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ORIGINAL REPORT

VITALITY AMONG SWEDISH PATIENTS WITH POST-POLIO: A PHYSIOLOGICAL PHENOMENON*

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Objective: **To evaluate vitality and fatigue in post-polio patients, and the relative contributions of physiological and psychological parameters to the level of vitality.**
Design: **Multi-centre study.**
Subjects: **One hundred and forty-three patients with post-polio syndrome.**
Methods: **Inventories of background, quality of life, fatigue and sleep quality were used. Pain was evaluated using a visual analogue scale. Descriptive statistics and correlations were used for all selected parameters. Hierarchical regression models were constructed to examine predictors of variations in vitality, pain, reduced activity and physical fatigue.**
Results: **General fatigue accounted for 68% of the variation in vitality. Of this, 91% was accounted for by physiological indicators. After controlling for age, physiological parameters accounted for 56.6% and 25%, if entered before and after the psychological parameters, respectively. The impact of the psychological parameters decreased after accounting for the physiological parameters. Physical fatigue, age and sleep quality were associated with variation in pain. Body mass index, pain and sleep quality accounted for differences in reduced activity and physical fatigue.**
Conclusion: **Vitality in post-polio patients depends on physiological parameters. Mental fatigue is not a prominent predictor. Subgroups with or without fatigue, independent of age, need further study.**

Key words: post-polio, fatigue, vitality, quality of life.

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INTRODUCTION

Poliomyelitis leads to muscle weakness due to destruction of the anterior horn cells. After an initial recovery there is a phase of functional stability that usually lasts from 10 to 40 years. During this phase the life circumstances of polio survivors do not differ much from the general population with respect to work and family situation (1). However, after the stable phase deterioration may occur; a condition termed post-polio syndrome (PPS) (2). The most commonly reported symptoms of PPS are increased muscle weakness, fatigue and pain in the muscles and joints. The last epidemic of polio in Sweden was in 1953 when more than 5000 people contracted poliomyelitis. Today, the prevalence of polio-affected individuals in Sweden is estimated to be 186/100,000 (3). Reported estimates of polio survivors eventually developing PPS vary from 20% to 68% (2, 4). Thus, the majority of polio survivors in Sweden are now middle-aged or older, and consequently at risk of developing PPS. Risk factors for developing PPS include time since the acute polio infection (5), age at presentation of symptoms, muscle pain at exercise, recent weight gain, joint pain (6) and female gender.

During the last decade, increasing research interest has focused on fatigue in patients with PPS (7). Jubelt & Agre (8) reported generalized fatigue as one of the most common symptoms in PPS. Mental, as well as physical, fatigue has been reported by both Bruno et al. (9) and Schanke & Stanghelle (10).

Interestingly, and related to mental fatigue, there are contradicting reports regarding cognitive dysfunction in patients with PPS. Difficulties with attention, word finding, maintaining wakefulness and ability to think clearly have been reported by Bruno et al. (11). However, in most other studies cognitive function is reported to be unaffected by mental fatigue (12, 13). Furthermore, fatigued polio survivors are reported to have more mental health problems than controls or polio survivors without severe fatigue (5). In a study by Conrady et al. (14) patients, both at a post polio-clinic and in a post-polio support group, experienced significantly elevated levels of psychological distress, such as somatization and depression. Gonzalez et al. (15) reported an increase in cytokines in the cerebrospinal fluid of patients with PPS, indicating an inflammatory process. The inflammatory processes were down-modulated by treatment with intravenous immunoglobulin followed by a clinical effect, especially on vitality, as evaluated by means of Short Form 36 (SF-36). This indicates that vitality has a central role in PPS that may be improved by means of pharmacological treatment. The subjective experience of vitality

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was described by O'Connor (16) as the presence of energy and absence of fatigue and as a core aspect of both biological and psychological aspects of health (17). The biological aspect refers to bodily sensations such as pain and muscle fatigue, while the psychological aspects refer to feelings and moods. Thus, vitality represents, also in patients with PPS, an absence of general fatigue.

The aim of the present study was to evaluate quality of life and the influence of different physiological and psychological parameters relevant to patients with PPS. Determinants of vitality in PPS were examined, focusing especially on the physiological and psychological fatigue parameters, and the extent to which these accounted for the vitality-related variation in general fatigue. An additional aim was to examine potential determinants of physical fatigue, physical activity and pain.

METHODS

Participants

The sample was selected from 4 Swedish hospitals and included 143 patients participating in a multicentre study (18). Inclusion criteria were: (*i*) 18–75 years of age with a prior polio infection; (*ii*) increasing muscular weakness/difficulties/pain after a stable period of at least 15 years; (*iii*) a variation in weight of not more than ± 7 kg during the past 5 years; and (*iv*) ability to stand and walk at least 2 m with or without walking aids. The age range of the participants was 25–75 years.

Background information

Participants were assessed on 2 occasions when entering the study. At the first meeting they answered questions about background and demographic information. The variables included in the present study were gender, age and duration of polio. Information about the extent to which the participants were working was collected subsequently through medical records. This variable is henceforth termed "Occupation/employment". Working was defined as working at least 25% of full-time.

Inventories and scales

At the second meeting, participants were administered self-report inventories about quality of life, fatigue, sleep and pain. SF-36 is a health-related quality of life (QoL) inventory comprising 36 questions assessing QoL along 8 dimensions. The physical health dimensions include Physical function, Role-Physical and Bodily pain. The psychological health dimensions include Social function, Role-Emotional and Mental health. Finally, Vitality and General health include dimensions of both physical and psychological health. A score of 0–100 is calculated for each health concept or dimension, with a higher score indicating better QoL (17).

The Multidimensional Fatigue Inventory 20 (MFI20) is a 20-item inventory measuring 5 different aspects of fatigue; General fatigue, Physical fatigue, Mental fatigue, Reduced motivation and Reduced activity. The statements refer to aspects of fatigue experienced during the previous days. The scale is a 7-point Likert scale, on which higher scores indicate a higher degree of fatigue (19).

A visual analogue scale (VAS) assessing present subjective experience of pain was also used. It was constructed as a 100-mm scale, on which 0 mm = no pain at all and 100 mm = the worst imaginable pain (20, 21).

The Sleep Quality Scale (SQS) is a 3-question inventory measuring sleep quality. Questions about whether the patient has difficulty falling asleep, whether they wake up during the night or have worried sleep, are asked. The scale is a 4-point Likert scale on which a higher score indicates worse sleeping problems (22). All 3 subscales were highly correlated ($ps < 0.01$) and were therefore collapsed into one variable (minimum value 3, maximum value 12) termed "Sleep quality total".

In order to examine the separate contributions of background, physiological and psychological variables these were entered block-wise and separately in the analyses.

The variables General health from SF-36, and General fatigue from MFI20 were both more strongly correlated with physical and physiological aspects in the respective questionnaire and were therefore labelled as physiological for the purposes of this study (17, 19, 23).

Background variables were: Gender, Age, Polio duration, and Occupation/employment level.

Physiological variables were, from the SF-36 inventory: Physical function and General health. From the MFI20 inventory: General fatigue, Physical fatigue and Reduced activity. The VAS measuring subjective pain and body mass index (BMI) were also sorted under the label "physiological".

Psychological variables constituted Mental health from the SF-36 inventory and Mental fatigue from MFI20.

Vitality from the SF-36 inventory was used as a main outcome variable and "Sleep quality total" as a clinical indicator in the last set of analyses.

The study and all procedures were approved by the ethics committee at Karolinska Institutet, and conducted in accordance with the Helsinki Declaration of 1975.

Statistical analyses

All statistical analyses were performed using SPSS software package for Windows (version 14.0).

Descriptive statistics were examined and all variables were subjected to correlations. Hierarchical regression analyses with Vitality as outcome were then carried out. The main purpose of these analyses was to examine: (*i*) the amount of variance in Vitality that was accounted for by General fatigue (model 1); and (*ii*) the extent to which the variance explained by General fatigue could in turn be accounted for by differences in: (a) physiological, and (b) psychological indicators (model 2). In order to examine the relative importance of physiological and psychological indicators, the entry order of the 2 blocks of predictors was varied (models 3 and 4). In models 3 and 4, in order to be able to generalize across the age range studied, we first controlled for chronological age before examining the relative importance of 2 sets of physiological and psychological indicators. Finally, in model 5, we examined the extent to which the same variation in Vitality was accounted for by Age, BMI, Occupation/employment level and Polio duration. These variables were entered in the first step and General fatigue was entered in the second step in order to accomplish this.

In the final set of regression analyses, we examined 3 other clinically and theoretically important variables, namely Pain, Reduced activity and Physical fatigue, entering the predictors in a stepwise fashion, where entry order was based on their clinical relevance for each outcome.

RESULTS

Descriptive data

Descriptive information for demographic data and pain, quality of life, fatigue and sleep quality is shown in Table I. Of the participants 64.3% were women and 36.4% were working. Of the participants between 25–64 years of age 65% were working compared with a working rate of 80.8% in the Swedish population (24). The variable Physical function from SF-36 had the lowest and Mental health the highest scores. Furthermore, Vitality was neither high nor low in this group. The participant's scores were equally high on General fatigue and Physical fatigue among the fatigue items and, finally, Sleep quality total indicated increased sleeping problems.

Table I. *Descriptive data for all independent and dependent variables, given as mean values with standard deviation in parentheses*

Characteristics	$n=143$
Females, %	64.3
Age, years	60.2 (9.7)
Polio duration, years	54.0 (8.2)
Occupation/employment level	1.6 (0.5)
Occupation/employment level, %	36.4
BMI	25.2 (2.6)
Pain, VAS	27.9 (24.0)
SF-36 Physical function	43.3 (23.0)
SF-36 General health	58.2 (22.4)
SF-36 Vitality	50.0 (24.2)
SF-36 Mental health	75.0 (18.6)
MFI General fatigue scale	14.0 (4.5)
MFI Physical fatigue scale	14.0 (4.7)
MFI Reduced activity scale	12.2 (4.2)
MFI Reduced motivation scale	7.8 (3.0)
MFI Mental fatigue scale	10.0 (4.1)
Sleep Quality Scale total	7.8 (2.6)

BMI: body mass index; VAS: visual analogue scale; SF-36: short form 36; MFI: Multidimensional Fatigue Inventory.

Correlations

The results of the correlations are shown in Table II. Increasing Vitality was associated with older age, better Physical function, better General and Mental health, less pain, less reduction in activity, less General, Physical and Mental fatigue as well as better sleep quality and a lower BMI. More pain (increase on VAS) was associated with younger age, increasing Physical fatigue and decreasing sleep quality and an increase in Reduced activity. Increasing Reduced activity was associated with more pain, higher BMI and worse sleep quality. Increasing Physical fatigue was associated with younger age, more pain, higher BMI and worse sleep quality. Increasing Age was associated with better General and Mental health, increase in Vitality, decrease in pain and decrease in General, Physical and Mental fatigue. Increasing Polio duration, finally, was associated with better General health and less Pain and Mental fatigue. Neither Age nor Polio duration correlated significantly with BMI.

Hierarchical regressions examining predictors of Vitality

General fatigue alone accounted for 68.5% of the variance in Vitality (Table III, model 1). Ninety-one percent of this variance was in turn explained by the physiological and psychological variables together (model 2). This figure was derived by subtracting the R^2 associated with General fatigue in step 3 of model 2 from the R^2 in model 1 and dividing the difference by the R^2 from model 1. Subsequent accounts were calculated in the same way. Overall, Physical fatigue and Mental health had the largest explanatory power.

After controlling for age, the physiological block of variables accounted for 56.6% of the variance in Vitality when entered before the block of psychological variables (model 3), and 24.9% when entered afterwards (model 4). The psychological variables accounted for 38.7% when entered before (model 4) and 13.4% when entered after the physiological variables (model 3).

Table II. *Correlations among all independent and dependent variables*

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Gender[a]	1														
2. Age	0.024	1													
3. Polio duration	0.029	0.785**	1												
4. Occupation/employment	–0.093	0.531**	0.320**	1											
5. BMI	–0.043	0.019	0.105	0.012	1										
6. Pain, VAS	0.095	–0.261**	–0.166*	–0.073	0.112	1									
7. Physical function	–0.177*	0.079	0.112	–0.039	–0.071	–0.323**	1								
8. General health	–0.073	0.253**	0.174*	0.023	–0.137	–0.518**	0.398**	1							
9. Vitality	–0.057	0.252**	0.116	0.165*	–0.176*	–0.474**	0.427**	0.645**	1						
10. Mental health	–0.072	0.176*	0.080	0.165*	–0.121	–0.354**	0.295**	0.563**	0.650**	1					
11. General fatigue	0.048	–0.274**	–0.157	–0.174*	0.179*	0.507**	–0.438**	–0.664**	–0.827**	–0.576**	1				
12. Physical fatigue	0.081	–0.211*	–0.158	–0.041	0.180*	0.442**	–0.560**	–0.680**	–0.738**	–0.443**	0.782**	1			
13. Reduced activity	0.031	–0.095	0–.082	0.032	0.166*	0.283**	–0.437**	–0.544**	–0.666**	–0.538**	0.688**	0.679**	1		
14. Reduced motivation	–0.008	–0.055	–0.074	0.017	0.184*	0.160	–0.314**	–0.390**	–0.442**	–0.500**	0.493**	0.435**	0.576**	1	
15. Mental fatigue	0.025	–0.270**	–0.212*	–0.108	0.115	0.253**	–0.165**	–0.420**	–0.427**	–0.500**	0.505**	0.385**	0.490**	0.492**	1
16. Sleep quality total	0.228*	–0.063	0.028	0.000	0.198*	0.380**	–0.224**	–0.309**	–0.306**	–0.310**	0.348**	0.332**	0.305**	0.210**	0.323**

[a]Calculated by point biserial correlations.
*$p<0.05$, **$p<0.01$
BMI: body mass index; VAS: visual analogue scale.

Table III. *Hierarchical regressions examining predictors of Vitality, Models 1, 2, 3, 4 and 5*

Entry order	Predictors	β	t	*p*	Total R^2	Incr R^2
	MODEL 1					
	General fatigue	–0.827	–17.499	0.000	0.685	0.685
	MODEL 2					
Step 1,	Reduced activity	–0.312	–4.401	0.000		
physiological	Physical fatigue	–0.442	–5.821	0.000		
	Pain	–0.190	–3.266	0.001	0.623	0.623
Step 2,	Mental fatigue	0.019	0.334	0.739		
psychological	Mental health	0.336	5.548	0.000	0.696	0.073
Step 3	General fatigue	–0.476	5.927	0.000	0.758	0.062
	MODEL 3					
Step 1	Age	0.252	3.095	0.002	0.064	0.064
Step 2,	Reduced activity	–0.319	–4.519	0.000		
physiological	Physical fatigue	–0.426	–5.606	0.000		
	Pain	–0.172	–2.920	0.004	0.630	0.566
Step 3,	Mental fatigue	0.036	0.621	0.535		
psychological	Mental health	0.334	5.535	0.000	0.700	0.134
Step 4	General fatigue	–0.468	–5.786	0.000	0.760	0.060
	MODEL 4					
Step 1	Age	0.252	3.095	0.002	0.064	0.064
Step 2,	Mental fatigue	–0.107	–1.437	0.153		
psychological	Mental health	0.575	7.917	0.000	0.451	0.387
Step 3,	Reduced activity	–0.185	–2.579	0.011		
physiological	Physical fatigue	–0.414	–6.005	0.000		
	Pain	–0.111	–2.036	0.044	0.700	0.249
Step 4	General fatigue	–0.468	–5.786	0.000	0.760	0.060
	MODEL 5					
Step 1	Age	0.377	2.541	0.012		
	BMI	–0.166	–2.044	0.043		
	Occupation/ employment	0.021	0.215	0.830		
	Polio duration	–0.169	–1.265	0.208	0.108	0.108
Step 2	General fatigue	–0.810	15.999	0.000	0.689	0.581

VAS: visual analogue scale; Incr: increment; BMI: body mass index.

Age, BMI, Occupation/employment level, and Polio duration accounted for 10.8% of the General fatigue related variance in Vitality. Of these, only Age and BMI made significant contributions (model 5). The results are displayed in Table III. The figures denote the coefficients obtained in the respective steps of predictor entrance.

Hierarchical regressions examining predictors of VAS Pain, Reduced activity and Physical fatigue

Results from the next set of hierarchical regressions appear in Table IV.

The first set of analyses examined the extent to which variation in Pain could be accounted for by differences in Physical fatigue, Reduced activity, Age and Sleep quality total. Together, these predictors accounted for 90.2% of the variance in Pain. The 3 factors that made a significant contribution to explained variance were Physical fatigue, Age and Sleep quality total, where increasing Physical fatigue was related to more pain (β 0.442), higher Age, to less pain (β –0.174) and increasing Sleep quality total to more pain (β 0.268).

In the second set of these analyses we examined the extent to which variation in Reduced activity could be accounted for by differences in Polio duration, BMI, Pain, Age and Sleep quality total. Together, the predictors accounted for 39.1% of the variance in Reduced activity. The 3 factors making a significant contribution to the explained variance were BMI, Pain and Sleep quality total, where increased BMI (β 0.177), more pain (β 0.258) and increased Sleep quality total (β 0.220) were associated with a greater reduction in activity

Table IV. *Hierarchical regressions examining predictors of Pain, Reduced activity and Physical fatigue*

Dependent variable	Predictors entry order	β	t	*p*	Incr R^2	Total R^2
Pain, VAS	1) Physical fatigue	0.442	5.859	0.000	0.196	
	2) Reduced activity	–0.032	–0.309	0.758	0.196	
	3) Age	–0.174	–2.275	0.024	0.225	
	4) Sleep quality total	0.268	–2.275	0.024	0.288	
						0.902
Reduced activity	1) Polio duration	–0.083	–0.987	0.325	0.007	
	2) BMI	0.177	2.121	0.036	0.038	
	3) Pain	0.258	3.141	0.002	0.102	
	4) Age	0.034	0.255	0.799	0.102	
	5) Sleep quality total	0.220	2.519	0.013	0,142	
						0.391
Physical fatigue	1) Polio duration	–0.158	–1.902	0.059	0.025	
	2) BMI	0.198	2.412	0.017	0.064	
	3) Pain	0.409	5.347	0.000	0.224	
	4) Age	–0.068	–0.549	0.584	0.225	
	5) Sleep quality total	0.181	2.221	0.028	0.252	
						0.790

VAS: visual analogue scale; Incr: increment; BMI: body mass index.

Finally, the third set of the analyses examined the extent to which variation in Physical fatigue could be accounted for by differences in Polio duration, BMI, Pain, Age and Sleep quality total. Together, these predictors accounted for 79% of the variance. The 3 factors that made a significant contribution to the explained variance were BMI, Pain and Sleep quality total, where increased BMI (β 0.198), more pain (β 0.409) and increased Sleep quality total (β 0.181) were related to increased Physical fatigue.

DISCUSSION

PPS is composed of different symptoms that have physiological or psychological components. Vitality is such a compound of different physiological and psychological aspects (17) and is perhaps best described as the absence of fatigue and the presence of energy (16). It may be noted, however, that this explanation is far from perfect. In the present study 32% of the variation in vitality was unaccounted for by differences in general fatigue (model 1, Table I). Fatigue is one of the most common symptoms in PPS. Furthermore, vitality has been shown to improve after pharmacological treatment in PPS. As expected, in the present study, general fatigue was the most important variable explaining vitality, an account of which the physiological and psychological variables together in turn explained more than 90%. Furthermore, after controlling for age, the physiological block of variables was found to account for most of the vitality associated with the psychological variables and uniquely for 25% of the vitality-related variation over and above that accounted for by age and psychological

determinants. Interestingly, age, BMI, occupation/employment level and polio duration were of no importance for the general fatigue related variance in vitality. Altogether, this suggests that the phenomenon of vitality in patients with PPS is mostly dependent on other than psychological parameters.

Healthy individuals perceive fatigue after mental work as a lack of energy, lack of motivation, and increased sleepiness (25). Similarly, polio survivors have been reported to suffer from brain- or mental fatigue (9). However, in a study by Schanke & Stanghelle (10) no difference in the experience of mental fatigue was seen between male polio survivors and normal controls. Furthermore, in a study by Östlund et al. (12) no evidence of mental fatigue was found when comparing a generally fatigued PPS group with a non-fatigued group. This is further supported by the recent findings that modafinil does not have an effect on fatigue in patients with PPS (26). The present results provide additional support for this by showing that mental fatigue is of minor importance for the experience of vitality in this group of patients. Thus, we conclude that mental fatigue is not a prominent determinant of vitality in PPS.

The patients with PPS in the present study reported good mental health, ranging from neither good nor bad to excellent and this, as discussed above, accounted for little of the variation in vitality once the physiological aspects were accounted for, whereas the physiological indicators made a relatively large independent contribution to explained variance in vitality. This indicates that psychological aspects are of lesser importance for vitality than physiological aspects in patients with PPS and, thus, mental health problems seem not to be the primary problem in this respect.

This result is in agreement with the finding of several other studies in which polio survivors did not differ from the general population in levels of depression (27) and, according to a study by Clark et al. (28) patients with PPS had in most aspects a normal psychological profile. As a caveat, it should be noted that we did not include a normal control group in our study, and may therefore not draw conclusions from the absolute levels among our participants. However, Kemp et al. (29) concluded in their study that higher depression scores and lower life satisfaction did not relate to PPS itself. Family function and the attitude towards disability were here found to be of greater importance. The differences in depression between polio survivors with and without PPS were also quite small in a study by Freidenberg et al. (30). Nevertheless, in a study by Schanke et al. (5) fatigued polio survivors reported more mental health problems than both healthy controls and polio survivors without severe fatigue. Importantly, depressed polio survivors also had poorer health, more pain, lower quality of life and poorer coping strategies than non-depressed polio survivors (31). From the results of the present and earlier studies, our conclusion is that psychological problems are not primary in PPS.

Pain is also one of the most common symptoms in PPS. In a study by Smith & McDermott (32) 90% of patients with PPS reported some kind of pain and in a study by Willén & Grimby (33) over half of the patients with PPS experienced pain every day. Both polio survivors with and without paralysis had, in a study by Farbu & Gilhus (34), more pain and fatigue than their siblings. In the present study the participants reported rather modest levels of pain according to VAS, and almost one-third of the variance in pain was explained by physical fatigue, age and sleep quality. This is in contrast with the results reported by Schanke et al. (5) where fatigue did not contribute to the experience of pain in polio survivors. In the present study, we did not assess the character of the pain in the patients with PPS. It may be of importance for both treatment and for future studies to discriminate between different types of pain, such as muscle or joint pain. For example, muscle pain was associated with more fatigue, lower vitality level and reduced mental health in a study by Vasiliades et al. (35) and in a recent study by Werhagen & Borg (personal communication), pain was more often reported by women than by men.

Sleep quality contributed significantly to the variance in pain, activity and physical function, respectively. However, the contribution was quite small. Also, sleep quality correlated with a majority of the physiological and psychological variables, indicating that the worse physical and mental health the worse sleep quality. This is an indication that a reduction in sleep quality may be a problem for a group of patients with PPS with more severe symptoms.

In clinical tradition, older age and polio duration (5) have been reported as risk factors for developing PPS (6). However, we found that age and polio duration did not contribute to the explanation of reduced activity. We also found that increasing age and longer polio duration correlated significantly, with better general health, less mental fatigue as well as less pain according to VAS. Furthermore, increasing age was significantly associated with higher vitality, better mental health and less general and physical fatigue. This is in agreement with a study by Nollet et al. (36) in which patients with PPS reported a decrease in fatigue over a period of 6 years. It is also in accordance with a study by Chetwynd et al. (37) who found, after controlling for baseline age, little evidence that symptoms associated with PPS, such as increasing muscle weakness, shortness of breath after wakening, pain and excessive tiredness, increased with time after the acute polio infection. However, Stanghelle & Festvåg (38) reported that subjective symptoms and physical disability in PPS did increase with age. Willén et al. (39) confirmed that physical mobility decreased over 4 years in their group of polio patients, especially in the older group (> 64 years). Interestingly, in the study by Schanke et al. (5) polio survivors with severe fatigue were slightly younger than polio survivors with mild fatigue, a finding corroborated by the data from the present study, where fatigue was more prominent in younger patients with PPS than in older patients. Willén et al. (39) also reported more distress and pain in the younger group of polio patients than in the older group, and this increased over 4 years.

The results of this study have implications for treatment and counselling of patients with PPS. Decreasing vitality may be due to an increase in physical fatigue. Therefore patients should be followed thoroughly and focus should be on physiological rather than psychological factors. Thus, decreasing vitality should be evaluated in terms of progression of PPS or overuse of remaining muscles. The observation of increasing

quality of life with increasing age was an unexpected finding, and needs future replication.

There is a need for more studies in this field. One hypothesis that requires further evaluation is that there may be subgroups of patients with PPS with or without fatigue where the presence of fatigue is not dependent on age or duration of polio.

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