Energy Cost and Cardiorespiratory Adaptation in the “Get-Up-and-Go” Test in Frail Elderly Women With Postural Abnormalities and in Controls

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Background. This study investigated the hypothesis that postural abnormalities might increase energy expenditure during a clinical functional test in frail elderly persons.

Methods. Two groups of hospitalized women (aged 73 to 100 years) were recruited. Women who showed postural and gait abnormalities as described in the psychomotor disadaptation syndrome (PDS) were compared with control participants. The authors measured energy expenditure during the timed “up and go” test. For each participant, oxygen uptake, carbon dioxide output, expiratory minute ventilation, breathing frequency, heart rate, and alveolar ventilation were recorded 10 minutes before, during, and 10 minutes after exercise. The arterial pressure of carbon dioxide was estimated from expired gases.

Results. The mean oxygen uptake values were significantly higher in women with PDS than in the control group during exercise and recovery periods (4.89 ± 1.68 vs 3.75 ± 1.25 ml·kg⁻¹·min⁻¹ and 4.69 ± 1.45 vs 3.76 ± 0.97 ml·kg⁻¹·min⁻¹, respectively [\(p < .05\)]. Expiratory minute ventilation was always higher in women with PDS than in controls regardless of the period of the test (\(p < .05\)), and alveolar ventilation was higher in women with PDS only during the exercise period (\(p < .05\)). The estimated arterial pressure of carbon dioxide did not change significantly between the different phases of the test but was always lower (\(p < .05\)) in women with PDS compared with the control group.

Conclusions. The significant increase in oxygen uptake during the exercise and recovery periods in women with PDS compared with controls suggests that postural abnormalities that characterize PDS may be associated with an increase in energy expenditure. In clinical practice, the low capacity to tolerate even moderate exercise must be considered when specific rehabilitation programs are offered to women with PDS.

The combination of aging and many diseases may lead to a vulnerable state that has been called “frailty” (1). Frailty has been characterized mainly by severely impaired muscle strength, mobility, balance, and endurance (2). The alteration of these features indicates the onset of frailty (1).

In some frail elderly persons, postural and gait abnormalities are the main clinical indications of their condition. The study of these components prompted us to describe a clinical condition called “psychomotor disadaptation syndrome” (PDS), which is the French equivalent of frontal-subcortical dysfunction (3,4). This clinical picture associates original postural impairment and gait abnormalities (5,6). Postural impairment is characterized by a tendency to backward disequilibrium and loss of reactive and protective postural reactions. Gait abnormalities are similar to those described in “senile gait” or “cautious gait,” the walking disorder consisting of a shortened stride, a tendency to shuffle, and a slowing of walking speed (6). In some cases, fear of falling is associated with these signs. Furthermore, motor dysfunction such as difficulties in rolling to the side in bed or standing up from a chair are usually observed and suggest serious functional disability.

Besides postural and motor alteration, Campbell and Buchner (7) have described the decrease in aerobic capacity as a key component of frailty. Aerobic capacity is usually assessed by measurement of maximum oxygen uptake (VO₂ max), which is difficult to accomplish in frail subjects. To our knowledge, data showing associations between aerobic capacity, functional status, and motor performance in older persons are scarce. We hypothesize that two cumulative factors often increase dependency in frail persons: (a) a diminished reserve in aerobic capacity and (b) increased energy cost of activities of daily life after a change in motor performance.

The aim of this study was to determine the impact of postural abnormalities on energy expenditure during a clinical functional test in a frail elderly population.

Methods

Participants

We recruited participants between September 2000 and December 2001 from the Geriatrics Department of the University Hospital of Dijon, Dijon, France. The Dijon Regional Ethics Committee approved the study.

The study included two groups. A PDS group consisted of 24 hospitalized women who were 75 years or older and showed postural and gait abnormalities according to the
clinical description of PDS previously published (5,6). Inclusion criteria included: (a) a tendency to backward falling (retropulsion) during the transfer from sitting to standing and in the standing position, (b) a gait pattern change to short shuffling steps, and (c) an increase in the duration of double support.

The control group consisted of 24 hospitalized frail women without postural abnormalities who were matched with the PDS patients by age, body mass index, and serum albumin level.

Exclusion criteria for both groups included: (a) acute cardiorespiratory state, (b) dementia and Parkinson’s disease, (c) nervous system deficits or osteoarticular diseases that could modify walking abilities, and (d) hormonal or inflammatory diseases likely to interfere with energy expenditure measurements.

The order of passage of controls and PDS patients was randomized, and each participant’s status was unknown to the experimenter.

**General Procedure**

Energy expenditure was measured during a short test of basic mobility skills used specifically in frail elderly persons: the timed “up and go” test (TUG) (8,9).

Measurements were made at normal room temperature between 2:00 PM and 4:00 PM, ensuring a delay from the meal, which was served at 11:30 AM.

For each participant, VO2, carbon dioxide output (VCO2), expiratory minute ventilation (VE), breathing frequency (fR), heart rate (HR), and tidal volume (Vt) were measured 10 minutes before, during, and 10 minutes after exercise. For these measurements, a bucco-nasal mask allowing the collection of expired gases was used. The gases were analyzed in real time and on each respiratory cycle using a bidirectional differential pressure preVent pneumotach (MedGraphics Corp, St. Paul, MN) coupled with an oxygen analyzer with zirconia cell and a fast CO2 infrared analyzer (CPX-D System; MedGraphics Corp). After data collection, the respiratory quotient (R), ventilatory equivalents for oxygen (VE/VO2) and CO2 (VE/VCO2), alveolar ventilation (VA), and oxygen pulses (VO2/HR) were calculated. The arterial pressure of CO2 was estimated (PaCO2est) from the PEND TIDAL CO2 value, as indicated by Jones and colleagues. (10). Physiologic dead space was determined as a percentage of tidal volume (Vt/Vt,est) [(PaCO2est – PECO2) × Vt/PaCO2est × (Vt – valve dead space)].

### Table 1. General Characteristics of Patients Showing PDS Compared to Control Subjects Without PDS

<table>
<thead>
<tr>
<th></th>
<th>PDS Group (N = 24)</th>
<th>Control Group (N = 24)</th>
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</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>86.2 ± 7.5</td>
<td>83.9 ± 6.1</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>53.5 ± 11.6</td>
<td>55.3 ± 10.9</td>
</tr>
<tr>
<td>Height, cm</td>
<td>150 ± 5</td>
<td>151 ± 7</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>23.7 ± 5.5</td>
<td>24.1 ± 4.0</td>
</tr>
<tr>
<td>Serum albumin, g/L</td>
<td>31.7 ± 4.8</td>
<td>32.7 ± 4.3</td>
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Notes: PDS group = patients showing Psychomotor Disadaptation Syndrome; BMI = body mass index.

Statistical Analysis

The statistical method took into account the data through four periods: initial rest (2 minutes preceding the exercise); exercise (time between rising from the armchair and returning to the sitting position); recovery (period between the end of the exercise and returning to pre-exercise VO2 values, determined graphically for each participant); and final rest (the end of the recording; i.e., 10 minutes after the end of the walk). Values are reported as the mean ± SD.

We studied differences between groups in general characteristics using the Fisher exact test for categorical data and the Mann–Whitney test for quantitative data.

For each respiratory parameter, we evaluated the area under the signal versus time curve within each period using the trapezoidal rule, and then we divided these areas by the corresponding duration to give average values of the signal. We studied the variations of this average using one-way (for the two groups) analysis of variance for a repeated measurement (the four periods).

### Results

Table 1 shows the general characteristics of the PDS and control groups. Age ranged from 73 to 100 years for women with PDS and from 73 to 93 years for control participants. We observed no significant difference for anthropometric parameters or for the serum level of albumin between the two groups.

Women with PDS performed the TUG test significantly more slowly than did the control participants, with exercise sessions lasting 68 ± 27 seconds versus 41 ± 12 seconds, respectively (p < .05).

Figure 1 shows the evolution of oxygen uptake in the two groups during the test. The mean VO2 values varied significantly (p < .05) during the test (initial rest, exercise, recovery, and final rest), with higher values in women with PDS compared with controls, even when this difference varied for different periods (significant interaction between groups and testing period, p < .05). Further analysis (confidence intervals) showed that mean VO2 values were significantly higher in women with PDS (p < .05) only during exercise and recovery periods (Table 2).

Because the duration of exercise and the VO2 values were higher in women with PDS than in control participants, we evaluated total oxygen consumption and found it to be greater in women with PDS than in controls (7.07 ± 4.14 ml/kg vs 3.44 ± 1.63 ml/kg; p < .05). Total oxygen uptake was also greater in women with PDS than in the controls during the recovery period (20.10 ± 7.88 ml/kg vs 12.41 ± 4.66 ml/kg; p < .05), with periods lasting 4.8 ± 1.5 minutes in PDS compared with 3.9 ± 1.4 minutes in controls (p < .05).
For the control participants, changes in VO2 values were regular throughout the different periods of the test. However, the VO2 values for most women with PDS showed a sawtooth pattern (Figure 2).

During the two TUG testing sessions, the duration values obtained in controls were (a) at normal walking pace: exercise duration, 34 ± 5 seconds; recovery duration, 4.2 ± 1.3 minutes; (b) at slow walking speed: exercise duration, 60 ± 10 seconds; recovery duration, 4.9 ± 0.8 minutes. The difference between paces was significant (p < .05).

Whatever the period of the test, we found no significant difference in VO2 values for both groups, pulmonary parameters (VE, fR, and VT) and VA showed similar variations to VO2 through the TUG test (Table 3). However, VE was always higher (p < .05) in women with PDS than in controls during the exercise period. We found no significant difference between the two groups in VT during the same period. We noted no significant change in PaCO2est between the different phases of the test, but it was always lower (p < .05) in the women with PDS than in the control group (Table 3). We observed no significant difference between PDS and control participants for VE/VO2, VE/VCO2, and VT/VTrest, which decreased during the exercise and the recovery periods before reverting to initial values (Table 3). Regression lines in each group for VE/VO2 from the rest, exercise, and recovery periods were very similar for slopes but not for origins (Figure 3).

Variations of HR during the TUG test were similar in the two groups (Table 3): HR increased during exercise and remained at higher values during recovery than at rest.

Table 2. Oxygen Uptake (mL · kg⁻¹ · min⁻¹) of Patients Showing PDS Compared to That of Control Subjects Without PDS During the TUG Test

<table>
<thead>
<tr>
<th>Period of the Test</th>
<th>PDS Group (N = 24)</th>
<th>Control Group (N = 24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial rest</td>
<td>3.19 ± 0.97</td>
<td>2.77 ± 0.66</td>
</tr>
<tr>
<td>Exercise</td>
<td>4.89 ± 1.68</td>
<td>3.75 ± 1.25*</td>
</tr>
<tr>
<td>Recovery</td>
<td>4.69 ± 1.45</td>
<td>3.76 ± 0.97*</td>
</tr>
<tr>
<td>Final rest</td>
<td>3.18 ± 1.04</td>
<td>2.69 ± 0.71</td>
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Notes: Values are means ± standard deviation. For details about periods (initial rest, exercise, recovery, and final rest), see “Methods” section. PDS = Psychomotor Disadaptation Syndrome; TUG = Timed Up and Go.

*p < .05 according to two-way repeated measures analysis of variance then Kolmogorov–Smirnov test.

For the control participants, changes in VO2 values were regular throughout the different periods of the test. However, the VO2 values for most women with PDS showed a sawtooth pattern (Figure 2).

During the two TUG testing sessions, the duration values obtained in controls were (a) at normal walking pace: exercise duration, 34 ± 5 seconds; recovery duration, 4.2 ± 1.3 minutes; (b) at slow walking speed: exercise duration, 60 ± 10 seconds; recovery duration, 4.9 ± 0.8 minutes. The difference between paces was significant (p < .05).

Whatever the period of the test, we found no significant difference in VO2 according to gait velocity (initial rest, 3.08 ± 0.74 vs 2.94 ± 0.61 mL · kg⁻¹ · min⁻¹; exercise 4.27 ± 1.01 vs 4.16 ± 1.12 mL · kg⁻¹ · min⁻¹; recovery, 3.92 ± 0.87 vs 4.06 ± 0.82 mL · kg⁻¹ · min⁻¹; final rest, 2.89 ± 0.61 vs 2.77 ± 0.61 mL · kg⁻¹ · min⁻¹).

The comparison of respiratory parameters between the PDS and control groups gave the following results. For both groups, pulmonary parameters (VE, fR, and VT) and VA showed similar variations to VO2 through the TUG test (Table 3). However, VE was always higher (p < .05) in women with PDS than in controls, regardless of the period of the test, in contrast to fR and VA, which were higher (p < .05) in women with PDS only during the exercise period. We found no significant difference between the two groups in VT during the same period. We noted no significant change in PaCO2est between the different phases of the test, but it was always lower (p < .05) in the women with PDS than in the control group (Table 3). We observed no significant difference between PDS and control participants for VE/VO2, VE/VCO2, and VT/VTrest, which decreased during the exercise and the recovery periods before reverting to initial values (Table 3). Regression lines in each group for VE/VO2 from the rest, exercise, and recovery periods were very similar for slopes but not for origins (Figure 3).

Variations of HR during the TUG test were similar in the two groups (Table 3): HR increased during exercise and remained at higher values during recovery than at rest.
Although HR increased more in the women with PDS than in the controls during these periods, there was no significant difference between the two groups. We also noted an increase in VO$_2$/HR during exercise and even more so during the phase of recovery for all participants, particularly the women with PDS (Table 3), but this difference was not significant. The respiratory quotient (R), steady throughout the test, was similar for both groups (Table 3).

In the 12 control participants who performed the TUG test twice, we observed no significant difference according to the speed of walking for all the parameters (VE, $f_b$, $V_T$, VA, PaCO$_{2est}$, VE/VO$_2$, VE/VCO$_2$, VD/VT est, HR, VO$_2$/HR, and R).

**DISCUSSION**

The primary finding of this study consists of greater oxygen consumption in women with PDS compared with controls during both exercise and recovery. We address the limitations of the study first.

**Study Limitations**

All the participants were hospitalized in a geriatric acute care unit and therefore could be labeled “elderly frail patients.” Compared with data in the literature (9,11), the duration of the TUG test was much longer in all of our study participants, regardless of their group. This feature emphasizes the frailty of the studied population. Because the sex ratio in a very old population shows a great predominance of women, we chose to include only women to obtain the best homogeneity of the data. In this study, to measure energy in frail elderly persons, we selected a simple test that was based on activities of daily life, which are usually characterized by a low energy cost (11).

We could not calculate the work cost because it is necessary to know the respiratory quotient (R) of the stable state to calculate the calorific equivalent of oxygen, and the participant must be stable for R to be representative of the metabolic state (12). Nevertheless, we can conclude that the increase in VO$_2$ during exercise is really the expression of metabolic state (12). Nevertheless, we can conclude that the increase in VO$_2$ during exercise is really the expression of metabolic state (12). Nevertheless, we can conclude that the increase in VO$_2$ during exercise is really the expression of metabolic state (12).

Walking speed is another factor that could influence the results, but in our study no parameter showed any significant difference regarding walking speed.

Because ethical considerations did not allow us to use an invasive method, we did not dispose of exact values for both PaCO$_2$ and the alveoloarterial difference in CO$_2$ [D(a – A)CO$_2$]. We could consider that our values for PaCO$_2$ were slightly underestimated and, consequently, VA and VD/VT est were overestimated (13,14).

**Analysis of Results**

One major result of our observation was significantly higher values for VO$_2$ in women with PDS compared with control participants: 106% during the exercise period and 62% during the recovery period. In contrast, we found no difference in VO$_2$ between groups during the initial and final rest periods.

The VO$_2$ values at rest correspond with data previously reported in the literature (13,15,16). During exercise, VO$_2$ increased as expected, and this increase corresponds to VO$_2$...
increases observed by others. For example, mean VO₂ measured in our control participants during the TUG test (6 meters of walking) corresponds to a mean VO₂ consumption of healthy elderly persons walking 8.7 m/min (17). In the same way, if we consider VO₂ consumption of the women with PDS, we can extrapolate that, with the same consumption value, the walking speed of healthy persons would be 17 m/min.

Perhaps the increase in VO₂ in the PDS group could be a result of hyperventilation observed in these women. This hyperventilation, which was observed regardless of the testing period, was associated with a proportionally higher increase in fR than in V̇E. High-intensity exercise is usually associated with such increases in healthy elderly persons (18). Nevertheless, our data show that hyperventilation cannot explain by itself the increase in VO₂ during exercise: after comparison at rest in the two groups, the estimation of the oxygen cost of pulmonary ventilation is 8.9 ml of oxygen per liter of VE. To our knowledge, the oxygen cost of breathing during exercise has not been studied in very old persons. However, this value is close to values observed in several conditions, such as chronic obstructive pulmonary disease (19,20), cardiorespiratory diseases (21), and respiratory impairment secondary to emphysema, scoliosis, or thoracoplasty (22). If we consider the estimation of the oxygen cost of ventilation (8.9 ml/l), the expected value linked to ventilation alone in the PDS group during exercise would be 30.3 ml/min. But, in fact, our data show a difference of 90.9 ml/min between VO₂ values at rest and during exercise in women with PDS. Finally, regression lines in Figure 3 strengthen the idea of a real link between VO₂ and effort cost. However, we found no link with regard to ventilatory cost.

Our data showed a high heart rate in both groups during exercise. If we compare our findings with data published in the literature for healthy older persons, our values correspond to 65% and 70% of maximum cardiac frequency in control and PDS groups, respectively (23–25). This result corresponds with high energy cost exercise during the TUG test in persons with PDS in particular.

Finally, the values of oxygen pulse (VO₂/HR) that we observed in our population, regardless of the group, were lower than those observed in younger persons. Such a decrease in oxygen pulse with increasing age in both active and sedentary men has previously been reported (26). A low oxygen pulse has been reported as indirect evidence of cardiac abnormalities or a low arteriovenous oxygen difference (23,27), which would be expected in our frail population.

General Discussion

To explain the increase in VO₂ consumption in women with PDS, we suggest two hypotheses. First, a neurovegetative dysregulation may be considered given the VO₂ variability we observed in some of the women with PDS. This variability was recorded at rest and during exercise and recovery, in contrast to controls, and appears to be independent of oxygen consumption linked to exercise (Figure 2). Inactivity and aging affect both the autonomic nervous system and the target organs (28), and several neurologic diseases are associated with autonomic disorders. We can hypothesize that the alteration of autonomic function can be found in our participants with PDS who showed frontal-subcortical dysfunction.

Second, the increase in peripheral oxygen consumption in women with PDS may be linked to postural and motor impairment. In this way, we believe that poor postural control and coordination oblige compensatory muscular processes, which are used to avoid disequilibrium and falls. These processes create an increase in energy expenditure.

This increase in energy expenditure may have a dramatic impact on functional capacities because these frail and dependent patients show loss of functional reserves compounded by physical inactivity.

In clinical practice, this increase in energy expenditure in women with PDS may be associated with the inability to tolerate even moderate exercise. Rehabilitation programs should account for this feature to improve motor abilities and to reduce cardiovascular risk. These patients must have access to rehabilitation programs, but the duration and intensity of the exercises must be rigorously controlled (29). Conversely, these programs must integrate specific balance training to improve postural abilities and so decrease energy expenditure. Further studies are needed to demonstrate the benefit of postural rehabilitation on energy cost.

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