The effect of exercise on gait and balance in patients with chronic fatigue syndrome

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Abstract

This study investigated anecdotal reports of gait and balance abnormalities in subjects with Chronic Fatigue Syndrome (CFS) by examining the effects of a light exercise test on postural sway and various gait parameters. Tests were performed on 11 CFS patients and 11 age- and sex-matched sedentary controls. Results demonstrated that postural sway was not significantly different in both groups before or after the exercise test. There were, however, significant differences in gait parameters between the two groups confirming anecdotal evidence, but these differences were not exacerbated by the exercise test. Heart rate responses demonstrated that both groups were exercising at similar loads, although this was perceived to be higher by the CFS group.

Keywords: Chronic fatigue syndrome; Gait analysis; Balance assessment; Exercise

1. Introduction

Chronic Fatigue Syndrome (CFS) is now the recognised term used to cover a number of previously reported conditions which had been named to reflect either the site of reported epidemics (e.g. Iceland Disease, Royal Free Disease), the causative agent (e.g. Epstein–Barr Virus Disease) or the symptoms produced (e.g. post-infection fatigue syndrome, effort syndrome, myalgic encephalomyelitis). As infection often appears to be the precipitating factor, patients commonly present with fever, sore throat, cervical adenopathy, cough or abdominal symptoms. Other clinical features associated with CFS are wide and varied and may fluctuate over time [1–3]. As the name suggests, fatigue is the primary and often the most debilitating symptom and anecdotally is reported to be exacerbated by mental and/or physical activity. The problem of diverse clinical presentations, lack of an objective test for diagnosis and a number of different terminologies led to a working case definition for Chronic Fatigue Syndrome being developed by the Centres for Disease Control (CDC) in the United States of America [4]. This case definition was more recently reviewed and updated [5]. The incidence of CFS in the population is difficult to determine accurately and has been reported to range from 0.86 to 2 per 1000 of the population [6,7]. There is, however, general agreement that females are more commonly affected than males [1,3] and that the condition most commonly affects those aged between 20 and 40 years [8].

Static and dynamic balance are essential elements for the performance of activities of daily living (ADL). Komaroff [2] estimated that between 30 and 50% of patients with CFS suffered some degree of dysequilibrium whilst Merry [9] suggested the incidence could be as high as 70% of all cases. Although impairment of balance appears to be a significant problem in patients with CFS, only a small number of studies have investigated this problem.

Furman [10] used dynamic posturography to assess the vestibular function of three subjects with CFS and
reported that all three had abnormal test results, one suggestive of a non-specific vestibular problem, the other two a defect in the central nervous system. However, no firm conclusion could be reached due to the small sample size. Ash-Bernal et al. [11] tested 11 CFS subjects, specifically those who presented with dysequilibrium. In order to examine their vestibular function all subjects undertook a comprehensive battery of tests including electronystagmography, earth vertical axis rotation, earth horizontal axis rotation and posturography. The study concluded that vestibular abnormalities did exist in all subjects studied but that different subjects had abnormalities in different tests and no consistent pattern was found which could identify one specific defect.

Gait is a fundamental activity and, like balance, can be affected by virtually all neuromuscular disorders [12]. Investigations of gait abnormalities in CFS are also very scarce. Boda et al. [13] analysed CFS subjects’ gait at pre-determined speeds on a treadmill and also timed the subjects’ running and walking for 30 m. The study reported that CFS subjects’ running speed was significantly slower than controls and, whilst walking on the treadmill, CFS subjects had smaller stride lengths at slower speeds. Although this study reported a number of gait abnormalities in subjects with CFS, the kinematic patterns of gait are different in free walking and treadmill walking [14,15] and so these results may not be representative of the subjects’ ‘normal’ gait pattern.

Saggini et al. [16] examined the gait patterns of 12 subjects with CFS and compared their results to an existing database of 596 normal subjects (aged 3–60 years). Subjects walked six times along a 2.5 m pressure platform, then walked for 212 m and their gait was reassessed. This protocol was repeated three times. The study found that in the initial gait assessment no significant differences were found in the gait parameters between CFS subjects and controls. However, following the 212 m walk the gait parameters of the CFS subjects were altered with half displaying abnormalities in the temporal phases of gait and 11 of the 12 subjects showing abnormalities in the spatial phases of gait. This study used a database of controls of varied age and presumably fitness (although this was not specified) and therefore presents a methodological problem. It is recognised that the use of sedentary controls is essential when studying subjects with CFS [17] and therefore it is unclear whether such a group forms a suitable control for comparisons with CFS patients.

It is generally agreed that the symptoms of CFS are exacerbated by even minor activity [17–21]. McCully et al. [17] reported that exacerbation of symptoms began 6–48 h after activity and may last 2–14 days. We have recently demonstrated that recovery of muscle function following fatiguing exercise is substantially reduced in CFS patients [22] however, apart from this study little has been done to examine this phenomenon of post-exertional malaise in those with CFS.

Gait and balance parameters in those with CFS have not been extensively examined and the effect of exercise on these basic pre-requisites for ADL has never been systematically investigated. The aims of this study were therefore to objectively examine the gait and balance of subjects with CFS, and a suitable control group, and to evaluate changes in these parameters at various time intervals following a 15 min period of light exercise.

2. Methods

2.1. Subjects

Eleven subjects with CFS and 11 control subjects participated in the study (Table 1). All patients fulfilled the CDC criteria for CFS [5]. Age and sex matched control subjects were healthy but sedentary individuals who did not participate in any regular exercise and who were previously unfamiliar with the equipment or protocols used in the study.

All testing was undertaken with informed consent and with local Ethical Committee approval. Tests were performed in the Clinical Research Centre of the Southern General Hospital, NHS Trust, Glasgow.

2.2. Balance assessment

To measure postural sway, as a measure of balance, subjects stood on a Kistler Force Platform (Model 9281C, Kistler Instruments Ltd, England) with their feet together and arms comfortably by their sides. Each test lasted 25 s and was performed under conditions of eyes opened (EO) and eyes closed (EC). The output from the Kistler Force Platform was digitised using a CED 1401 Plus (Cambridge Electronic Design, England), at a sampling frequency of 50 Hz, and stored on an Elonex 486DX computer for off-line analysis.

Table 1

<table>
<thead>
<tr>
<th>Description of the subjects participating in the study</th>
<th>Chronic fatigue syndrome</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Female</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Mean age in years</strong></td>
<td>33.09 (± 7.20)</td>
<td>33.91 (± 7.27)</td>
</tr>
<tr>
<td><strong>Mean height in cm</strong></td>
<td>163.64 (± 7.38)</td>
<td>166.09 (± 8.23)</td>
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2.2.1. Dispersion X and dispersion Y
Dispersion X and Y describe the postural sway in the anteroposterior and mediolateral directions, respectively. The average positions of the centre of pressure in both the anteroposterior (Ax) and mediolateral (Ay) directions were calculated. The absolute difference between the average position of the centre of pressure and each data point was calculated and averaged over the 25 s duration of the test. Dispersion was calculated according to the following equation.

Dispersion X

\[ \frac{\sum_{i=1}^{n} \text{Absolute value of}(Ax(i) - \text{Average} \ Ax)}{n} \]

where: dispersion X is the total movement (in cm) of the subject’s centre of pressure in the anteroposterior direction; Ax(i) is the centre of pressure in the anteroposterior direction for each sample i = 1 to n; n is the number of samples.

A similar calculation was performed for Dispersion Y with respect to dispersion in the mediolateral direction.

2.2.2. Total dispersion
Total dispersion describes the overall postural sway during the test. The total dispersion value was calculated by combining the excursion from the average centre of pressure for each point. Therefore:

Dispersion =

\[ \frac{\sum_{i=1}^{n} \sqrt{(\text{Average} \ Ay - Ay(i))^2 + (\text{Average} \ Ax - Ax(i))^2}}{n} \]

where: dispersion is the total movement (in cm) of the subject’s centre of pressure; Ax(i) is the centre of pressure in the anteroposterior direction for each sample; Ay(i) is the centre of pressure in the mediolateral direction for each sample; n is the number of samples.

2.3. Gait analysis
Gait was analysed on the CalMat, a computer controlled, pressure sensitive, instrumented walkway which is 4.5 m in length [23]. The active section is 3 m long and consists of an array of 2.3 cm² pressure sensitive cells arranged along the length of the walkway. Contact from the subject’s foot or shoe activates these cells and produces data relating to the position and timing of foot contact. Subjects are not attached to any apparatus and thus their gait is not impeded in any way. Subjects walked along the walkmat three times at their own preferred walking speed. On completion of each test the data was verified to be complete and stored on the hard disc of a Dan PC486 for off-line analysis using custom written software. Parameters of step distance, step time, time of single and double support, velocity, relative velocity and cadence were recorded.

2.4. Exercise test
Following the initial assessment of balance and gait, as described, subjects underwent a Sub-Anaerobic Threshold Exercise Test (SATET) following the protocol described by Nashef and Lane and previously used with CFS patients [24]. Subjects pedalled a bicycle ergometer (Tunturi ECB Pro Ergometer 850E) for 15 min at 90% of their predicted work rate at their anaerobic threshold, based on sex, age and weight. A sub-anaerobic threshold test was chosen to more closely reflect the activities of daily living and to prevent the possibility of overly exacerbating symptoms in the CFS patients.

Just before the exercise test began and at 1 min intervals during the steady state test, the subject’s heart rate was recorded using a Polar heart rate monitor. At the same time intervals subjects were asked to rate their level of perceived exertion using the 15 point Borg scale [25].

Following the 15 min exercise period each subject’s balance and gait were reassessed as described above. Balance and gait assessments were repeated at 20 min intervals for the following hour with subjects resting, seated on a chair between tests.

All subjects returned to the Clinical Research Centre 24 h following the exercise period for a further assessment of balance and gait and to examine any longer effects of the previous day’s exercise.

2.5. Statistical analysis
For each of the ten gait parameters, a ‘mixed model’ was fitted, which included case-control status and time-point as fixed factors, case-control pair as a random factor, together with its interactions with the fixed factors, and (except for relative velocity) a single covariate, namely height. The statistical significance of case-control differences, differences between time points and the extent to which case-control effects depend on time points was assessed using Analysis of Variance (ANOVA), and specific comparisons were made using follow-up t-tests. The same structure of mixed model was used in the analysis of balance parameters (height was not included as a covariate).

ANOVA was also used to examine heart rate and the level of perceived exertion during the exercise test. Fixed effects were subject group and time point, and matched pairs were included as a random effect. Matched cases and controls were compared, using paired t-tests, on heart rate and level of perceived exertion on the Borg scale.
respectively). Finally there was no significant difference between time points for any of the three balance parameters \( P = 0.650, 0.561 \) and 0.419, respectively). The results therefore suggest that exercise had no significant effect on the postural sway of either CFS subjects or controls under eyes opened conditions.

Similarly under eyes closed conditions there was no statistically significant difference in Dispersion, averaged over time points, between CFS subjects and controls \( \text{Dispersion } X; P = 0.669, \text{Dispersion } Y; P = 0.399, \text{Total Dispersion; } P = 0.503 \). There were, however, statistically significant differences between time points for all three balance parameters \( p = 0.030, 0.033 \) and 0.012, respectively) but there was no evidence that this pattern was different for CFS subjects and controls, as demonstrated by a non-significant interaction effect \( P = 0.626, 0.686 \) and 0.533, respectively). Thus whilst exercise may have had some effect on postural stability with subjects’ eyes closed the effect was similar for both CFS subjects and controls.

### 3.2. Gait results

Table 2 shows a summary of the gait results for 11 CFS subjects and 11 matched controls. An ANOVA was performed on each of the gait parameters (with height included as a covariate for all parameters except relative velocity). The results of the ANOVA suggested that there was a statistically significant difference between the two groups, averaged over time, for all of the gait parameters measured, with the exception of single support on the left side and the time of double support. In clinical terms this means that CFS subjects walked with smaller steps and the time taken by CFS subjects for each step was more than that taken by control subjects. As a consequence velocity and relative velocity were reduced and cadence was increased in those with CFS.

ANOVA showed that, with one exception, there were no statistically significant differences between time points for any of the gait parameters after exercise. This would suggest that the period of exercise did not affect
Fig. 1. Dispersion for CFS patients (black bars) and control subjects (white bars) before, immediately after, and at various time points following the Sub-Anaerobic Threshold Exercise Tolerance test. (a) Dispersion in the anteroposterior (X) direction with eyes open; (b) Dispersion in the anteroposterior (X) direction with eyes closed; (c) Dispersion in the mediolateral (Y) direction with eyes open; (d) Dispersion in the mediolateral (Y) direction with eyes closed; (e) Total dispersion with eyes open; (f) Total Dispersion with eyes closed. All values are mean ± standard error, n = 10 in each group.
the gait pattern of either the CFS or control group. The exception was single support time on the right where there was a statistically significant interaction between CFS/control and time point \( (P = 0.044) \). However, the CFS/control differences did not follow any obvious pattern with time elapsed following exercise. There is no apparent explanation for this isolated effect and it may be due to chance given the marginal \( P \)-value.

3.3. Heart rate and ratings of perceived exertion (RPE) scores during exercise

All CFS and control subjects were able to complete the exercise protocol. Fig. 2 shows the mean heart rate and Fig. 3 the mean RPE scores taken during each minute of the exercise period. Both responses were analysed using ANOVA where fixed effects were subject group (CFS or control) and time point, and matched pairs were included as a random effect. The heart rate response of both the CFS and control group were similar (Fig. 2) and this was confirmed by ANOVA. The increasing trend in heart rate was statistically significant \( (P < 0.001) \) but the difference between subject groups, averaged over time, was not \( (P = 0.230) \). In addition the interaction between time point and subject group was not statistically significant \( (P = 0.789) \).

The mean RPE scores, however, were very different in the two groups (Fig. 3) and ANOVA demonstrated that there was a statistically significant difference between the two groups averaged over time points \( (P < 0.001) \). The difference between the CFS and control groups in the slope of the trend lines was also statistically significant \( (P < 0.001) \). Therefore, although the physiological response to exercise appeared similar in both groups, as demonstrated by the heart rate response, the CFS group perceived the workload to be significantly greater.

4. Discussion

The results of the present study demonstrate that there was no significant difference in postural stability between CFS and control subjects as evidenced by differences in dispersion under eyes open and eyes closed conditions (Fig. 1), and thus do not support the suggestion that patients with CFS display some degree of dysequilibrium [2,9]. Whilst exercise does affect postural stability to a significant extent, it does so for both patients and controls and there is no significant difference in the degree of impairment observed between the two groups. Some studies have previously demonstrated balance problems in patients with CFS [10,11] however, these abnormalities were non-specific and were observed mainly in subjects who presented with pre-existing balance problems. The present results suggest that balance abnormalities, either at rest or after exercise.
exercise, are not a feature of the general population of CFS patients. It has been reported that postural sway, measured in a stance position on a fixed force plate, may be normal in the presence of many postural defects [26] and it may be that the static balance tests employed in the current study are not sensitive enough to detect subtle balance abnormalities which may exist in these subjects. It is hoped, in future research, to employ more dynamic balance tests in order to observe if these reveal more minor postural deficits which may exist.

The results of the gait analysis show that CFS patients demonstrate significant differences in many gait parameters compared to control subjects (Table 2). These differences are seen pre- and post-exercise, although exercise does not exacerbate the effects in the CFS patients. Only two of the measured gait parameters — single support time on the left and double support time — were not significantly different between the CFS and control groups. These observations would support the clinical impression that CFS subjects walk more slowly and with smaller steps compared to normal control subjects, and are consistent with slower movements and reaction times observed in CFS patients [27]. Data relating to step width was also collected but, because of the technical specification of the walkway, this parameter was deemed to have too much associated measurement error and thus this data was not formally analysed.

The results of the present study contrast with those of Boda et al. [13] which did not demonstrate any significant difference in walking times between CFS patients and controls. However, the Calmat computerised walkway used in the present study may allow for more accurate timings of gait parameters than in previous studies. The smaller step length observed in the current study is consistent with the findings of Boda et al. [13], who demonstrated that the degree of hip and knee movement was less in subjects with CFS, and suggested that this may be an attempt to improve overall stability during the gait cycle. Saggini et al. [16] reported no difference in gait parameters between CFS patients and controls before exercise but did demonstrate some spatial and temporal abnormalities following exercise. However, the lack of a sedentary control group precludes any useful comparison with the present study. This is considered to be a vital requirement in selecting control subjects for studies involving CFS patients due to the deconditioning effect of the disorder [17]. The present study did use sedentary controls and the results would therefore suggest that CFS patients, similar to controls, do not have any significant alterations in gait after exercise.

Gait changes may occur in CFS subjects as a result of balance problems, peripheral neuromuscular dysfunction or abnormalities in the higher central nervous system, acting either individually or in combination...
The results of the current study suggest that balance problems may not be a contributory factor to gait abnormalities since double support time in the CFS subjects was not significantly different from controls (although the differences did approach significance), and static balance was not significantly affected in CFS patients. We have previously demonstrated that there is reduced voluntary muscle force in the quadriceps muscle in CFS patients [22], which may contribute to observed initial reductions in step length, cadence and velocity in these patients. Fifteen minutes of sub-anaerobic exercise did not exacerbate the abnormal gait parameters in the present study however, and therefore does not support the anecdotal evidence that symptoms of CFS, as evidenced by gait changes, are affected by a period of sub-maximal exercise. This suggests that CFS patients may be able to participate in light, sub-anaerobic exercise protocols without detrimental effects on their gait or balance. This observation may therefore be useful for health-care professionals wishing to educate CFS patients on an appropriate level of exercise to reduce the possible effects of deconditioning without leading to worsening of symptoms [28].

The heart rate responses to exercise show that both the CFS patients and the control subjects were exercising at similar physiological workload, since the steady state heart rate achieved after 3 or so minutes was not significantly different between the two groups, being approximately 125–130 beats per min (Fig. 2). This heart rate also confirms that subjects were exercising at a fairly light intensity, well below anaerobic threshold. It may be that exercising at a higher intensity would have produced more demonstrable effects on the gait abnormalities observed post-exercise.

Despite the fact that the CFS patients were exercising at a clearly sub-maximal level, which was not significantly different from the control subjects, the patients reported a significantly greater perception of effort, reflected in a mean RPE rating of 16 towards the end of the exercise period compared to a mean rating of about 10 for the control group (Fig. 3). This rating for the control group more accurately reflects the actual physiological load undertaken by the subject. However, the patient group obviously perceives this workload to be much higher than it actually is. The RPE rating suggests that the patients were working at close to maximal levels, whilst the heart rate data demonstrates that they were well below this level. This may be due to an increased sense of effort [19,29] possibly linked to alterations in 5-hydroxytryptamine (5HT) levels in the brain [30] and increased sensitivity of the 5HT receptors [31], or to a degree of hyperalgesia within the muscles themselves [32]. Since ratings of perceived exertion are often used in many areas of rehabilitation to allow patients to monitor their workload, the results of the present study would suggest that this is inappropriate in CFS patients.

5. Conclusion

In conclusion, the results presented here would suggest that balance problems are not a consistent feature in CFS patients. However, more dynamic assessments of this patient group are required. CFS patients do tend to walk with an altered gait pattern compared to normal controls and this concurs with the general notion that these patients have slower movements than normal. This finding would suggest that gait analysis may be a useful outcome measure with which to monitor the progress of the disease or to determine the effectiveness of treatment interventions, therapeutic or pharmacological. Patients with CFS perceive the exercise load to be considerably higher than the actual physiological load thus the use of the RPE scale would not be a valid method of monitoring exercise intensity in this group.

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References


