mean FAI 26.4). The characteristics of the present sample were similar to those of our original population [3].

Figure 2 shows the proportion of subjects with decreased isokinetic muscle strength at follow-up, taking into consideration cases who were lost to follow-up or had different lengths of follow-up. At the final follow-up, approximately 90% of the subjects had decreased knee extension strength at both angular velocities (60 and 120 deg/sec). Similarly, approximately 80% of the subjects had decreased knee flexion strength at both angular velocities.

Figure 3 shows the secular changes of the values of isokinetic muscle strength measured as PT of knee extension and flexion at angular velocities of 60 and 120 deg/sec. At both speeds and in both directions, the PT values were almost constant during the first three years, and then reduced. However, this trend was not statistically significant on ANOVA, probably due to the number of lost-to-follow-up cases.

The annual average rate of decrease in the PT (%change of PT) is shown in Fig 4. At an angular velocity of 60 deg/sec, the rate of decrease in knee extension (7.8%) was greater than that of knee flexion (5.1%) (Fig.4, left). Similarly, at an angular velocity of 120 deg/sec, the rate of decrease in knee extension (8.8%) was significantly greater than that in knee flexion (1.6%) (Fig. 4, right).

Table 1. Subjects' characteristics

Characteristic	Number (%)	Mean (SD)	Range
Age, yrs		54.50 (8.12)	41 — 76
Gender			
Male	27 (42.9)		
Female	36 (57.1)		
Age at polio onset, yrs		2.28 (3.69)	0.25 — 28.0
Body height, cm		155.68 (8.62)	134.6 — 177.0
Body weight, kg		55.75 (12.19)	30.4 — 83.6
Body Mass Index, kg/m^2		22.82 (3.68)	15.76 — 30.76
Manual Muscle Test total		83.51 (14.51)	20.0 — 110.0
Braces	25* (39.7)		
Knee-ankle-foot orthosis	12 (19.1)		
Ankle-foot orthosis	14 (22.2)		
Barthel ADL index		98.42 (4.66)	71 — 100
Frenchay Activities Index		26.35 (9.00)	2.0 — 42.0

SD: standard deviation, *: One case used left knee-ankle-foot orthosis and right ankle-foot orthosis. N=63

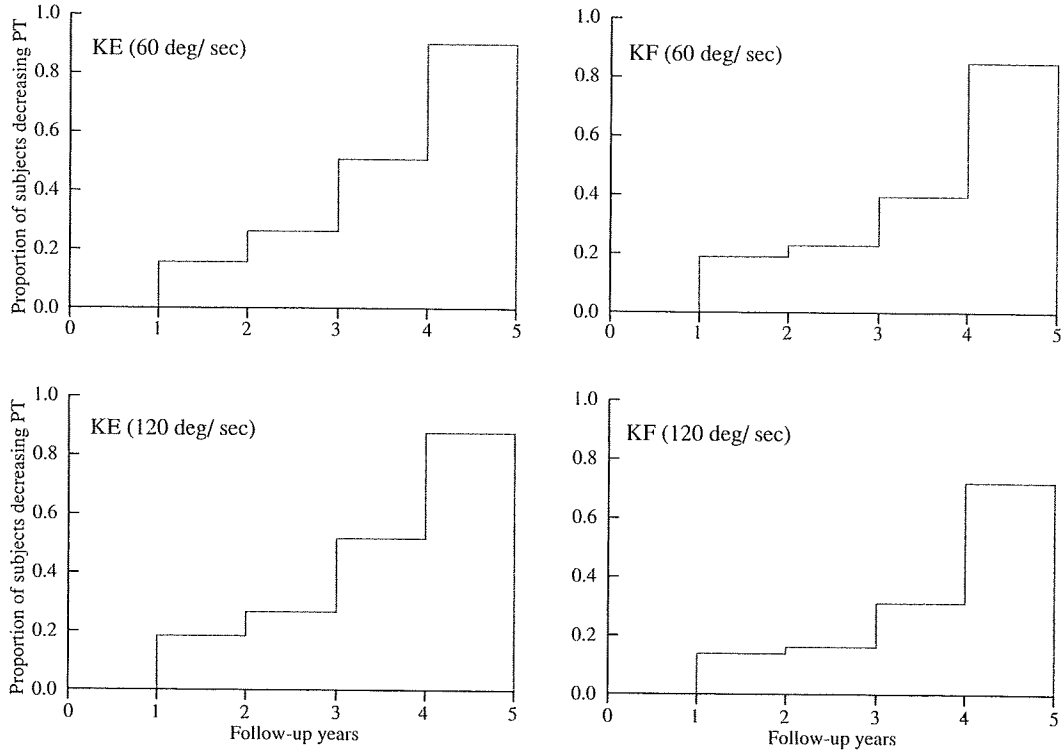

Fig. 2. Proportion of the subjects with progressing muscle weakness in Kaplan-Meier method. PT: peak torque, KE: knee extension, KF: knee flexion.

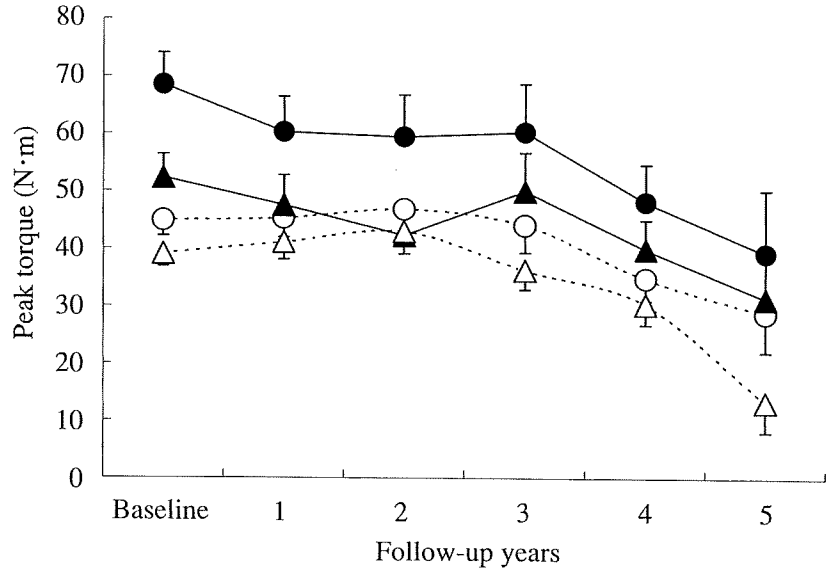

Fig. 3. Deterioration of isokinetic muscle strength during the study.

—●—: knee extension (60), ··○··: knee flexion (60),

—▲—: knee extension (120), ··△··: knee flexion (120 deg/sec).

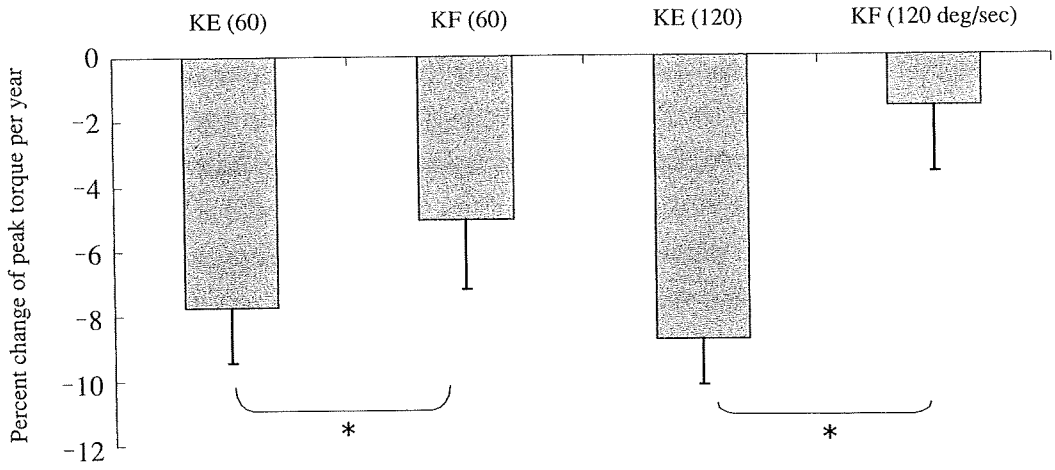

Fig. 4. Percent change of peak torque per year isokinetic muscle strength.
KE: knee extension, KF:knee flexion, Mean±SE, *: $P<0.01$.

Discussion

This study design was unique and reliable in that quantitative muscle strength testing was performed using the fixed dynamometer (Biodex) rather than the MMT evaluation, and the follow-up was long (5 years), according to the recommendations of Stolwijk-Swüste *et al*. [19]. Because of the subjectivity of the MMT, dynamometry was used to provide objective data to establish muscle strength exactly.

The results of the present study were compared to the studies using fixed dynamometers [5—8, 10, 11, 13, 17, 24]. Many such studies reported decreased muscle strength over time, while one study by Munin *et al*. [13] reported increased muscle strength; 7 PPS patients who were followed-up for 3 years had increased isokinetic muscle strength, from 15% to 36%. Their results appear to have been overestimated because of the small number of cases, some missing values, and the short duration of follow-up. Considering the overlapping sample, the studies reporting reduced muscle strength using the fixed dynamometer were collected into two groups: Agre's [8, 10, 17] and Grimby's [5—7, 11, 24].

The results of the present 5-year follow-up study indicate that this sample population consisted of mostly post-polio patients who had progressive decreases in lower extremity isokinetic muscle strength (Fig. 3). In addition, the annual rate of decrease was greater for knee extension than for knee flexion. In particular, muscle strength was almost constant during the first three years, and then a gradual reduction was seen (Fig. 3). The results of the Kaplan-Meier analysis, which considered the cases lost to follow-up, showed an increasing

proportion of subjects with reduced muscle strength over time (approximately 90% in knee extension and 80% in knee flexion at 5-years; see Fig 2). Muscular strength over a 4-year follow-up period clearly decreases 50 years after an episode of poliomyelitis. These results showing a reduction of muscle strength over time agreed with the studies by Agre [8, 10, 17] and Grimby [5–7, 11, 24], though the reduction rates were different. However, the average annual rates of decrease in the present study, 7.8% per year (60 deg/sec) and 8.8% per year (120 deg/sec) for knee extension, were greater than those of other studies. Agre *et al*. [10] reported an 8% reduction of isokinetic knee extensor strength over 4 years, while Grimby *et al*. [7] reported a 13% reduction at 60 deg/sec and a 15% reduction at 180 deg/sec over 8 years. The reason for the differences in the rates is mostly due to sample characteristics. The present sample was highly active, but older and included a higher proportion of PPS than Grimby's [7]. The initial muscle strength in the present sample was lower than that in Grimby's [7], which might have caused an overestimation of the rate of change even for a small absolute change over time. However, the present study, involving a larger sample, provided reliable data and consistent evidence that lower extremity muscle strength decreases over time in polio survivors.

The rate of lower extremity muscle deterioration was higher for knee extension than for knee flexion (Fig. 4). A previous study [9] reported that polio survivors developed deterioration of the knee flexors, not the knee extensors, because their braces compensated for the extensors in the stance phase, but the flexors in the swing phase were subject to repetitive stress for which the braces provided no compensation. However, the results of the study by Klein *et al*. [9] using HHD cannot be compared with the results of the present study using the fixed dynamometer. Furthermore, their sample was older than the present sample (mean age: 64 years vs. 54 years) and used braces more frequently (45 vs. 40%). We believe that deterioration in the strength of the knee extensor, the weight-bearing muscle, was more important for locomotion in polio survivors who were active.

The findings from the present study must be interpreted in light of the following limitations. First, since the majority of the subjects who were involved participated voluntarily, there could have been a selection bias. However, the sample would be representative of PPS patients in the area because the characteristics of the present sample were similar to those of our original population. Therefore, selection bias was thought to be minimal. Ninety-seven percent of the subjects were thought to have developed PPS, but cases with severe muscle weakness were excluded; thus, the findings in this study could be generalized only to survivors of mild to moderate polio. Second, the cases lost to follow-up during the observation period may have affected the results. Since this limitation might underestimate the association or reduce the statistical power, survival analysis that took each follow-up period into consideration was used, and the annual change of PT was calculated by averaging muscle strength during the observation period. Third, a fixed dynamometer was used for isokinetic muscle strength testing, which is more dynamic and changeable than isometric muscle

strength. Finally, the absence of age-matched controls without a history of poliomyelitis prevents examination of the cause of muscle weakness: normal aging or PPS. Delbaere *et al*. reported that the decline in muscle strength of the lower extremities was 40 to 47% during 20 years (2 to 3%per year) in middle-aged men using the Biodex [25]. Comparing this data of healthy subjects, and a larger decline rate in our subjects (8% per year) suggested that factors other than normal aging might influence the muscle weakness in polio survivors.

Despite these limitations, our findings demonstrate the consistency of the fact that polio survivors developed progressive muscle weakness that was greater than the usual rate of strength reduction over time. The present study used a reliable measurement method involving the dynamometer and a longer follow-up period. Further follow-up studies should be performed to clarify which intervention would be effective for improving or maintaining muscle strength.

Conclusions

The results of the present 5-year follow-up study demonstrate that this sample population, which consisted primarily of post-polio patients, had a progressive decrease in isokinetic lower extremity muscle strength. In addition, the annual rate of decrease was greater for the knee extensor, the weight-bearing muscle, than for the knee flexor.

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ポリオ罹患者における等運動性下肢筋力の5 年間の変化

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要　　旨: 5 年間にわたるポリオ罹患者の下肢筋力の変化を評価するため, 自主的に参加した地域在住のポリオ罹患者(63 名, そのうち61 名がポリオ後症候群)を対象として, 前向き縦断研究を実施した. すなわち, 5 年間にわたって毎年1 回, 固定式ダイナモメーター(Biodex)を用いた等運動性膝伸展筋力および膝屈曲筋力(ピークトルク値)を60°／秒および120°／秒の角速度で測定した. 5 年後の時点で, 対象者の約90%の者が両角速度での膝伸展筋力の低下を認め, 同様に80%の対象者が膝屈曲筋力の低下を認めた. 膝伸展筋力(ピークトルク値)の1 年あたりの低下率は, 両角速度において膝屈曲筋力のそれよりも有意に大きく, その差は角速度の速い場合により顕著であった. ポリオ罹患者の等運動性下肢筋力は, 経年的に進行性低下をきたすこと, また, 荷重筋である膝伸展筋力の低下率が膝屈曲筋力より大きいことが明らかとなった.

キーワード: 筋力, 等運動性筋力, ポリオ, リハビリテーション.

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