calculated with Fisher's exact test.

SD: standard deviation; PPS: post-polio syndrome; MMT: manual muscle testing; NSAIDs: non-steroidal anti-inflammatory drugs.

## DISCUSSION

This study shows that falls are a common problem among polio survivors and frequently lead to injuries, fear of falling and activity avoidance. The falls mainly occur during ambulation, inside the home and in the afternoon. Fear of falling, quadriceps weakness of the weakest leg and self-reported problems maintaining balance are independently associated with falls.

### *Falling is a problem: frequency and consequences*

The rate of falling among polio survivors is high, with up to 4 times as many of our population than community-dwelling over-55 year olds falling once and 1.5 times as many falling multiple times in the last year (15, 21). Previous studies among polio survivors reported similar single fall frequencies (50–84%) (5, 11–13), but much lower recurrent fall frequencies (25%) (11).

Negative consequences of falls were also frequent in our population. Four-fifths sustained an injury after a fall in the last year and one-fifth of these a major injury, two-thirds reported fear of falling and approximately one-third of these had reduced their walking activity because of this fear. By comparison, community-dwelling older adults reported just over half the number of major injuries (9%) (15) and extremely varying percentages of

Table V. *Odds ratio of each factor potentially associated with falls or recurrent falls (*n = *289†)*

| | Falls (≥1) | | | | Recurrent falls (≥2) | | | |
|---|---|---|---|---|---|---|---|---|
| Potentially associated factor | Prf (%) | Pnrf (%) | OR | 95% CI | Prf (%) | Pnrf (%) | OR | 95% CI |
| Age (≤57.7)‡ | – | – | – | – | 64.8 | 57.6 | 1.4 | 0.84–2.18 |
| Acute infection + initial treatment outside EU, % | – | – | – | – | 73.7 | 59.4 | 1.9 | 0.89–4.12 |
| MMT lower limbs | | | | | | | | |
| Sum score (≤64.5)‡ (*n* = 258) | 83.1 | 67.9 | **2.3** | **1.28–4.22** | 67.8 | 55.0 | **1.7** | **1.03–2.87** |
| Knee extension weakest leg (≤3)‡ (*n* = 270) | 84.8 | 67.6 | **2.7** | **1.47–4.87** | 69.6 | 54.5 | **1.9** | **1.16–3.16** |
| Orthosis | 82.9 | 69.3 | **2.2** | **1.21–3.82** | 67.5 | 56.6 | 1.6 | 0.98–2.59 |
| Physical complaints | | | | | | | | |
| Rigidity joints and muscles | 78.4 | 66.7 | **1.8** | **1.03–3.20** | – | – | – | – |
| Problems maintaining balance | 85.1 | 61.2 | **3.6** | **2.07–6.36** | 72.6 | 45.5 | **3.2** | **1.94–5.21** |
| Reduced sensation legs | 82.5 | 72.2 | 1.8 | 0.94–3.47 | 68.8 | 58.4 | 1.6 | 0.91–2.71 |
| Back pain | 77.8 | 70.2 | 1.5 | 0.87–2.57 | 64.9 | 54.8 | 1.5 | 0.93–2.49 |
| Fear of falling | 81.4 | 64.2 | **2.4** | **1.42–4.22** | 67.2 | 50.9 | **2.0** | **1.21–3.22** |
| Total FES (≥5,5)‡ (*n* = 273) | 83.4 | 64.8 | **2.7** | **1.55–4.83** | 71.0 | 50.0 | **2.5** | **1.49–4.04** |

All OR and 95% confidence intervals are uncorrected for multiple comparisons. Significant values are shown in bold.
†The total number of people for whom information about a variable was available is noted behind each potentially associated factor when it differed from the total (i.e. 289: 16 full-time wheel chair users removed).
‡The continuous variables were transformed to dichotomous variables using their median values as cut-off points (median).
Prf: the percentage of falls or recurrent falls in the presence of the potentially associated factor; Pnrf: the percentage of falls or recurrent falls in the presence of the potentially associated factor.
OR: odds ratio; CI: confidence interval; MMT: manual muscle testing; FES: falls-efficacy scale.

fear of falls (21–77%) (22, 30, 31). Unfortunately comparison with injury rates in large studies among polio survivors was not possible as these studies reported injuries over a longer time period (i.e. 5 years) (13, 14), but 1 small study reported similar fracture rates (i.e. 7% of fallers, *n* = 1) (11). Levels of fear of falling and reduced walking activity were comparable to that reported previously (11–13) and as both variables are also risk factors for more falls, they may contribute doubly to the problem of falling of polio survivors (22).

*Fall mechanisms: circumstances and associated factors*

Knowledge of fall mechanisms can help in targeting or creating fall intervention strategies. Evaluation of the fall circumstances and factors potentially associated with falls in this group revealed some patterns that point to different fall mechanisms than those present in elderly people.

Most participants reported falls in the afternoon and during ambulation (mainly while walking), just as community-dwelling elderly do (32, 33). It is possible that (muscle) fatigue is a contributor to these falls as in late polio, muscle load during normal daily activities can be close to the maximum muscle capacity, leaving little reserve for other activities later in the day (34). Furthermore, in community-dwelling elderly people, a larger proportion of people also report falls in the morning (30%) and at night (4%) than in our group (32). Most polio survivors fell in a familiar environment, presumably because more time was spent at home due to retirement or disability and because people concentrated less in familiar places. Interestingly, more falls occurred inside the home than just outside the home (40% and 10%, respectively), while the opposite seems to be the case for older adults (23% and 35%, respectively) (32). These findings emphasize the importance of removal of domestic hazards for fall prevention.

Three factors potentially associated with falls were found to be independently associated with both falls and recurrent falls. These were: quadriceps weakness of the weakest leg, fear of falling and frequent complaints of problems maintaining balance. Those with quadriceps weakness (MRC ≤3) had both single and recurrent falls more often than those with mild or no paresis (MRC < 3). This points to muscle weakness as a likely risk factor for falls in polio survivors, although a longitudinal study is necessary to confirm this. That *knee extensors* seemingly play a more important role than other lower limb muscle groups in polio survivors is new and differs from previous

Table VI. *Remaining predictor variables after stepwise binary logistic regression (*n = *270)†*

| | Falls (≥ 1) | | Recurrent falls (≥ 2) | |
|---|---|---|---|---|
| Potentially associated factor | Exp B | 95% CI | Exp B | 95% CI |
| Problems maintaining balance | 3.42 | 1.87–6.25 | 3.01 | 1.78–5.08 |
| Weakness knee extention weakest leg (≤3) | 2.66 | 1.42–4.89 | 1.88 | 1.11–3.18 |
| Fear of falling | 1.98 | 1.08–3.61 | 1.72 | 1.01–2.94 |

All odds ratio (OR) and 95% confidence intervals corrected for multiple comparisons.
†16 full-time wheelchair users removed and 19 missing for whom information on MMT knee extension was not available.
CI: confidence interval; Exp B: Expected B (≈odds ratio).

research in polio survivors (5). As powerful *knee extension* is necessary for knee stability during the stance phase, weakness of the quadriceps could lead to knee buckling. Meanwhile, sufficient *hip flexion and ankle dorsal flexion* ensure foot clearance during the swing phase, thus failure of these muscles could lead to increased tripping and stumbling. It follows that knee buckling may be the most important fall mechanism in our group. However, as gait can be altered considerably by a variety of common problems in polio survivors, (e.g. the distribution and severity of pareses, bone and joint deformations and contractures) failure of quadriceps strength should always be evaluated in the perspective of the individual's gait pattern. Further research into the role of the severity and location of muscle weakness in falls is necessary. The univariate association between orthosis use and falls can be explained by the underlying muscle weakness for which the orthoses were prescribed. Since muscle weakness was associated with falls despite the use of orthoses, it is questionable whether orthoses are effective tools for realizing the objective of more and safer mobility. Further research is necessary to elucidate the exact role of orthoses in falls, since, in this study, those who were not wearing their orthosis during the last fall could not be distinguished from those whose orthosis was associated with a fall. *Fear of falling* is both a consequence (12, 13, 22) and a risk factor (22) for falls and was independently associated with both single and recurrent falls in this study. Three of the 4 FES-items that caused the most concern irrespective of fall frequency involved walking (climbing stairs, walking around neighbourhood and going shopping), which was also the activity most frequently associated with falls. The variable "self-reported *problems maintaining balance*" was the third factor independently associated with (recurrent) falls. The feeling of balance is determined by a variety of factors besides muscle strength, including sensory input, range of motion and central nervous system functioning (e.g. vestibular apparatus and cerebellum). Perhaps the perceived imbalance in our population can be (partially) explained by underlying problems of rigidity of joints and muscles and reduced sensation in the legs, as both were reported significantly more often among (recurrent) fallers than non-(recurrent) fallers. Although reduced sensation is not a classical symptom of polio (35, 36) there is some evidence that polio survivors have reduced proprioceptive input during muscle contraction due to altered sensibility of muscle spindles at different contraction levels (37). Further clinical information on these possible sensory disturbances was unfortunately not available here, but future research on this topic would be valuable in order to clarify their role in causing balance disturbances and falls.

Among community-dwelling elderly people, medication use (18–21) and increasing age (15, 21, 38) are risk factors for falls that were not associated with falls in our population, but which deserve comment. The lack of a significant association between polypharmacy or the use of specific drug classes and (recurrent) falls may be due to lack of power as the proportion that used multiple drugs and "high-risk" drugs was relatively low. It may still be important to assess medication use at an individual level. The majority of our group were affected by the last major epidemic of polio in the Netherlands (1956) at a young age, resulting in a limited age range in the population (74% was between 50 and 70 years old), complicating statistical analyses. This may explain why we (and another study in a developed country) (13) found no association between fall status and age.

*Study strengths and limitations*

A great strength of the study is the high response rate and the large sample size in combination with the diversity in severity of polio residuals of the participants. These features ensured that the population is representative for all polio patients who are referred to specialized centres. One limitation of this study is the potential recall bias, an unfortunate by-product of retrospective studies that may have led to an inaccurate description of the consequences and circumstances of falls and even an underestimation of fall incidence here. (i.e. in a previous study among cognitively unimpaired over-60 year olds, 9% did not recall a fall they had experienced in the preceding year) (39). In order to maximize the accuracy of recall of the circumstances of falls, we asked for details of the most recent fall only. The sample size was sufficiently large to compensate for any extraordinary fall circumstances that may have been included due to this method. A second limitation is that due to the cross-sectional design of the study, causality cannot be established. Longitudinal studies are necessary in order to determine whether the factors we found to be associated with falls are in fact also risk factors for falls. A third limitation is the use of MRC sum-score retrieved from patient files. First of all, the use of MRC-scores recorded in the files automatically includes values measured by different physicians under different circumstances, inevitably involving inter-rater differences. Secondly, MRC-scores are a qualitative ordinal scale and, as such, the validity of a sum score is questionable. Thirdly, 38 patients had to be excluded from analyses with MRC sum scores due to incomplete data. Thus, lower limb MRC sum scores might not have reflected muscle strength with sufficient accuracy. Instead of including a control group we chose to compare our findings with the extensive literature on falls in elderly people, for whom successful fall interventions already exist. Although an own control group is always preferable, the comparisons with Stalenhoef et al., (15) especially, are very relevant, as the questionnaires used in this study were for a large part identical.

In conclusion, falls are an important problem for polio survivors. The frequency with which falls occur and the severity of the consequences merit the development of fall intervention strategies. As there are some essential differences between the fall mechanisms in our group and those that have been described previously in elderly people, existing fall intervention strategies cannot simply be applied to this group. Tailor-made interventions are required and, based on our findings, these should focus on: increasing safety of walking and reduction in domestic hazards, reduction in fear of falling and on increasing muscle strength or stability where possible (especially of the quadriceps). Meanwhile, additional research is necessary to elucidate the role of: orthoses, muscle weakness in the context of abnormal gait, sensory problems, fatigue and the possible causes of perceived loss of balance.

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