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Men With Late Effects of Polio Decline More Than Women in Lower Limb Muscle Strength: A 4-Year Longitudinal Study.

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Men with late effects of polio decline more than women in lower limb muscle strength: a 4-year longitudinal study

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Short title: Muscle strength and late effects of polio

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ABSTRACT

Background: In persons with prior paralytic poliomyelitis, progressive muscle weakness can occur after a stable period of at least 15 years. Knowledge is limited about which factors influence changes in lower limb muscle strength in these persons.

Objective: To assess changes in lower limb muscle strength annually over 4 years in persons with late effects of polio and to identify prognostic factors for changes in muscle strength.

Design: A prospective, longitudinal study.

Setting: University hospital outpatient program.

Participants: Fifty-two ambulant persons (mean age ± standard deviation: 64 ± 6 years) with verified late effects of polio.

Methods: Mixed Linear Models were used to analyze changes in muscle strength and to identify determinants among the following covariates: gender, age, age at acute polio infection, time with late effects of polio, body mass index and estimated baseline muscle weakness.

Main Outcome Measurements: Knee extensor and flexor, and ankle dorsiflexor muscle strength were measured annually with a Biodex® dynamometer.

Results: The men (n=28) had significant linear change over time for all knee muscle strength measurements, from −1.4% ($P < .05$) per year for isokinetic knee flexion in the less affected lower limb to –4.2% ($P < .001$) for isokinetic knee extension in the more affected lower limb, and for two ankle dorsiflexor muscle strength measurements (–3.3% to 1.4% per year [$P < .05$]). The women (n=24) had a significant linear change over time only for ankle dorsiflexor measurements (4.0% -5.5% per year [$P < .01$]). Gender was the strongest factor that predicted a change in muscle strength over time.

Conclusions: Over 4 years, men had a greater decline in muscle strength than did women, but the rate of decline did not accelerate. This indicates that gender could be a contributing factor to the progressive decline in muscle strength in persons with late effects of polio.

Key words: Postpoliomyelitis syndrome; Muscle, skeletal; Outcome Assessment; Longitudinal studies; Rehabilitation;

INTRODUCTION

In persons with a history of an acute paralytic poliomyelitis infection, new symptoms are experienced by 28%-64% after a stable period of at least 15 years [1, 2]. These new symptoms are referred to as 'late effects of polio' or 'post-polio syndrome' [3] and often include muscle weakness, general fatigue, muscle pain and/or joint pain [1, 4-6]. These symptoms can lead to reduced mobility in daily activities such as, walking, standing, and climbing stairs [7-9]. Progressive decline in muscle strength is an underlying cause of the reduced mobility [10, 11] and is likely to increase when these persons acquire additional disabilities [12, 13].

In healthy men and women (50-70 years) the predicted decline in knee and ankle dorsiflexor muscle strength is 1%-2% per year [14]. A decline in muscle strength also occurs over time in persons with late effects of polio but the rapidity of this decline is unclear. In a review from 2005 (including 17 articles with sample sizes from 12-103 participants) most studies showed a slow rate of decline in muscle strength over time [15], with approximately 7% over 4 years and 15% over 8 years [16-19]. Thereafter, few studies have assessed the decline in lower limb muscle strength in persons with late effects of polio [20-23]. The decline in muscle strength in those studies is reported to be between 1% and 3% [20, 22, 23], except for one study which reported a larger and more progressive decline (5%-8% per year) [21].

Very few studies have assessed prognostic factors for the decline in muscle strength in persons with late effects of polio. One study showed that men declined more rapidly in isokinetic knee extensor strength than did women [11]. Willén et al. [23] found that the decline in muscle strength over four years was higher in those who were stronger at the baseline assessment. In a recent study, Bickerstaffe et al. [20] showed that persons with higher isometric maximal voluntary contraction (MVC) at baseline had a greater decline in strength over 10 years.

Even though previous studies have evaluated the decline in muscle strength over time in persons with late effects of polio, they differ with regard to study design and the statistical methods used. To analyze longitudinal data in order to identify potential determinants, the mixed-random and fixed effect regression models (the Mixed Linear Models; MLM) are recommended [24-26]. To our knowledge no study has used the MLM model to assess changes in muscle strength over time in persons with late effects of polio.

The main aim of this study was to assess changes in strength in the knee extensor and flexor muscles and ankle dorsiflexor muscles annually over 4 years in persons with late

effects of polio. The second aim was to identify determinants of changes in muscle strength, such as gender, age, age at acute polio infection, length of time with new symptoms, body mass index (BMI) and estimated baseline weakness.

MATERIAL AND METHODS

Participants

Fifty-two community-dwelling ambulant persons were recruited from a post-polio rehabilitation clinic at a university hospital in the south of Sweden. Inclusion criteria were (1) 50-75 years of age; (2) a confirmed history of acute poliomyelitis affecting the lower limbs, with new weakness after a period of functional stability of at least 15 years; and (3) ability to walk at least 300 m with or without an assistive and/or orthotic device. Exclusion criteria were (1) using wheelchair as their main mode of transportation; and (2) ongoing major depression, systemic disease or any other disease that could affect their muscle strength. The treating physician selected participants who met the inclusion and exclusion criteria and were mildly to moderately affected in their lower limbs. These persons were invited consecutively to participate in the study in connection with their regular follow-up visits to the clinic. We aimed for at least 50 participants to obtain a reasonably large sample that could be assessed annually over the 4-year period. Inclusion continued for 18 months (2007 to 2009) until 52 persons had agreed to participate.

For all 52 participants an electromyogram (EMG) had been recorded in the lower limbs limbs (vastus lateralis and tibialis anterior muscles) as part of the initial routine clinical examination and verification of prior polio, and there were no other diseases that could explain their new symptoms. According to the National Rehabilitation Hospital (NRH) Post-Polio Limb Classification [27], all participants had post-polio NRH class II to V (indicating clinically stable or unstable polio) in at least one of their knee or ankle dorsiflexor muscles. According to the persons' own perception of their muscle weakness, one lower limb was defined as the "more-affected limb" and the other lower limb that was less or not affected, as the "less-affected limb".

Prior to inclusion, information about the purpose of the study was provided, and each individual gave his or her written informed consent to participate. The study followed the principles of the Helsinki declaration.

Muscle strength measurements

Isokinetic concentric knee extension, knee flexion and ankle dorsiflexion muscle strength and isometric knee extension and ankle dorsiflexion muscle strength were measured with a Biodex Multi-Joint System 3 PRO dynamometer using a standard protocol developed in our research group [28, 29]. These studies have shown that lower limb muscle strength can be reliably measured in persons with late effects of polio (for knee extensors and flexors, intra-class correlation coefficients [$ICC_{2,1}$] ranging from 0.85-0.99; standard error of measurement [SEM] from 10.2 to 13.9 Newton meter [Nm] and for ankle dorsiflexors, $ICC_{2,1}$ from 0.85-0.99 and SEM from 2.5 to 3.7 Nm).

Before each strength measurement the range of motion (ROM) was set and the Biodex software applied the gravity correction. For the knee muscle strength measurements the participants were seated in the adjustable chair of the dynamometer, without shoes or an orthotic device, and were stabilized with straps across the shoulders, waist and thigh. After a structured warm-up the participants performed three maximal isokinetic extensor and flexor contractions at 60°/s and the highest peak torques were recorded (in Nm). After a 2-minute rest, the participants performed 2 maximal isometric knee extensor muscle contractions with a knee flexion angle at 90º, and the highest MVC was recorded (in Nm).

For the ankle dorsiflexor strength measurements the participants were seated in the adjustable chair of the dynamometer, with the leg elevated by a support arm just above the knee with the angles of the hip at 90º flexion and the knee joints at 30º flexion. The ankle was placed and secured on the Biodex footplate. To warm-up and become familiar with the ankle dorsiflexor strength measurements, 3-5 submaximal contractions with the dorsiflexor muscles were performed. After a 1-minute rest 3 maximal contractions at 30º/s were performed, with 30 seconds rest between each contraction. Each contraction started from a relaxed plantar-flexed position without any preload and the highest peak torques were recorded (in Nm). After a 2-minutes rest, testing continued with 2 maximal isometric contractions with a 60-seconds rest between each contraction. The ankle was fixed in 10° plantar-flexed position and the highest MVC was recorded (in Nm).

Procedures

All strength measurements were performed by the same physiotherapist (U.-B.F.). The participants were tested annually over 4 years (a total of 5 times) and as close as possible to one year between each test. The knee muscle strength was measured before the ankle dorsiflexor muscle strength, and the strength of the less-affected lower limb was measured

before that of the more-affected lower limb. Consistent verbal encouragement was given throughout the tests. The total time for the strength measurements at each test session was approximately 1 hour. After completion of the annual test sessions, a summary of the test results were given to the participants.

Statistics

Data from the muscle strength measurements provided 10 quantitative variables for the analyzes: 4 knee extension and 2 knee flexion strength measurements and 4 ankle dorsiflexor strength measurements. Of the 52 participants 1 participant missed 1 test session the third year and another 3 participants missed the last 2 or 3 test sessions. The missing values were compensated for in the statistical model. Because of weakness and/or stiffness, 30 participants were unable to perform the ankle dorsiflexors strength measurements with the more affected lower limb and 6 participants were unable to do so with the less affected lower limb. The statistical analyzes for the ankle dorsiflexors were therefore based on 22 participants for the more affected lower limb and on 46 participants for the less affected lower limb.

The characteristics of the sample were described by frequencies, means and standard deviations (SDs). Differences between men and women at baseline were analyzed by independent samples *t*-tests. For each participant the predicted muscle strength for isometric knee extension and ankle dorsiflexion was calculated based on gender, age, height, and body mass specific values for a healthy population [14]. These values were used to calculate the predicted muscle weakness at baseline (ie, the differences between the predicted and the measured muscle strength values).

MLM [26] were used for the longitudinal data analyzes. Estimated means and SDs of all muscle strength measurements were obtained based on the covariance matrix. The fixed linear effects (mean values for the group), the random effects (individual variations around the mean) and the deviations from the linear slopes over the 4 years were calculated for men and women, respectively.

To analyze prognostic determinants for any changes in muscle strength, the independent variables (covariates) gender, age, age at acute polio, length of time with new symptoms, BMI and the predicted baseline weakness in isometric muscle strength were analyzed in the mixed linear regression models. First, all covariates and their interaction with time were inserted into the models. The nonsignificant predictors were then removed in a backward manner, starting with the least significant interaction term; no covariate was removed when the interaction term was statistically significant. The final models contained

only covariates where the covariate itself or its interaction with time was significant. All interval scaled variables used in the analyzes were centred to the mean, giving positive covariate values for the participants above the mean values of age, age at acute polio, time with new symptoms, BMI and baseline weakness. The variable gender was coded 0 (women) and 1 (men).

All calculations were performed using the IBM SPSS Statistics Software version 21.0 (IBM Corp, Armonk, NY). Significance of random effects was tested with the deviance test (2 degrees of freedom [*df*] based on restricted maximum likelihood. Significance levels below .05 represent statistical significance.

RESULTS

In Table 1, the characteristics of the 52 participants (28 men and 24 women) are presented. Their mean age at the study enrolment was 64 years (SD 6, range 52-74) and the mean time since onset of new symptoms was 13 years (SD 7, range 2-28). Fifty-two percent were most affected in their right lower limb and 71% had verified prior polio in both lower limbs. Walking aids were used by 10% of the participants and ankle foot orthoses by 19%. The mean time between each test session was close to 1 year (12.1 months, SD 0.8) and the participants were all free from acute illnesses and injuries at each testing session.

[Insert Table 1 about here]

At baseline the men were significantly stronger than the women in all knee muscle strength measurements and for the less affected lower limb regarding ankle dorsiflexor strength, and thus data for the men and women were analyzed separately.

Linear trends and random effects in muscle strength over time

In Tables 2 and 3, time from baseline and the estimated means and SDs at each test occasion over 4 years, along with the fixed linear effects for the group and the random effects for the individuals, are presented for men and women, respectively.

The men experienced a significant fixed linear decline over time for all knee muscle strength measurements, ranging from –1.0 to –4.5 Nm/y (from –1.4% [$P < .05$] per year for less-affected isokinetic knee flexion to –4.2% [$P < .001$] for more-affected isokinetic knee extension; Table 2). For the ankle dorsiflexors a significant fixed linear effect of time was found only for isokinetic muscle strength in the more-affected limb and for isometric

muscle strength in the less-affected limb, ranging from –0.82 to 0.42 Nm/y respectively (–3.3%-1.4% per year [$P < .05$]). The random effect of time was significant for all strength measurements of the less-affected limb as well as for isokinetic measurements of the more-affected limb (deviance [$df=2$]: 7.7 [$P < .05$] to 14.6 [$P < .01$]).

[Insert Table 2 about here]

For the women (Table 3), no significant fixed linear decline over time was observed for the knee muscle strength measurements. There was a significantly increased isometric ankle dorsiflexor muscle strength ($P < .01$), for both the less-affected lower limbs (0.71 Nm/y; 4.0%) and the more affected lower limbs (0.87 Nm/y; 5.5%), but no significant fixed linear effect of time for isokinetic ankle dorsiflexor strength measurements. A significant random effect of time was found for 3 of the strength measurements in the less-affected limb (isokinetic knee extensors and isokinetic and isometric ankle dorsiflexors; (deviance [$df=2$] 7.8 [$P < .05$] to 13.3 [$P < .01$]), but no significant random effect was found for the more-affected limb.

[Insert Table 3 about here]

Over the 4 years, no significant deviation from the linear slopes occurred for any strength measurement, either for the men or for the women, indicating that the change in muscle strength over time did not accelerate.

Determinants of change in muscle strength over time

All covariates and interactions with time that were significantly related to knee muscle strength are presented as the final model in Table 4. The strongest influence was found for the participants' gender; the decline in strength over time was significantly larger for the men than for the women for all knee muscle strength measurements in the more-affected lower limb and for the knee flexor strength in the less-affected lower limb. Among the other covariates the only interaction with time was found for the more affected isokinetic knee extensor strength measurements. Younger persons, those who have had new symptoms for longer time, and those with less baseline weakness declined more in muscle strength, even though the interactions with time were quite small.

[Insert Table 4 about here]

All covariates and the interactions with time that were significantly related to ankle dorsiflexor muscle strength are presented as the final model in Table 5. The strongest influence was found for the participants' gender; the men were significantly stronger at baseline in both the less- and the more-affected lower limb. The only interaction with time was for isokinetic dorsiflexion in the more-affected lower limb; the decline in muscle strength was significantly larger for the men than for the women. For all other covariates there were only 2 minor interactions with time in the more affected ankle dorsiflexor measurements, namely those with more baseline weakness and older persons. These participants had declined more in muscle strength over time.

[Insert Table 5 about here]

DISCUSSION

This longitudinal study over 4 years found that men with late effects of polio declined more in muscle strength than did women. Men had a significant effect over time for all knee muscle strength measurements and for 2 of the ankle dorsiflexors muscle strength measurements ($P < .05$ to $P < .001$). Women had a significant effect only for the isometric ankle dorsiflexor strength measurements. No significant deviations from the linear slopes occurred over the 4 years. The strongest prognostic determinant for the decline in muscle strength was the participants' gender.

Several factors may explain the differences between the results in the present and previous studies. In the present study, we found a decline in knee muscle strength measurements for men (–4.5% and –1.8% per year) but no significant linear trend for any of the knee muscle strength measurements for women. Instead, we found a significant positive linear trend for isometric ankle dorsiflexor strength measurements. Contrary to previous studies [11, 20, 21, 23] our population consisted of roughly equal proportions of men and women (54% men). The balanced gender distribution made it possible for us to analyze if there were any differences for the men and the women in muscle strength over 4 years. In other studies [20, 21, 23] the measurements for men and women were combined and only one study has shown that men decline more rapidly in muscle strength than women with regard to isokinetic knee extension strength [11].

The characteristics of the participants could also have influenced the results. Many studies of persons with late effects of polio are published between 1994 and 1998 [11, 16-19]. In the present study the participants were generally older (mean age 64 years) compared to other studies, where the mean age was around 50 years [11, 16-18, 20, 21]. Even if the participants in this study were older, there were no deviations from the linear slopes over the four years, and age explained only a small additional part of the linear trend. Thus, it seems that the decline in muscle strength in older persons with late effects of polio is fairly stable.

Furthermore, in previous studies isometric knee extension strength has been the most common measurement and the values at baseline have varied between 57 and 176 Nm [11, 16, 18, 20]. In many studies, only one limb has been measured, [16-18, 20], so the isometric knee extension muscle strength can be a measure of either the more or the less affected lower limb and therefore the strength values are not comparable to our study.

Another factor that might have influenced the results is the outcome measurement used. To be able to follow muscle strength over time reproducible and sensitive measurement tools are needed. For many years manual muscle testing and handhold dynamometer have been used to measure muscle strength in persons with late effects of polio. However, these measurements are less reproducible and sensitive than isokinetic dynamometry [30, 31]. In this study we have used isokinetic dynamometry which is currently the recommended measurement tool to evaluate changes in muscle strength over time [32, 33]. Furthermore, the test protocols were standardized and carefully followed at each test session.

Other factors that could have influenced the result are the frequency of strength measurements and the length of follow-ups. In our study, all participants were measured annually over 4 years, the minimum follow-up time suggested for persons with late effects of polio [15]. In most previous studies the follow-up times have varied between 4 and 10 years [16-18, 20, 21, 23], but only two studies have performed the measurements annually [18, 21]. If the follow-up time is short, long-term changes are difficult to estimate; on the other hand, if annual measurements are performed, a progressive decline in muscle strength can more easily be detected. In one study with annual follow-ups, including 23 persons with late effects of polio (stable and unstable, i.e., those with new weakness) and 14 healthy controls [18], no significant differences in the mean change in muscle strength (the slope of the lines) for the 3 groups were found over a 7-year period. In the other study [21], a large decline in strength occurred over 5 years. Isokinetic knee muscle strength at 60°/s declined 7.8% for the extensors and 5.1% for the flexors per year with a progressive decline in strength over time. However, the progressive decline was not significant, probably because of a large number of

dropouts; only 8 of the 76 baseline limb measurements were repeated during the whole period. In our study, almost all participants performed every test session and no significant change of the slope over time was found indicating that the change in muscle strength was similar over time.

The statistical method used could also have influenced the results. We used the MLM models, which are recommended for longitudinal clinical studies [24-26]. The MLM technique takes into account the correlation between the measures obtained in the same persons, as well as missing observations. The MLM combines the effect of average time with any individual variation over time (linear trends, random effects and changes in the slope). To be able to calculate deviations from the linear slopes over time at least 3 measurement points are required [25]. In previous follow-up studies in persons with late effects of polio, older and more traditional statistical methods have been used to analyze the longitudinal data and most participants have only been measured twice. To our knowledge, this is the first study using the MLM in a longitudinal study of the annual decline in muscle strength in persons with late effect of polio.

Few studies [11, 20, 23] have analyzed potential prognostic factors for a change in muscle strength. In this study, we formed a model with covariates and identified different significant factors that could explain parts of the outcome for the strength measurements. The covariates – gender, age and BMI – were chosen as they are of importance when calculating normal values for muscle strength [14]. The final model showed that gender was the strongest predictor for the effect of time and only for isokinetic knee extensors in the more affected lower limb; baseline weakness together with age, and time with new symptoms could explain a small additional part of the linear trend. In the study by Willén et al [23], the decrease in muscle strength was higher in persons who were stronger at the baseline assessment for both isokinetic knee flexion and ankle dorsiflexion. In another study, men declined more rapidly in knee extensor strength than women but only for isokinetic strength [11]. Taken together, more studies are needed to control for the effect of gender. There might be other factors not used in our model with covariates, such as pain, fatigue, physical activity or the size of motor units at baseline, that could explain the differences between men and women [4, 34-36] .

Strengths and limitations

Only 4 persons missed 1 to 3 test-sessions during the 4 years (altogether 8 out of a total of 260), which could be considered a very low dropout rate, especially because the statistical model compensated for the missing values. Both lower limbs were measured and the less

affected limbs in 15 participants were "almost" healthy because they did not have any polio-related weakness in that limb. Even though persons with late effects of polio are a heterogeneous group, the paresis in the lower limb can differ within the limb as well as between limbs. In addition, the weakness in one lower limb has probably had an influence on the other limb during mobility-related activities already since childhood.

In this study, we measured knee muscle strength and ankle dorsiflexor strength. Strength measurements in these muscles have been shown to be reproducible using a Biodex dynamometer [28, 29]. Other muscle groups, such as the hip extensors and flexors, could have been selected because they are also related to gait performance. However, our clinical experience is that they are less affected in persons with late effect of polio and therefore they were not measured. Furthermore, these muscles are more difficult to measure isokinetically than knee extensors, knee flexors and ankle dorsiflexors, and there no data are available on the reproducibility of isokinetic measurements of these muscles in persons with late effects of polio.

For ankle muscle strength measurements the variation over time was hardly significant. However, few participants (n=22) could perform measurement of their more-affected ankle dorsiflexors; several participants had a pronounced weakness in this muscle group and were therefore unable to perform any active movement in the ankle. On the other hand, 46 of the participants were able to perform the ankle dorsiflexor measurements in the less affected lower limb and there were no discernible differences between the more-affected and the less-affected lower limb. The positive linear trends for the ankle dorsiflexor muscles for both men and women are somewhat surprising but could be due to the fact that we had a selected group of participants or due to a learning effect. A small nonsignificant learning effect has been reported in a previous test-retest reliability study [28] and the technique to perform the measurements might be improved when repeated several times. In future research other measurement modes, such as passive modes, might be more useful in very weak muscles.

Overall, we found small changes in muscle strength over time, which could be due to both the study sample, and the length of follow-up. Not enough data are available to perform a comprehensive power analysis, because gender differences have not been the primary aim of previous studies of changes in muscle strength in persons with late effect of polio. A sample size of 52 persons could be considered small, but annual data collection is very time consuming for both participants and assessors. It is important that the assessments are performed regularly and by the same assessor following a strict protocol. We chose to

follow the participants for 4 years because this has been recommended as the minimum follow-up time for persons with late effects of polio [15]. Compared to previous studies with annual measurements [18, 21], and taking into account the very low dropout rate in this study, we still believe the number of participants to be satisfactory for this type of analyzes.

All participants were ambulant and had mild to moderate late effects of polio. They were weaker in the ankle dorsiflexors than in their knee muscles and this weakness was compensated for by an ankle-foot-orthosis (AFO) in 10 participants, but no one needed a knee-ankle-foot orthosis (KAFO). Thus, the results in this study are limited to those with mild to moderate disability. In future studies a larger sample with a wider range of disability, as well as a longer follow-up period would be desirable. However, some of the participants in this study were already quite old (at the last test-session the oldest person was 78 years), and a reduction in muscle strength will probably continue in both men and women as a result of normal aging [37].

CONCLUSION

Small changes in muscle strength were seen in persons with late effects of polio over four years. The strongest predictor of change in lower limb muscle strength was the participants' gender. Men declined more in muscle strength than did women, especially in the knee muscles, but the rate of the decline did not accelerate over time, which indicates that gender could be a contributing factor to the progressive decline in muscle strength in persons with late effects of polio.

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Table 1. *Characteristics of the 52 participants with late effects of polio.* 1
                               2

Gender	
Men	28 (54)
Women	24 (46)
Age, y	64 (6); 52 to 74
BMI	26 (3); 21 to 37
Age at acute polio infection, y	5 (4); 0 to 15
Time with new symptoms, y	13 (7); 2 to 28
Most-affected leg	
Right	27 (52)
Left	25 (48)
Both lower limbs affected by polio	37 (71)
Walking aid	
None	47 (90)
Stick or crutch	4 (8)
Rollator	1 (2)
Orthotic device	
None	42 (81)
Ankle Foot Orthosis	10 (19)
Baseline isometric weakness, Nm*	
Less affected knee extension	66 (50); 40 to 250
More affected knee extension	115 (51); 40 to 251
Less affected ankle dorsiflexors	18 (12); –3 to 39
More affected ankle dorsiflexors	11 (10); –10 to 43

Values are represented as n (%) or mean (SD); range

SD= standard deviation; BMI =body mass index; Nm = newton meter

*For each participant the baseline isometric weakness was calculated as the difference between the predicted muscle strength, based on age, gender, length and body weight specific values for a healthy population [14], and the measured muscle strength value.

Table 2. *Estimated mean of strength measurements for knee extensors, knee flexors and ankle dorsiflexors (Newton meter) in 28 men with late effects of polio*

Test assessment	Estimated mean of fixed effects					Fixed linear effect	Random effect†
	At baseline	After 1 year	After 2 years	After 3 years	After 4 years		
Less-affected lower limb							
Knee extensors isokinetic 60°/s	130.1 (9.0)	130.6 (9.0)	124.4 (9.1)	123.4 (9.1)	122.2 (9.1)	–2.30**	9.8**
Knee flexors isokinetic 60°/s	71.0 (5.0)	73.4 (5.0)	70.8 (5.0)	67.7 (5.0)	68.7 (5.0)	–1.00*	12.7**
Knee extensors isometric MVC	158.4 (10.6)	155.0 (10.6)	147.4 (10.6)	140.7 (10.6)	143.3 (10.6)	–4.47***	8.4*
Ankle dorsiflexors isokinetic 30°/s§	28.8 (2.2)	28.6 (2.2)	28.0 (2.2)	28.7 (2.2)	28.4 (2.2)	–0.06‡	10.2**
Ankle dorsiflexors isometric MVC§	30.6 (2.7)	30.0 (2.7)	30.8 (2.7)	31.4 (2.7)	32.1 (2.7)	0.42*	14.6**
More-affected lower limb							
Knee extensors isokinetic 60°/s	91.0 (9.2)	91.3 (9.2)	84.4 (9.2)	81.7 (9.3)	76.5 (9.3)	–3.83***	8.6*
Knee flexors isokinetic 60°/s	51.0 (4.8)	52.3 (4.8)	49.7 (4.8)	46.8 (4.9)	48.3 (4.9)	–1.07*	7.7*
Knee extensors isometric MVC	96.3 (10.7)	95.6 (10.7)	93.6 (10.7)	86.1 (10.7)	86.6 (10.7)	–2.85***	1.06‡
Ankle dorsiflexors isokinetic 30°/s¶	24.6 (3.3)	26.3 (3.3)	23.9 (3.3)	22.6 (3.3)	22.3 (3.3)	–0.82*	12.6**
Ankle dorsiflexors isometric MVC¶	24.0 (4.0)	23.9 (4.0)	23.6 (4.0)	22.8 (4.0)	23.6 (4.0)	–0.18‡	1.9‡

Estimated values are presented as mean and (SD)¸
SD =standard deviation; MVC =maximal voluntary contraction.
* *P* < .05.
** *P* < .01.
*** *P* < .001.
† Deviance (*df*=2)
‡ Not significant.
§ Participants able to perform the measurements n=24,
¶ Participants able to perform the measurements n=12.

Table 3. *Estimated mean of strength measurements for knee extensors, knee flexors and ankle dorsiflexors (Newton meter; Nm) in 24 women with late effects of polio*

Test assessment	Estimated mean of fixed effects					Fixed linear effect	Random effect†
	At baseline	After 1 year	After 2 years	After 3 years	After 4 years		
Less-affected lower limb							
Knee extensors isokinetic 60°/s	81.8 (6.1)	80.8 (6.1)	77.9 (6.1)	80.7 (6.1)	80.9 (6.1)	–0.19‡	7.8*
Knee flexors isokinetic 60°/s	40.3 (3.0)	42.7 (3.0)	42.1 (3.0)	41.4 (3.0)	44.4 (3.0)	0.68‡	2.4‡
Knee extensors isometric MVC	92.9 (6.9)	86.0 (6.9)	86.1 (6.9)	85.2 (6.9)	86.4 (6.9)	–1.38‡	5.8‡
Ankle dorsiflexors isokinetic 30°/s§	19.5 (1.4)	20.2 (1.4)	20.3 (1.4)	19.7 (1.4)	19.6 (1.4)	–0.04‡	13.3**
Ankle dorsiflexors isometric MVC§	17.7 (1.6)	18.1 (1.6)	18.8 (1.6)	19.5 (1.6)	20.6 (1.6)	0.71**	9.5**
More-affected lower limb							
Knee extensors isokinetic 60°/s	59.0 (6.2)	61.9 (6.2)	58.9 (6.2)	58.4 (6.2)	58.7 (6.2)	–0.43‡	1.1‡
Knee flexors isokinetic 60°/s	25.4 (2.9)	26.0 (2.9)	26.2 (2.9)	26.0 (2.9)	27.8 (2.8)	0.47‡	1.7‡
Knee extensors isometric MVC	61.0 (6.8)	62.7 (6.8)	61.7 (6.8)	60.1 (6.8)	60.8 (6.8)	–0.30‡	0.7‡
Ankle dorsiflexors isokinetic 30°/s¶	16.8 (2.5)	16.8 (2.5)	17.5 (2.5)	17.3 (2.5)	17.0 (2.5)	0.10‡	3.9‡
Ankle dorsiflexors isometric MVC¶	15.9 (2.4)	19.1 (2.4)	17.2 (2.4)	20.4 (2.4)	19.6 (2.4)	0.87**	2.8‡

Estimated values are presented as mean and (SD),
SD =standard deviation; MVC =maximal voluntary contraction.
* $P < .05$.
** $P < .01$.
† Deviance (*df*=2)
‡ Not significant.
§ Participants able to perform the measurements n=22,
¶ Participants able to perform the measurements n=10.

Table 4. *Knee muscle strength measurements, and the final models with covariates and interaction with time for the total sample.*

	Inter-cept	Trend	gender[†]	gender *time	age[‡]	age *time	BMI	BMI *time	age acute polio	age acute polio *time	PPS	PPS *time	less aff weak-ness	less aff weak-ness *time	more aff weak-ness	more aff weak-ness *time
Less-affected lower limb																
Isokinetic extensors	80.0	−1.3§	54.1***	-	−1.5*	-	-	-	2.3*	-	-	-	−0.6***	-	-	-
Isokinetic flexors	39.2	0.7§	35.4***	−1.8*	−1.1*	-	-	-	2.2**	-	-	-	−0.2***	-	-	-
Isometric MVC extensors	90.5	−3.0**	72.7***	-	-	-	2.0*	-	-	-	-	-	−0.8***	-	-	-
More affected lower limb																
Isokinetic extensors	42.0	0.6§	69.6***	−4.9***	−1.4*	0.2*	-	-	-	-	−0.2§	−0.2*	0.1*	-	−0.9***	0.03*
Isokinetic flexors	18.4	0.5§	40.2***	−1.6*	−0.9*	-	-	-	1.4*	-	-	-	0.1**	-	−0.3***	-
Isometric MVC extensors	41.5	−0.3§	76.5***	−2.6*	−1.2*	-	2.4*	-	-	-	-	-	0.2**	-	−1.0***	-

Intercept and trend for the significant factors in the final model for each strength measurement.

BMI = body mass index; PPS = time with late effects of polio; less aff weakness = baseline weakness for less affected isometric knee extensor muscle strength; more aff weakness = baseline weakness for more affected isometric knee extensor muscle strength MVC = maximal voluntary contraction

* P < .05.

** P < .01.

*** P < .001.

[†] Woman is reference category

[‡] Baseline Age

[§] Not significant.

Table 5. *Ankle dorsiflexor muscle strength measurements and the final models with covariates and interaction with time for the total sample.*

justeras	Inter-cept	Trend	gender[†]	gender *time	age[‡]	age *time	age acute polio	age acute polio *time	BMI	BMI *time	PPS	PPS *time	less aff weak-ness	less aff weak-ness *time	more aff weak-ness	more aff weak-ness *time
Less affected lower limb[¶]																
Isokinetic strength	19.4	-0.1§	9.9***	-	-	-	-	-	-	-	-	-	-0.7***	-	-	-
isometric MVC	16.1	0.5**	14.3***	-	-	-	-	-	-	-	-	-	-0.9***	-	-	-
More affected lower limb[#]																
Isokinetic strength	14.2	0.6§	13.5***	-1.4**	-	-		-	-	-	-	-	-	-	-0.8***	0.1**
Isometric MVC	12.3	0.1§	14.7***	-	0.2§	-0.1*	-	-	-	-	-	-	-	-	-0.9***	-

Intercept and trend for the significant factors in the final model for each strength measurement.

BMI = body mass index; PPS = time with late effects of polio; less aff weakness = baseline weakness for less affected isometric knee extensor muscle strength; more aff weakness = baseline weakness for more affected isometric knee extensor muscle strength MVC = maximal voluntary contraction

* *P* < .05.

** *P* < .01.

*** *P* < .001.

[†] Woman is reference category

[‡] Baseline Age

[§] Not significant.

[¶] Participants able to perform the measurements n=46

[#] Participants able to perform the measurements n=22