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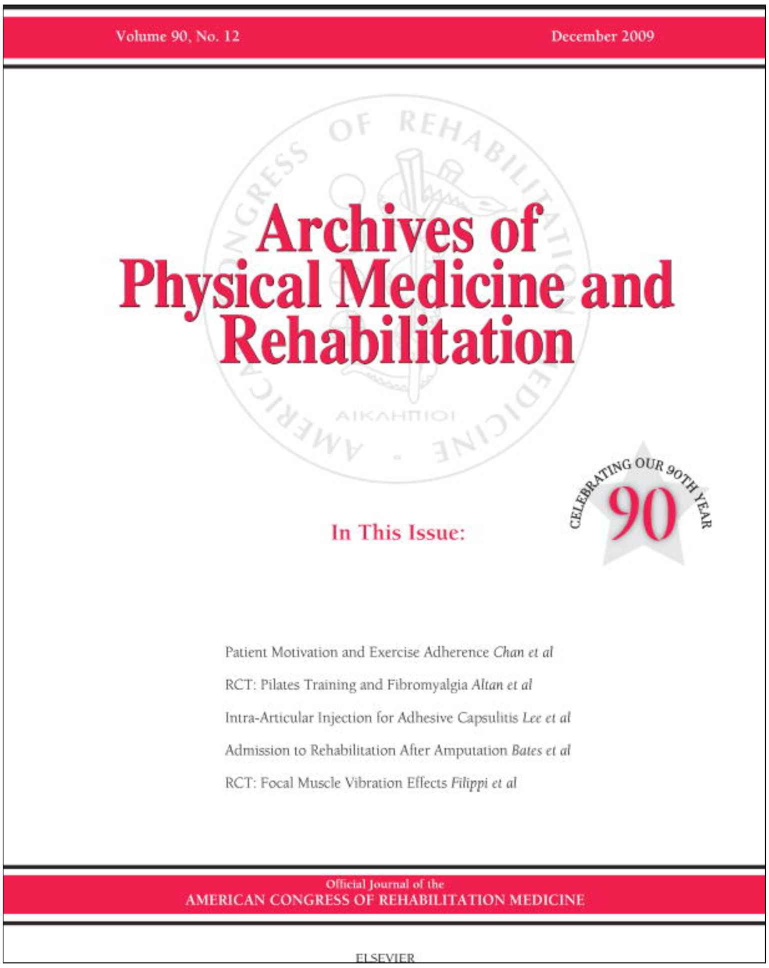


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ORIGINAL ARTICLE

# Physical Performance as a Predictor of Attention and Processing Speed in Fibromyalgia

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ABSTRACT. Cherry BJ, Weiss J, Barakat BK, Rutledge DN, Jones CJ. Physical performance as a predictor of attention and processing speed in fibromyalgia. Arch Phys Med Rehabil 2009;90:2066-73.

**Objective:** To explore the associations between physical (both self-report and objective measures) and cognitive function for persons with fibromyalgia (FM).

**Design:** Correlational study.

**Setting:** An exercise testing laboratory in southern California.

**Participants:** Community-residing and functionally independent (not wheelchair-bound) adults meeting the American College of Rheumatology 1990 criteria for FM (N=51) with a mean age of 54 years and no history of stroke.

**Interventions:** Not applicable.

**Main Outcome Measures:** Composite Physical Function Scale, Fibromyalgia Impact Questionnaire, adapted Trail Making Test parts A (TMT-A) and B (TMT-B), Digit Symbol Substitution Test, a composite index of TMT-A, TMT-B, and Digit Symbol Substitution Test combined, and physical performance assessments.

**Results:** Hierarchical regression analyses indicated that better objective physical performance predicted increased cognitive function for TMT-A and the composite cognitive score after controlling for age and symptom burden. That is, as the physical performance level decreased, cognitive performance levels decreased.

**Conclusions:** Findings suggest that research is needed to determine whether patterns of physical activity participation, through their effects on physical fitness and performance, can enhance cognitive performance in persons with FM. Physiologic changes in specific brain regions in FM (eg, hippocampus, neural pain regions) suggest that further research is also warranted in determining specific relationships between biomarkers and cognitive performance in persons with FM.

**Key Words:** Attention; Fibromyalgia; Physical fitness; Physiology; Rehabilitation.

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FIBROMYALGIA IS A CHRONIC widespread pain syndrome, often accompanied by overlapping conditions such as chronic fatigue syndrome, myofascial regional pain, restless leg syndrome, multiple chemical sensitivities, and visceral organ problems.[1] Common symptoms include sleep disturbance, fatigue, stiffness, exercise intolerance, cognitive problems, and mood disorders.[2] Many persons with FM report reduced physical abilities, increased functional impairments that impact ADLs and IADLs, and increased incidence of disabilities,[3-5] consequences that, in turn, can lead to a decreased quality of life.[3-5]

Several studies have documented cognitive impairments in persons with FM.[6-10] In fact, persons with widespread pain (such as those with FM) have significantly more concentration and memory difficulties than patients with clearly localized pain.[11,12] People with diagnosed FM report declines in cognitive function and mental alertness, along with a reduced ability to process information, trouble remembering things, and a decreased capacity for accomplishing demanding cognitive tasks.[7,13] Katz et al,[7] for example, documented cognitive complaints such as mental confusion, memory declines, and speech difficulties in individuals with rheumatic disease, both with and without FM, and found that 82% of those with FM reported these symptoms compared with 30% without FM. In addition, a recent review of both objective and subjective assessments of cognitive dysfunction in FM suggests a fairly strong correlation between objective and self-report measures.[6,13] Moreover, many people with FM state that cognitive symptoms are more disturbing and disabling than pain.[7,13,14] Although such complaints are common among patients with FM, only a few studies have adopted an objective approach to examine the nature of the cognitive deficits. Studies that have used objective cognitive measures report that patients with FM may show deficits in attention, concentration, speed of processing, episodic memory, verbal fluency, and/or working memory.[6,8,15-18] Some of the challenges inherent to this area of research are small sample sizes and large numbers of variables (due to the many symptoms of FM), and/or the insensitivity of measures, with studies comparing individuals with FM with control participants ranging from approximately 20 to 30 per group.[6,8,15-18] Several studies have reported significant differences between groups for attention or working memory, or for both,[6,15,18] whereas another found no such differences.[18] Results for processing speed are also mixed, with some studies showing no differences between FM groups and controls,[6,8] and another showing

**List of Abbreviations**

| | |
|---|---|
| ADLs | activities of daily living |
| BDI | Beck Depression Inventory |
| CCS | composite cognitive score |
| DSST | Digit Symbol Substitution Test |
| FIQ | Fibromyalgia Impact Questionnaire |
| FM | fibromyalgia |
| IADLs | instrumental activities of daily living |
| PPMs | physical performance measures |
| TMT-A | Trail Making Test part A |
| TMT-B | Trail Making Test part B |

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significant differences.[18] Despite some of these inconsistencies, FM impairments in mental processes have been likened to the cognitive changes seen in normal aging.[8,16] Because cognitive and physical decline can each individually potentially lead to disability, understanding the interrelationship of these variables is a critical step in finding ways to delay the onset of functional dependence and the potential cascade of health problems with this high-risk population. As a potential model, recent research on aging suggests a strong association between physical performance levels and cognitive functioning (especially for domains such as attention and processing speed), with a particular focus on how exercise and physical fitness can promote both successful cognitive aging and neuroplasticity.[19-22]

The present study focused on objective measures of attention and processing speed with an adapted version of the TMT-A and TMT-B,[23,24] and the DSST from the Wechsler Adult Intelligence Scales,[25] cognitive measures that have been used across a variety of studies and clinical populations and are markers for complex attention, executive function, cognitive flexibility, and psychomotor speed. These particular measures were selected because of their association with chronic pain, ADLs and IADLs, cognitive aging (especially studies linking cognitive ability to physical activity levels), and risk for falls.[15-22,26-27] To measure self-reported physical ability/disability, both the FIQ, which has 11 items measuring physical function "purposely biased to the use of large muscle groups rather than fine hand movements,"[28(S154)] and the Composite Physical Function Scale were administered. Finally, because self-report measures may not be as sensitive as actual performance (objective) measures, physical performance was also assessed with tests that measured body strength and flexibility, dynamic balance, and overall functional mobility.

The primary goal of this study was to determine whether physical function would be associated with attention and processing speed in persons with FM. That is, do physical measures predict these cognitive domains in individuals with FM after controlling for age and symptoms typically associated with FM (eg, fatigue, pain, depression, anxiety)? The second goal was to determine whether actual PPMs were a better predictor of attention and processing speed than perceived physical function.

## METHODS

### Participants

Participants were recruited from an advertisement sent to local FM support groups, an online invitation from the National Fibromyalgia Association, and a "research interest list" from our Fibromyalgia Research and Education Center. To be included, participants had to be at least 18 years of age, be community-residing and functionally independent (not wheelchair bound), and with a signed document from a licensed physician as having met the American College of Rheumatology 1990 criteria for FM.[29] Criteria for exclusion were any neurologic or medical conditions that would contraindicate submaximal testing according to American College of Sports Medicine guidelines.[30] Medical clearance to participate was necessary if any one of the following applied: (1) participant's physician has advised not to exercise because of medical condition(s); (2) participant has had congestive heart failure; (3) participant currently has severe joint pain, chest pain, dizziness, or exertional angina; or (4) participant has uncontrolled high blood pressure (160/100mmHg or above). All participants read and signed an informed consent that was approved by the Institutional Review Board at California State University, Fullerton.

### Measures

***Demographic variables.*** A Health/Activity Questionnaire (shortened version of a validated questionnaire used for a national fibromyalgia survey[2]) was used to obtain both demographic and FM symptom information. A series of demographic and descriptive questions consisting of age, sex, ethnicity, medical history, and medications were asked. Participants' characteristics are presented in table 1.

***Fibromyalgia symptoms.*** Numeric rating scales included in the Health/Activity Questionnaire were taken from the National Fibromyalgia Association Questionnaire[2] to evaluate 19 symptoms (eg, pain, fatigue) in terms of intensity (items with endpoints of 0 = least, to 10 = most). Internal consistency of responses to the symptom battery, as shown by Cronbach alpha, was moderately high at .88. Test-retest of individual items (intraclass correlation coefficients) indicates moderate to high stability (.53–.94).[31]

***Perceived physical function.*** Two questionnaires were used to measure perceived physical function. The FIQ[32] was administered as a partial index of perceived physical function because it is frequently used in the FM literature. For the FIQ, higher scores indicate a greater impact of FM on the person.

**Table 1: Sample Demographics (N=51)**

| Variables | Values |
|---|---|
| Age (y) | 54±13.1 (27–80) |
| 27–39 | 7 (13.7) |
| 40–59 | 27 (52.9) |
| 60–80 | 17 (33.3) |
| Sex | |
| Male | 5 (9.8) |
| Female | 46 (90.2) |
| Education | |
| <High school | 1 (2.0) |
| High school | 8 (15.7) |
| Some college*/professional training | 19 (37.3) |
| Baccalaureate | 13 (25.5) |
| Graduate degree | 10 (19.6) |
| Ethnicity | |
| White | 33 (64.7) |
| Not specified | 7 (13.7) |
| Hispanic/Mexican/Latino | 6 (11.8) |
| Black | 3 (5.9) |
| Asian/Pacific Islander | 1 (2.0) |
| Native American/Indian | 1 (2.0) |
| Comorbidities | |
| Other health problems | 32 (62.7) |
| Hypertension | 17 (33.3) |
| Other arthritis (nonrheumatoid) | 17 (33.3) |
| Neuropathies | 13 (25.5) |
| Osteoporosis | 8 (15.7) |
| Other neurologic condition | 7 (13.7) |
| Diabetes | 6 (11.8) |
| Respiratory disease | 6 (11.8) |
| Cancer | 5 (9.8) |
| Rheumatoid arthritis | 4 (7.8) |
| Angina/chest pain | 2 (3.9) |
| Epilepsy/seizure disorder | 2 (3.9) |
| Joint replacement | 2 (3.9) |
| Heart attack | 1 (2.0) |
| Transient ischemic attack | 1 (2.0) |

NOTE. Values are mean ± SD (range) or n (%).
*College not completed.

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While the FIQ captures the total spectrum of problems related to FM,[28] it does not evaluate a wide range of tasks related to physical function. An adapted version of the 12-item Composite Physical Function Scale[33] was also used to specifically measure functional limitations[2]: measures of ADLs, IADLs, and advanced activities (eg, strenuous, more vigorous sports/exercise activities). The adapted Composite Physical Function Scale discriminates across a wider range of functional abilities than the FIQ, with 5 rather than 4 response categories (0, cannot do at all; 1, cannot do without help; 2, can do with a lot of difficulty; 3, can do with some difficulty; 4, can do without difficulty). Support exists for the predictive validity (can predict falls), stability over time, and sensitivity of the adapted Composite Physical Function Scale.[33-35] Previous research has also shown the adapted Composite Physical Function Scale to have very high test-retest reliability (.98) and acceptable concurrent validity ($r=-.71$; $P<.01$) with the FIQ for women with FM.[36]

***Physical performance measures.*** Assessments of actual physical performance allowed determination of whether these objective measures might be more sensitive to cognitive function/dysfunction than standard self-report instruments. Nine performance-based test items, easy to perform in both clinical and community settings, measured physical ability/physical impairments. Test protocols met scientific standards with respect to reliability and validity with various populations, including people with FM.[34,37] Five measures were selected from the Senior Fitness Test battery[34,38]: (1) 30-second chair stand (number of chair stands performed in 30s; lower body strength), (2) 30-second arm curl (number of arm curls in 30s; upper body strength), (3) back scratch (number of inches down the back a person can reach with an arm; upper body flexibility), (4) chair sit and reach (number of inches person can reach from a chair down an extended leg with both arms; lower body, especially hamstring, flexibility), and (5) 8 Foot Up and Go (dynamic balance and overall functional mobility). Because of time restrictions and to minimize the effect of fatigue on cognitive scores, the 6-minute walk (aerobic endurance) was not used. As recent research suggests that FM participants are at increased risk for balance problems and falls,[2,39] 4 items from the Fullerton Advance Balance Scale[40] were selected to determine multidimensional balance: (1) step up and over, (2) tandem walk, (3) stand on one leg, and (4) stand on foam with eyes closed. These 4 items from the Fullerton Advance Balance Scale have acceptable test-retest reliability for people with FM,[37] and are highly predictive of falls among older adults.[41] Detailed test protocols are explained elsewhere for both the Senior Fitness Test items[34,38] and the original Fullerton Advance Balance Scale.[40,42]

***Trail Making Test.*** Complex attention, executive function, and cognitive flexibility were measured with an adapted version of the TMT-A and TMT-B.[23,24] (The form used in the present study was a slightly smaller version [approximately 80%] of the 8.5 by 11-in version typically administered; this reduction was the only change made to the standard instrument.) The TMT is a set of visual search and sequencing tasks that are sensitive to impairment in multiple cognitive domains. On TMT-A, subjects were asked to connect numbers consecutively (eg, 1-2-3), whereas on TMT-B, they alternated between consecutive numbers and letters (eg, 1-A-2-B). The number of correct connections and number of seconds to complete the task are associated with age-related declines in executive cognitive function.[43] The TMT has been shown to be a reliable measure of attention, concentration, resistance to distraction, and cognitive flexibility/executive function.[23,44,45]

***Digit Symbol Substitution Test.*** The DSST-coding of the Wechsler Adult Intelligence Scales III was used to measure complex psychomotor speed.[25,46] The DSST evaluates information processing speed and is sensitive to both age and general cognitive ability[47] and physical health.[23] Participants were presented with symbols and digits paired in a code box, followed by a series of double boxes where the top contained a digit and the bottom box was blank. Participants were to use the code table to write in as many symbols as possible within 120 seconds. The score was the number of squares correctly completed. Test-retest reliability for adults has been reported to range from .82 to .88.[23]

***Beck Depression Inventory.*** The BDI[48] was used to measure depressive symptoms among participants. The BDI is composed of 21 items, each with 4 possible responses (range, 0–3). Items 1 to 13 assess symptoms that are psychologic in nature, while items 14 to 21 assess more physical indicators. The BDI is frequently used in studies of FM and is considered a well-validated self-report measure of depressive symptoms.

## Procedures

Before testing, participants received a telephone call to determine study eligibility, and to schedule an assessment date and time (≈8 participants per hour). Before assessments, participants were asked to wear proper exercise attire (loose clothing, walking shoes), refrain from heavy exertion and alcoholic beverages, and maintain their normal regimen of medications within the preceding 24 hours. In addition, they were instructed to eat a light meal approximately 1 hour before performance testing.

Eligible participants were sent a study consent form and the Health/Activity Questionnaire by mail. All participants were called the day before assessments and reminded to bring the completed consent form and questionnaire to scheduled appointments.

On assessment day, questions about informed consent were answered, and consent forms witnessed by the lead investigator were checked for proper signatures. Health/Activity Questionnaires were reviewed to ensure completeness. Participants then filled out the Composite Physical Function Scale and FIQ. Once the paperwork was completed, the lead investigator thanked participants and briefly explained study procedures. Participants were assigned to private rooms to complete cognitive tests (≈5–10min). All participants performed the TMTs first, followed by the DSST, with test administrators using standard procedures read from a script. Once cognitive tests were completed, participants were led through a 5-minute warmup and static stretch routine, and then were assigned to 1 of the 6 physical performance assessment stations. Physical assessment rotations were not randomly assigned but dependent on the availability of the various stations to reduce the influence of fatigue on participants; in addition, participants were encouraged to rest between tests. All test administrators were trained according to standard protocols and were evaluated. All participants received the same instructions before testing—to do the best that they could but to never push themselves to a point of overexertion or beyond what they thought was safe for them. Participants were also reminded that they could withdraw from the study at any time.

## Data Analysis

Hierarchical regression analyses were used to assess the relationships between cognitive function and measures of FM symptoms, perceived physical function, and physical perfor-

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mance. FM symptoms were measured with the same response set (0–10); therefore, the sum of these items was used as a composite score. Participants' total scores from the FIQ and Composite Physical Function Scale were used as measures of perceived physical function. A factor analysis with an oblique rotation was used to calculate a composite score of participants' PPMs. Four outcome variables were used, including TMT-A, TMT-B, DSST, and a composite score of these 3 cognitive measures. The CCS was attained by summing the $z$ scores of the 3 cognitive measures (DSST scores were first inverted so that higher scores reflected poorer performance). For each outcome variable, 3 hierarchical models were tested. Age, sex, education, and depression, as measured by the BDI,[48] were evaluated as potential control variables. Only age showed significant effects; the other variables were dropped from further analysis. For all analyses, cases with missing data points were excluded via listwise deletion. For model 1, age was entered as a control variable in step 1, FM symptoms were entered in step 2, and FIQ was entered in step 3. In models 2 and 3, steps 1 and 2 were the same as in model 1. However, in model 2, the Composite Physical Function Scale was entered in step 3, and in model 3, the PPMs were entered in step 3 (fig 1). Because of the small sample size and number of variables included in the analyses, bootstrap procedures were also used to estimate SEs.[49] The pattern of results was equivalent regardless of the statistical method used, and the results below report standard regression procedures.

## RESULTS

### Descriptive Statistics

In fall 2007, 51 people completed the required questionnaires and assessments (91% women; mean age, 54y) (see table 1). The average age and sex in this study are similar to those reported in other studies with this population.[2,50] No participants reported having Parkinson's disease, multiple sclerosis, or postpolio syndrome. Those who reported epilepsy/seizure disorder (n=2) or other neurologic conditions (n=7) were included after analyses excluding these conditions revealed the same pattern of results as those reported below. Participants reported varying average severity scores ± SD for FM symptoms, ranging from 1.09±2.44 for rashes to 6.94±1.79 for fatigue. Average pain intensity ± SD was 6.45±1.73. More than half of the sample indicated severity scores of 7 or higher for fatigue (59%), not feeling rested after sleep (59%), stiffness in the morning (59%), and concentration problems (51%). The sample exhibited moderate-high intensities of the classic FM symptom set—sleep-related problems, fatigue, and pain[3]—along with morning stiffness and concentration problems. A summary of descriptive statistics for the PPMs can be found in table 2. A summary of descriptive statistics for the cognitive measures as well as a comparison with normative data for the DSST can be found in tables 3 and 4.

### Regression Analyses on Relationships Between Physical Self-Report Measures (Fibromyalgia Impact Questionnaire—Model 1; Composite Physical Function Scale—Model 2) and Cognitive Function

The results indicated that the overall fit of model 1 was not significant for TMT-A, TMT-B, or DSST. However, for CCS, the overall model fit was significant in step 1 ($F_{1,46}=5.00$, $P=.03$, $R^2=.10$). The overall model fit remained significant in steps 2 and 3, but these were not significant changes in model fit, with only age acting as a significant predictor. FM symptoms and the FIQ did not significantly predict cognitive performance.

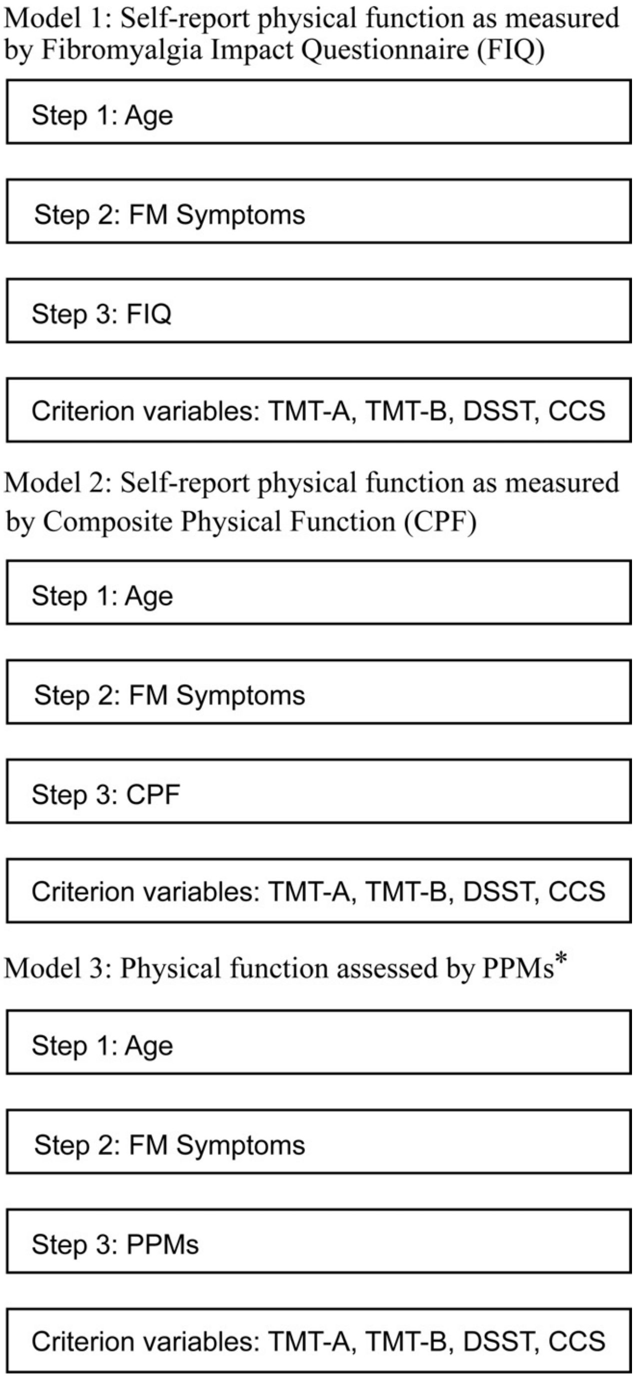


**Fig 1. Diagram of regression analyses (models 1, 2, and 3) using 4 separate criterion variables (TMT-A, TMT-B, DSST, and a composite score of these 3 variables). Only objective measures of physical performance predicted cognitive function. *PPMs significantly predicted cognitive performance for TMT-A and Composite Score after controlling for Age and FM symptoms. See text for details.**

The regression analyses for model 2 indicated that the overall model fit was not significant for TMT-A. For TMT-B, the overall model fit was significant in step 1 ($F_{1,48}=4.57$, $P=.04$, $R^2=.09$) but was not significant in steps 2 or 3, with only age acting as a significant predictor in steps 1 and 2. Similarly, for

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**Table 2: Descriptive Statistics for PPMs**

| Variables | Values |
|---|---|
| Physical measures | |
| Lower body strength (no. of stands in 30s) | 10.09±4.11 |
| Upper body strength (no. of arm curls in 30s) | 12.16±3.89 |
| Upper flexibility (in)* | −2.00±3.77 |
| Lower flexibility (in)† | −.57±4.30 |
| 8 Foot Up and Go (no. of seconds to get out of chair, walk 8ft around a cone, sit back down) | 6.78±2.13 |
| Multidimensional balance (FAB; 0–20; higher scores equate to better balance) | 13.64±2.32 |
| Step up and over (0–4)‡ | 3.77±.42 |
| Tandem walk (0–4)‡ | 3.18±.99 |
| Stand on 1 leg (0–4)‡ | 2.87±1.21 |
| Stand on foam, eyes closed (0–4)‡ | 3.81±.48 |
| FIQ total (0–100; higher scores equate to higher impairment) | 61.48±17.98 |
| CPF total (0–60; higher scores equate to higher function) | 35.20±9.63 |

NOTE. Values are mean ± SD.
Abbreviations: CPF, Composite Physical Function (Scale); FAB, Fullerton Advance Balance (Scale).
*Negative values indicated participants' inability to touch toes.
†Negative values indicated participants' inability to touch middle fingers.
‡Ordinal scale, 0–4; 0 is lowest score.

**Table 4: Descriptive Statistics for DSST Compared With Normative Data**

| Variables | DSST Scores | Normative Values |
|---|---|---|
| DSST | | |
| Age (y) | | |
| 25–29 | 49.0* | 78.0±15.5 |
| 30–34 | ND | 77.0±16.0 |
| 35–44 | 59.8±16.9 | 75.0±16.5 |
| 45–54 | 54.3±11.4 | 70.0±15.2 |
| 55–64 | 46.7±15.9 | 61.0±15.0 |
| 65–69 | 40.0±11.4 | 54.0±15.0 |
| 70–74 | 49.0±8.2 | 51.0±14.7 |
| 75–79 | 53.7±15.9 | 47.0±14.5 |
| 80–84 | 44.0* | 42.0±15.0 |

NOTE. Values are mean ± SD. Norms for DSST are based on Ardila.[54]
*No SD, only one participant.

DSST, the overall model fit was significant in step 1 ($F_{1,48}$=4.31, $P$=.04, $R^2$=.08), but there was significant change in model fit for steps 2 and 3, and only age acted as a significant predictor in steps 1 and 2. For CCS, the overall fit of step 1 was significant ($F_{1,48}$=6.07, $P$=.02, $R^2$=.11). When FM symptoms were added in step 2, the overall model remained significant ($F_{2,47}$=5.70, $P$=.01, $R^2$=.20). This was a significant change in model fit ($\Delta R^2$=.08, $P$=.03) with FM symptoms acting as a significant predictor ($\beta$=.30, $t_{47}$=2.20, $P$=.03, $r_p$=.31). When Composite Physical Function Scale was added in step 3, the overall model remained significant ($F_{3,46}$=4.37, $P$=.01, $R^2$=.22). However, this was not a significant change in model fit, and none of the predictors were significant.

### Regression Analyses on Physical Performance Measures (Model 3) and Cognitive Function

For TMT-A, the overall fit of step 1 in model 3 was not significant. However, step 2 in model 3 was significant ($F_{2,40}$=3.57, $P$=.04, $R^2$=.15) with FM symptoms acting as a significant predictor of cognitive function ($\beta$=.35, $t_{40}$=2.31, $P$=.03, $r_p$=.34). When PPMs were added to the model in step 3, the overall fit of the model remained significant ($F_{3,39}$=4.68, $P$=.007, $R^2$=.27). This was a significant change in overall model fit ($\Delta R^2$=.11, $P$=.02). Furthermore, the role of FM symptoms became nonsignificant, whereas PPMs were a significant predictor ($\beta$=−.41, $t_{39}$=−2.45, $P$=.02, $r_p$=−.37). In this analysis, the effect of PPMs was significant above and beyond the effect of age and FM symptoms. The participants' observed physical performance was a significant predictor of performance on TMT-A, in which poor physical performance predicted slower cognitive performance.

**Table 3: Descriptive Statistics for Cognitive Measures**

| Variables | Values |
|---|---|
| TMT-A (s) | 52.2±22.6 |
| TMT-B (s) | 89.7±34.4 |
| DSST | 51.3±14.0 |
| CCS | 0±2.2 |

NOTE. Values are mean ± SD. Value for DSST represents number of items correct, and value for CCS represents combined *z* scores.

For TMT-B, the overall fit of model 3 was significant in step 1 ($F_{1,41}$=5.04, $P$=.03, $R^2$=.11). The overall model remained significant in steps 2 and 3; however, the change in model fit was not significant, and only age acted as a significant predictor in steps 1 and 2. None of the predictors were significant in step 3.

For DSST, the overall fit of step 2 in model 3 was significant ($F_{2,40}$=3.27, $P$=.05, $R^2$=.14) with FM symptoms acting as a significant predictor ($\beta$=–.32, $t_{40}$=–2.11, $P$=.04, $r_p$=−.32). When PPMs were added in step 3, the model became nonsignificant with no significant predictors.

For CCS, the overall fit of step 1 in model 3 was significant ($F_{1,41}$=4.83, $P$=.03, $R^2$=.11) with age acting as a significant predictor. When FM symptoms was entered in step 2, the model remained significant ($F_{2,40}$=6.42, $P$=.004, $R^2$=.24). This was a significant change in model fit ($\Delta R^2$=.14, $P$=.01) in which FM symptoms acted as a significant predictor ($\beta$=.38, $t_{40}$=2.70, $P$=.01, $r_p$=.39), and age was no longer significant. When PPMs were added in step 3, the overall fit of the model remained significant ($F_{3,39}$=6.15, $P$=.002, $R^2$=.32). This was a significant change in overall model fit ($\Delta R^2$=.08, $P$=.04). Furthermore, in step 3, the role of age and FM symptoms became nonsignificant, whereas PPMs were a significant predictor ($\beta$=–.34, $t_{39}$=–2.12, $P$=.04, $r_p$=-.32). The effect of PPMs was significant above and beyond the effect of age and FM symptoms. The participants' physical performance was a significant predictor of overall performance on the cognitive tasks, in which poor physical performance was associated with poor cognitive performance.

## DISCUSSION

The 2 purposes of the present study were to determine whether physical function would predict attention and processing speed in persons with FM, and whether actual PPMs were a better predictor of these cognitive domains than perceived or self-reported physical function. In this small study of predominately white, well-educated persons with FM, better physical performance was significantly associated with better cognitive performance for the TMT-A (complex attention, executive function) and the CCS, which included all 3 measures of

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cognitive function (TMT-A, TMT-B, and DSST) after controlling for age and symptom burden, but only when objective PPMs were used to assess physical function. This result used scores on performance tests that measured multiple physical functions (ie, upper and lower body strength and flexibility, dynamic balance, overall functional mobility) and cognitive domains of complex attention, cognitive flexibility/executive function, and psychomotor speed.

Most studies in FM to date[51,52] have not investigated whether patterns of physical activity participation, through their effects on physical fitness and performance, are related to or can enhance cognitive performance. However, recently Munguia-Izquierdo and Legaz-Arrese[53] found that after a 16-week warm water exercise training program, women with FM had significant enhancements in 10 of 11 cognitive assessments (including TMT-A and TMT-B), while women not in the program showed no change. Pain also significantly decreased in the exercising women but not in those in the control group. These authors "consider that the cognitive improvement after exercise therapy is fundamentally due to an increase in pain threshold,"[53(p827)] as they found significant correlations between some of their neuropsychological tests and pain threshold. Actual physical performance was not assessed in this Spanish study[53]; thus, further research is needed to tease apart the contributions of enhanced physical performance, decreased pain, and cognitive improvement in persons with FM.

Use of a nonstandardized version of the TMT precluded comparison with normative data for TMT-A and TMT-B; however, we were able to make comparisons between FM performance in the present study and normative data for healthy adults for the DSST. Those individuals in the current study who were 70 years or older showed comparable scores on the DSST compared with age-appropriate normative data[54] (see table 4). Those individuals who were younger than 70 years, however, showed declines compared with age-matched norms.[1] Note though that several other studies have found no differences for processing speed for individuals with FM compared with age-matched controls,[6,8,16] and none of the physical measures predicted psychomotor speed (DSST) by itself in our regression analyses.

Alterations in cognition in FM are evident across studies and could compromise tasks of daily living and quality of life. For example, recent research suggests that decreased executive function (as measured by the TMT) predicts decreased performance on IADLs in both community-dwelling older adults and clinical populations.[26] Moreover, a recent Internet study of 1735 women with FM reported that they had less functional ability in ADLs and IADLs than did normal community-dwelling individuals in their 80s.[4] Physiologic changes in the brain in persons with FM (eg, alterations in hippocampal function[55] or in neural pain processing areas,[1,56,57] or both) may be associated with various cognitive performance deficits. Further research is warranted to determine specific relations between biomarkers and cognitive performance in persons with FM.

Our findings indicate the need for future work to determine whether physical activity participation, through its effect on physical performance, can enhance cognitive performance in persons with FM. Previous work in older men and women establishes positive relationships between executive performance and habitual physical activity[19] and between memory change and exercise involving higher resistance levels,[58] although studies also indicate that improvements in cognitive function after exercise may not occur in optimally functioning older adults.[59]

### Study Limitations

Several limitations of the study are worthy of comment. First, the sample was small and consisted primarily of white, well-educated women, and we did not control for medications used. Thus, caution is needed in generalization to other populations. In addition, our focus was primarily on attention and processing speed as measured by the TMT and DSST. Future studies might include a more comprehensive neuropsychologic testing, such as immediate and delayed recall of information as well as more expanded assessment of attention and executive function. This study, however, provided an opportunity to explore the impact of both perceived physical function and physical performance on cognitive performance. In so doing, this study provides additional information to the existing literature. Our data collection was cross-sectional rather than longitudinal; therefore, more research is clearly needed to elucidate the causal relations between physical and cognitive dysfunction among people with FM.

## CONCLUSIONS

Data from the present study suggest that physical ability is strongly associated with cognitive ability for people with FM. That is, better physical performance on tests that measured body strength and flexibility, dynamic balance, and overall functional mobility was associated with better performance on objective measures of complex attention, cognitive flexibility/executive function, and psychomotor speed. This relationship was only significant when using objective PPMs of function rather than self-report measures such as the FIQ or Composite Physical Function Scale. This suggests that like current research in cognitive aging, interventions that promote physical function may also enhance cognitive health in this population.

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