VNIVERSITAT DE VALÈNCIA

Facultat de Fisioteràpia

“Caracterización de la capacidad funcional y de la calidad de vida en mujeres con fibromialgia”

TESIS DOCTORAL
PROGRAMA DE DOCTORADO 3165
DEPARTAMENT DE FISIOTERÀPIA

PRESENTADA POR:
Dña. Núria Sempere Rubio

DIRIGIDA POR:
Dra. Dña. Pilar Serra Añó

Valencia 2019

Dr. Dña. Pilar Serra Añó, Profesora Titular de la Universitat de València, adscrita al Departament de Fisioteràpia

HACE CONSTAR:

Que el presente trabajo, titulado "Caracterización de la capacidad funcional y de la calidad de vida en mujeres con fibromialgia", ha sido realizado bajo su dirección, por Dña. Núria Sempere Rubio, para optar al grado de Doctor por la Universitat de València. Habiéndose concluido, y reuniendo a su juicio las condiciones de originalidad y rigor científico necesarias, autoriza su presentación a fin de que pueda ser defendido ante el tribunal correspondiente.

Y para que así conste expide y firma la presente documentación en València a 16 de septiembre de 2019.

Fdo: Pilar Serra Añó

Deseo expresar mi agradecimiento:

En primer lugar, agradecer que no ha sido un camino solitario, he estado acompañada por grandes personas que, durante estos años, me han ayudado a perseverar, crecer y mejorar. Me han tendido la mano, y me dieron los remos para empezar de nuevo, siempre incondicionales, sin esperar nada a cambio, de forma altruista, deseándome lo mejor.

Una de ellas, fue mi gran amiga y directora; una persona afectuosa, decidida, incansable, exigente, dispuesta a mejorar y ser rigurosa en todas sus facetas. Confió en mí y me brindó su ayuda, de forma generosa, para poder conseguir mis objetivos. Si no fuese por ella, hoy no estaría en esta situación.

También quería agradecer al Degà de la Facultat de Fisioteràpia, Dr. D. Antonio Alberola, por sus palabras de afecto.

A mis compañeras del grupo de investigación UBIC, en especial a Marta Aguilar, por su sonrisa y su tiempo; a Sara Cortés y Gemma Espí por su apoyo.

A mis compañeros del departament de Fisioteràpia, en especial a Juanjo Carrascosa, Sofía Perez y Marta Inglés, por su generosidad y sus valiosos consejos.

A las participantes, a todas las mujeres con fibromialgia que compartieron su tiempo conmigo; en especial a las asociaciones de fibromialgia de Valencia, Alzira, Ontinyent y Horta Nord. A las mujeres voluntarias de Alcoi, Villar del Arzobispo y Valencia.

A mis compañeros de Fisioterapia Marítim, en particular a mi amiga Esther López.

A mis amigas, en especial Maria Vilaplana, por disfrutar y sufrir el camino juntas. Quiero dar las gracias a mi familia. A mis padres y mi hermana, por estar siempre, por su cariño, ayuda, apoyo y valores que me han transmitido. Y por último a mis hijos, disculpadme por las incontables horas robadas.

Gracias.

Als meus fills, Guillem i Eric.

Espere haver-vos mostrat com cal afrontar la vida, sobretot amb les dificultats, perseverant, amb esforç i passió, viatjant cap a Ítaca.

"Quan surts per fer el viatge cap a Itaca,
has de pregar que el camí sigui llarg,
ple d'aventures, ple de coneixences.
has de pregar que el camí sigui llarg,
que siguen moltes les matinades
que entraràs en un port que els teus ulls ignoraven,
i vagis a ciutats per aprendre dels que saben.
Tingues sempre al cor la idea d'Itaca.
Has d'arribar-hi, és el teu destí,
Però no forcis gens la travessia.
És preferible que duri molts anys,
Que siguis vell quan fondegis l'illa,
ric de tot el que hauràs guanyat fent el camí,
sense esperar que et doni més riqueses".

Konstantinos Kavafi - Carles Riba

ÍNDICE DE CONTENIDOS

PRESENTACIÓN DE LOS ESTUDIOS 18

SECCIÓN PRIMERA: MARCO TEÓRICO
INTRODUCCIÓN GENERAL
1. DESCRIPCIÓN DEL SÍNDROME DE LA FIBROMIALGIA 23
1.1. Concepto 23
1.2. Epidemiología 27
1.3. Repercusión en el Sistema Nacional de Salud 30
2. MÉTODOS DIAGNÓSTICOS. EVOLUCIÓN Y RETOS 32
2.1. Evolución 32
2.2. Retos 41
3. REPERCUSIÓN FUNCIONAL DEL SÍNDROME DE LA FIBROMIALGIA 44
3.1. Concepto de capacidad física 44
3.2. Capacidad física en fibromialgia 45
4. OBJETIVOS 47
4.1. Ojetivo general 47
4.2. Objetivos específicos 47

SECCIÓN SEGUNDA: PROCEDIMIENTO GENERAL
1. PROYECTO FIBROVAL 53
1.1. Petición del proyecto 53
1.2. Reunión con los responsables de los centros de fibromialgia y búsqueda de participantes 54
2. PARTICIPANTES 58
3. MATERIAL Y MÉTODOS 59
3.1. Formulario de registro 60
3.2. Cuestionarios y escalas utilizados para la valoración de las participantes 60
3.3. Pruebas clínicas de condición física 63
3.4. Valoración de la postura 66
3.5. Valoración del umbral de presión al dolor 69
REFERENCIAS BIBLIOGRÁFICAS 73

SECCIÓN TERCERA: TRABAJOS PUBLICADOS

Estudio 1: Characterization of postural control impairment in women with fibromyalgia

Abstract 93
1. Introduction 94
2. Materials and methods 95
2.1. Participants 95
2.2. Procedures 96
2.3. Reliability studies 98
2.4. Stabilometry data analysis 98
2.5. Statistics 100
3. Results 101
3.1. Participants 101
3.2. Postural control between groups 101
3.3. Sensory input results 103
3.4. Impact of self-induced anxiety on postural control 103
3.5. Relationship between lower limb strength and postural control 105
3.6. Test-retest reliability of strength and bmi assessment procedures 105
4. Discussion 105
5. Conclusions 109
6. Acknowledgments 109
7. References 109

Estudio 2: Impaired trunk posture in women with fibromyalgia

Abstract 119
1. Introductions 121
2. Methods 122
2.1. Participants 122
2.2. Measurements 122
2.3. Thoracic kyphosis test 122
2.4. Craniovertebral angle test 123
2.5. Baseline and maximum shoulder protraction test 123
2.6. Test on the change in cervical and thoracic angle in sitting position 124
2.7. Reliability studies 125
2.8. Sample size calculation 125

2.9. Statistics 126
3. Results 126
3.1. Participants 126
3.2. Participants posture variables 127
3.3. Effect of sendetary behavior on trunk posture 128
3.4. Reliability studies 128
4. Discussion 130
5. Conclusions 132
6. References 132

Estudio 3: Physical condition factors that predict a better quality of life in women with fibromyalgia

Abstract 139
1. Introduction 140
2. Methods 141
2.1. Participants 141
2.2 Assessment procedures 141
2.2.1. Quality of life measures 142
2.2.2. Functional capacity 142
2.2.3. Upper limb strength 142
2.2.4. Maintenance of thoracic posture 143
2.2.5. Postural control 143
2.2.6. Flexibility 144
2.2.7. Pain threshold 144
2.2.8. Anxiety 144
2.3. Data analysis 144
2.4. Ethical approval 145
3. Results 145
3.1. Participants 145
3.2. Between-group comparisons 145
3.3. Quality of life prediction 147
4. Discussion 147
5. Limitations 152
5. Conclusions 152
6. References 152

SECCIÓN CUARTA: CONCLUSIONES GENERALES

CONCLUSIÓN GENERAL 165
CONCLUSIONES ESPECÍFICAS 165
Estudio 1 165
Estudio 2 165
Estudio 3 166
LÍNEAS PRESENTES Y FUTURAS 167

ANEXOS

ANEXO I: Aprobación comité ética 171
ANEXO II: Carta para el reclutamiento de participantes 172
ANEXO III: Texto para el reclutamiento de participantes vía WhatsApp 175
ANEXO IV: Bando en Villar del Arzobispo 176
ANEXO V: Consentimiento informado 177
ANEXO VI: Autorización para el uso de la imagen 180
ANEXO VII: Formulario de cumplimentación de la historia clínica del paciente 181
ANEXO VIII: Copia original del Estudio 1: Characterization of postural control impairment in women with fibromyalgia, en la revista *Plos One* 185
ANEXO IX: Copia original del Estudio 2: Impaired trunk posture in women with fibromyalgia, en la revista *Spine* 201
ANEXO X: Copia original del Estudio 3: Physical condition factors that predict a better quality of life in women with fibromyalgia, en la revista *International Journal of Environmental Reasearch and Public Health* 211

ÍNDICE DE FIGURAS

INTRODUCCIÓN GENERAL

Figura 1. Prevalencia del síndrome de la fibromialgia en el mundo respecto a la población general. Prevalencia por regiones de la OMS. Prevalencia mujeres. Prevalencia hombres. Ratio mujeres: hombres 29
Figura 2. Estado laboral de los pacientes con fibromialgia en España..... 31
Figura 3. Localización anatómica de los puntos sensibles utilizados en los criterios diagnósticos de ACR de 1990 33
Figura 4. Áreas del cuerpo que aparecen en el Índice de dolor generalizado 35

PROCEDIMIENTO GENERAL

Figura 1. Entorno gráfico del software de adquisición de la señal posturográfica. 64
Figura 2. Determinación del ángulo cráneovertebral de una participante. 67
Figura 3. Prueba del mantenimiento de la postura del tronco. 68

ESTUDIO 1

Fig 1. Differences between groups in postural control variables. 102

ESTUDIO 2

Figure 1. Trunk posture in sitting position..... 124
Figure 2. It presents the effect of FMS in a prolonged sitting posture. 127

ÍNDICE DE TABLAS

INTRODUCCIÓN GENERAL

Tabla 1. Entidades clínicas consideradas como Síndromes de sensibilización central. 24
Tabla 2. Manifestaciones clínicas y comorbilidades asociadas a la fibromialgia.....24
Tabla 3. Índice de dolor generalizado, validado al español de los criterios preliminares diagnósticos de 2010. 36
Tabla 4. Escala de severidad de los síntomas, segunda parte; síntomas experimentados durante la semana anterior. Criterios 2010 ACR. 37
Tabla 5. Criterios 2016 ACR, las 5 regiones de dolor generalizado. 41

PROCEDIMIENTO GENERAL

Tabla 1. Medios de captación de las participantes con fibromialgia..... 56
Tabla 2. Medios de captación de las participantes sin fibromialgia. 57
Tabla 3. Justificación de las variables posturográficas. 65

ESTUDIO 1

Table 1. Pairwise comparisons of the posturographic variables..... 104

ESTUDIO 2

Table 1. Descriptive results of the posture variables and statistical differences between groups. 127
Table 2. Descriptive results of the posture variables and statistical differences between the sedentary and nonsedentary groups. 128
Table 3. Analysis of the reliability and consistency of the posture procedures. 129

ESTUDIO 3

Table 1. Results of the comparison between women with fibromyalgia and their healthy counterparts..... 146
Table 2. Multiple regression model for quality of life in women with fibromyalgia.....147

PRESENTACIÓN DE LOS ESTUDIOS

PRESENTACIÓN DE LOS ESTUDIOS

El presente documento comprende la tesis doctoral realizada por Núria Sempere Rubio, en el marco del programa de doctorado en Fisioterapia, código 3165, de la Universitat de València, R.D. 99/2011. La memoria que se presenta a continuación, se acoge a la modalidad por compendio de publicaciones. Los artículos que conforman el documento han sido publicados durante los años del programa de doctorado y se engloban dentro de una misma línea de investigación.

Esta tesis forma parte del proyecto de investigación llevado a cabo por la Dra. Dña Pilar Serra Añó, cuyo título es "Desarrollo de una metodología de valoración del síndrome de fibromialgia (FIBROVAL)"; Referencia GV/2016/140, convocatoria DOGV 15/09/2015, con una financiación de 6.200,00 euros. El trabajo de investigación pretende desarrollar un índice que contemple diferentes pruebas de valoración objetivas asignando un peso específico a cada una de ellas para que faciliten la identificación de las personas que sufren este síndrome. Para ello, se determinaron varias temáticas dentro del proyecto de investigación, para poder profundizar, describir y analizar aquellas condiciones físicas que describen a las mujeres con fibromialgia. Se llevó a cabo el diseño y la ejecución de tres investigaciones que se redactan en esta tesis doctoral.

Todos los resultados fueron publicados en revistas indexadas en el Journal Citation Reports (JCR) de la Web of Knowledge (WoS), cuyo factor de impacto, cuartil y área de conocimiento (año 2018 y 2019) se muestra a continuación.

PRESENTACIÓN DE LOS ESTUDIOS

Estudio 1. Characterization of postural control impairment in women with fibromyalgia.

Revista: *Plos One*.

ISSN: 1932-6203

DOI: https://doi.org/10.1371/journal. pone.0196575

Categoría		Multidisciplinary sciences	
Factor de impacto	**Ranking**	**Cuartil**	**Percentil de factor de impacto**
2.776	24/69	2	75.926

Estudio 2. Impaired trunk posture in women with fibromyalgia.

Revista: *Spine.*

ISSN: 0362-2436

DOI: https://doi.org/10.1371/10.1097/BRS.0000000000002681

Categoría		Orthopedics	
Factor de impacto	**Ranking**	**Cuartil**	**Percentil de factor de impacto**
2.903	19/76	1	75.658

Estudio 3. Physical condition factors that predict a better quality of life in women with fibromyalgia.

Revista: *International Journal of Environmental Reasearch and Public Health.*

ISSN: 1660-4601

DOI: https://doi.org/10.3390/ijerph16173173

Categoría			
Factor de impacto	**Ranking**	**Cuartil**	**Percentil de factor de impacto**
2,468	112/250	2	55.400

SECCIÓN PRIMERA

INTRODUCCIÓN GENERAL

INTRODUCCIÓN GENERAL

1. DESCRIPCIÓN DEL SÍNDROME DE LA FIBROMIALGIA

1.1. Concepto

La fibromialgia (FMS) es un síndrome reumático que se caracteriza por dolor musculoesquelético generalizado presente durante al menos tres meses, de origen desconocido. Se acompaña de otros síntomas y manifestaciones clínicas, tales como: fatiga, trastornos del sueño, alteraciones del estado de ánimo, rigidez matutina, sensación subjetiva de inflamación articular, parestesias, ansiedad, depresión, síntomas cognitivos, síndrome del colon irritable y alteraciones del control postural [1-4]. Se diagnostica sobre todo en la etapa adulta, entre los 20 y los 50 años de edad, afectando mayormente a las mujeres [5]. Se trata de una entidad con una elevada comorbilidad y que afecta a la calidad de vida de las personas que lo padecen [6].

El hallazgo típico que presentan las/los pacientes con FMS es el dolor. Por un lado, se observa una disminución del umbral de dolor a la presión (PPT), en diferentes zonas del cuerpo, manifestando alodinia [7]. Esta se define como percepción anormal del dolor, nacido de un estímulo mecánico o térmico que habitualmente es indoloro. Además, otra característica de la FM es la hiperalgesia: las/los pacientes perciben una sensación de mayor intensidad del dolor respecto a lo normal [7]. Por otro lado, durante el transcurso del síndrome, el dolor puede ser de intensidad variable y cambiar de localización [8].

Estas manifestaciones clínicas del dolor en el FMS son producto de diferentes alteraciones de los mecanismos de sensibilización central [9]. Por este motivo, desde hace un tiempo, este síndrome se incluye dentro de los *síndromes de sensibilización central* (SSC), enumerados en la Tabla 1 [10,11].

Tabla 1. Entidades clínicas consideradas como Síndromes de sensibilización central

Síndromes clínicos (cont.)
Fibromialgia
Síndrome de Fatiga Crónica
Síndrome del intestino irritable y otros trastornos gastrointestinales funcionales
Trastorno temporomandibular
Síndrome de piernas inquietas y movimientos periódicos de las extremidades
Dolor lumbar idiopático
Sensibilidad química múltiple
Dismenorrea primaria
Dolor de cabeza (tensión, migraña, mixta)
Migraña
Cistitis intersticial, prostatitis crónica, síndrome de vejiga dolorosa
Dolor pélvico crónico y endometriosis
Síndrome de dolor miofascial / síndrome de dolor regional complejo

Fuente: Smith *et al.*, 2010.

Como se ha adelantado, existen numerosas manifestaciones clínicas y comorbilidades asociadas al FMS además del dolor [1,2,4,6,12]. A parte del dolor, a grandes rasgos podemos dividirlos en problemas cognitivos, disfunciones a nivel sexual, fatiga, trastornos del sueño, rigidez articular, trastornos del estado de ánimo, ansiedad y disfunción física. A continuación, se enumeran en la Tabla 2.

Tabla 2. Manifestaciones clínicas y comorbilidades asociadas al FMS

Manifestaciones clínicas y comorbilidades asociadas al FMS (cont.)
Acidez de estómago
Aftas orales (úlceras)
Alteraciones actividad cerebral
Alteraciones del control postural
Alteraciones del estado de ánimo
Ansiedad
Boca seca
Caída del cabello
Calambres en el abdomen
Convulsiones

Manifestaciones clínicas y comorbilidades asociadas al FMS (cont.)
Debilidad muscular
Depresión
Diarrea
Disfunciones sexuales
Disminución capacidad para realizar las actividades de la vida diaria
Dolor de cabeza, migrañas
Dolor en la parte alta del abdomen
Dolor muscular
Dolor torácico
Entumecimiento / hormigueos
Erupciones
Espasmos vesicales
Estreñimiento
Fatiga o agotamiento
Fenómeno de Raynaud
Insomnio
Intolerancia al sol
Mareos
Micción dolorosa
Micción frecuente
Moretones frecuentes (hematomas)
Nauseas
Ojo seco
Parestesias, hormigueos
Pérdida de apetito
Pérdida o cambios en el gusto
Picores
Pitidos al respira (sibilancias)
Problemas de comprensión o memoria
Respiración entrecortada
Rigidez matutina
Sensación subjetiva de inflamación articular
Síndrome del Colon Irritable
Síntomas cognitivos: problemas de comprensión o de memoria

Manifestaciones clínicas y comorbilidades asociadas al FMS (cont.)
Trastornos auditivos
Trastornos del sueño
Trastornos temporomandibulares
Urticaria
Visión borrosa
Vómitos
Zumbidos en los oídos

Fuente: elaboración propia.

Dadas todas estas manifestaciones clínicas, el FMS tiene un gran impacto sobre la calidad de vida (QOL) de las personas que lo sufren [13,14] interfiriendo en su trabajo y sus actividades sociales, presentando un deterioro de su condiciones físicas y una reducción de su capacidad funcional [14-16].

Existen descripciones del síndrome desde la antigüedad que han ido evolucionado con el tiempo. En 1750, Richard Mannigham, describió el síndrome de "Pequeña fiebre o febrícula", en el cual, las/los pacientes presentaban cansancio y dolor sin una causa aparente. Actualmente se cree que posiblemente se refiriera al FMS o al síndrome de fatiga crónica. En 1904, William Gowers definió el término de "fibrositis", como una inflamación de los tejidos fibrosos que recubren los músculos, considerándolo un reumatismo. En línea con esta definición; durante el siglo XX se intentó averiguar la causa inflamatoria del síndrome. Paralelamente, se descubrieron puntos dolorosos que describían el cuadro síntomático, denominándolo como: "puntos sensibles, dolor muscular, myositis o fibromiositis". En 1947, se cambió el nombre por "reumatismo psicógeno" pues con los estudios anatomopatológicos de la época, no encontraron hallazgos inflamatorios y se decidió englobar el síndrome como una psiconeurosis. Hench en 1975, utilizó por primera vez el término de "fibromialgia", al no haber encontrado signos de inflamación tisular, quedando en desuso la palabra "fibrositis" [17].

En 1990, la ACR (*American College of Rheumatology*), describió unos criterios de clasificación para el FMS, marcando un punto de inflexión, con la finalidad de poder atender a un gran número de personas que presentaban síntomas parecidos y necesitaban atención y cuidados médicos [18].

Dos años después, en 1992, la Organización Mundial de la Salud (OMS), reconoció el FMS como una entidad clínica, incorporándolo a la clasificación internacional de enfermedades (CIE) [19]. En un primer momento, en la CIE-9 el FMS se clasificó con el código 729.1 junto con todas las mialgias y miositis no especificadas, y posteriormente, en la CIE-10 se listó dentro del apartado M79 *Other soft tissue disorders, not elsewhere classified*, con el código M79.7 *Fibromyalgia*, donde se incluyeron a su vez: *Fibromyositis, Fibrositis* y *Myofibrositis* [20]. En la última versión publicada en junio del 2018 y que entrará en vigor el 1 de enero de 2022, la CIE-11 la fibromialgia se incluye en el apartado MG30.01, *Chronic widespread pain* [21] y se describe como: "… dolor difuso en al menos 4 de las 5 regiones del cuerpo y que se asocia con un malestar emocional significativo (ansiedad, enojo / frustración o estado de ánimo deprimido) o discapacidad funcional (interferencia en las actividades de la vida diaria y participación reducida en los roles sociales). El dolor crónico generalizado es multifactorial: factores biológicos, psicológicos y sociales contribuyen al síndrome de dolor. El diagnóstico es apropiado cuando el dolor no es directamente atribuible a un proceso nociceptivo en estas regiones y existen características compatibles con el dolor fantasma y los contribuyentes psicológicos y sociales identificados".

1.2. Epidemiología

Prevalencia en la población general

Se estima que la prevalencia del FMS en la población general a nivel mundial es de 1,78 % [5]. No obstante, no existe consenso al respecto, ya que dependiendo de los autores y de los criterios utilizados, el porcentaje varía entre el 1,7 % y el 5,4 % [10,22].

Con respecto a la prevalencia por regiones del mundo, también existe cierta controversia entre los estudios. Según Branco *et al.*, [23] en Europa la prevalencia es del 2,9 %, mayor que en los otros continentes. En cambio, en la revisión de Queiroz [24], se muestra que esta es mayor en la región de América con un 3,1 % seguida de Europa, con una prevalencia del 2,5 % y finalmente Asia, que le sigue con un 1,7 %.

Según el metaánalisis de Heidari *et al.,* donde se muestra la prevalencia según las diferentes regiones definidas por la OMS para la población general, se estima que es mayor la prevalencia en la región del mediterráneo oriental con un 4,43 %, seguida de la europea con un 2,64 %, luego la americana 2,41 % y, por último, la región del pacífico oeste, con una prevalencia del 1,62 % [5]. En general, se observa en todas las investigaciones que, en la región de Europa, la prevalencia del FMS oscila entre el 2,31 % y el 2,9 % [5,23,25].

Respecto a España, el estudio EPISER, publicado en 2001, sitúa la prevalencia del FMS en un 2,4 % [26]. Se calcula que existen 800.000 adultos que padecen este síndrome [23]. Y más específicamente, en la Comunitat Valenciana, el estudio de Cabo-Meseguer *et al.*, indica que la prevalencia es mayor que en el resto del país, concretamente, de un 3,69 %; lo que se corresponde con 183.429 personas diagnosticadas según datos consultados de fuentes oficiales de información sanitaria de diciembre de 2016 [25].

Prevalencia por sexo

El FMS es más prevalente en mujeres que en hombres. Durante años se ha considerado que la prevalencia era mucho mayor en mujeres que en hombres, con una ratio de 9:1 según la guía de Ministerio de Sanidad del 2011 [20] o incluso 21:1 en el estudio EPISER [26], pues se usaban los criterios diagnósticos de la ACR de 1990 [18]. Actualmente, al usar los nuevos criterios [1], la ratio se sitúa en 4:1, con una prevalencia de 2,3 % en mujeres y 1,8 % en hombres, como puede observarse en la Figura 1 [25]. En la revisión internacional de Heidari *et al.*, la prevalencia es mayor, siendo de 3,98 % en mujeres y 0,01 % en hombres [5], pero en ella, cada estudio usa criterios diagnósticos distintos. Estos cambios en la ratio según el criterio diagnóstico empleado, se observan claramente en el estudio de Jones *et al.,* donde se describe que, con los criterios de ACR 1990, la proporción de mujeres a hombres era de 13,7: 1; con los criterios de ACR 2010 la ratio descendía a 4,8: 1, y con los criterios modificados de ACR de 2010, la ratio era de 2,3: 1 [27].

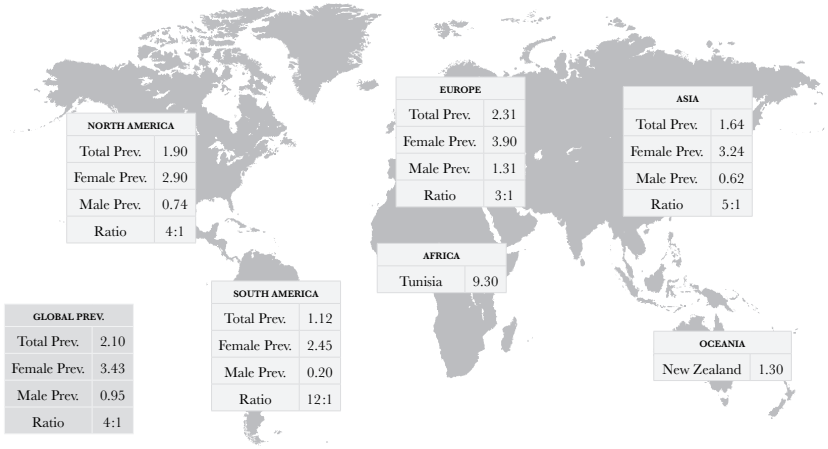

Figura 1. Prevalencia del síndrome de la fibromialgia en el mundo respcto a la población general. Prevalencia por regiones de la OMS. Prevalencia mujeres. Prevalencia hombres. Ratio mujeres: hombres. Fuente: Cabo-Meseguer, *et al.,* 2017 [25].

Prevalencia de edad

En España, dentro del grupo etario más frecuente, el promedio es de 49 años, con una prevalencia mayor en el grupo de edad entre los 46 a 65 años. Los síntomas empiezan sobre los 37 años de edad [25].

Del síndrome de la fibromialgia juvenil, todavía no se conoce mucho y existe una menor prevalencia que en la edad adulta. Parece ser que 1 de cada 20 niños, predominantemente niñas adolescentes, lo sufren [28].

Prevalencia de comorbilidades

El FMS se asocia con altas tasas de comorbilidades, y a la vez se relaciona con un estado de salud menos favorable, síntomas más graves y función alterada [29]. Más del 67 % de los pacientes con FMS presentan comorbilidades, incluso más de una (el 48 % de los que sufren comorbilidades, tienen varias). Por orden de mayor a menor prevalencia las comorbilidades son las enfermedades cardiovasculares (36,7 %), seguidas por las enfermedades endocrinas (30,8 %), las reumatológicas (12,4 %) y por último las neurológicas (5,9 %) [30]. Otros autores, observan que las personas con FMS presentan comorbilidades, sobre todo a nivel psicológico, (entre un 30-65 % sufren depresión y entre un 15-67 %, ansiedad), a nivel musculoesquelético, cardiovascular (hipertensión), trastornos respiratorios y otros trastornos torácicos,

trastornos de la espalda, dolor abdominal, trastornos del intestino irritable o neoplasias [29,31]. En cuanto a comorbilidades reumáticas, de mayor a menor prevalencia se encuentran la artritis reumatoide, el lupus eritematoso sistémico, la espondilitis anquilosante y la osteoartritis [25,31]. Y, finalmente, respecto a comorbilidades cardiovasculares, algunas de las más habituales son la hipertensión, la hiperlipidemia, la diabetes mellitus, las enfermedades cerebrovasculares y la insuficiencia cardíaca congestiva [31].

Incidencia

Se estima una tasa de incidencia ajustada por edad de 11,28 casos nuevos por cada 1.000 persona-año y de 6,88 casos nuevos por 1.000 persona-año, para los hombres [32]. En el Reino Unido se realizó un estudio entre el 2001 y el 2013, analizando la tendencia de la incidencia, se estimó que la incidencia anual ha ido aumentando en los últimos años, siendo de 38,2 por 100.000 personas en el año 2013 [33].

1.3. Repercusión en el Sistema Nacional de Salud

En las consultas de reumatología, las nuevas visitas por el FMS, comprenden el 14-20 %, lo que convierte a este síndrome en la segunda causa más común para consultar con el reumatólogo [29], por detrás de la osteoartritis [15].

Se trata de un síndrome muy incapacitante, que afecta a la calidad de vida de estas/estos pacientes [14] produciendo un impacto negativo en las actividades de la vida diaria, interfiriendo en su capacidad física, sus habilidades sociales y de ocio, así como en su vida laboral [15].

Dado que el FMS produce diversas manifestaciones clínicas, es común encontrar dificultad para su diagnóstico, lo que conlleva excesivas pruebas y un tratamiento inadecuado. Esta demora en el diagnóstico causa una carga económica en el Sistema Nacional de Salud y frustración en las/los pacientes y sus familias [34], produce pérdidas en la productividad, reducción de horas de trabajo, ausentismo, discapacidad, desempleo y jubilación anticipada [29,35]. Al ser un síndrome de carácter crónico, la atención sociosanitaria implica grandes costes para la sociedad con un importante consumo de recursos tanto sanitarios como para las familias [35].

Según la revisión de Ghavidel-Parsa *et al.*, el coste promedio anual por paciente, varió de 2.274 dólares hasta incluso 13.000 dólares [29]. En España, sus costes sociosanitarios ascienden a 11.000€ por paciente/año, correspondiendo un 66 % a costes sanitarios indirectos, derivados de las bajas laborales y el absentismo laboral [26]. Sin embargo, estos datos podrían modificarse, pues se espera que en el 2020 salga la publicación de la prevalencia de enfermedades reumáticas en edad adulta en el estado español del estudio EPISER 2016 [36], donde se prevé un aumento de los costes. En 2017, el coste para el conjunto del estado español se estimó en 12.993 millones de euros anuales. Respecto a la Comunidad Valenciana, se produjo un coste total de más de 2.132 millones de euros al año, representando un impacto económico del FMS por habitante en esta comunidad de 429 euros por año por cada habitante [25]. Estos son valores aproximados, pues el coste anual promedio puede variar, dependiendo de la gravedad de los síntomas y la forma de calcular los costes.

La capacidad de trabajo de las personas que sufren FMS se ve limitada debido a varios de los síntomas que padecen como el dolor, la fatiga, la debilidad muscular y las dificultades de memoria y de concentración. La mayoría necesitan pasar más días en cama, más de la mitad, deben reducir las horas que están en el trabajo, e incluso, cambiar de puesto de trabajo [34]. En el caso de España, entre el 43 % y el 78 % de los pacientes con FMS estaban de baja y la discapacidad total oscilaba entre el 6,7 % y el 30 %. A continuación, se observa en la Figura 2, el estado laboral de los pacientes con FMS en España.

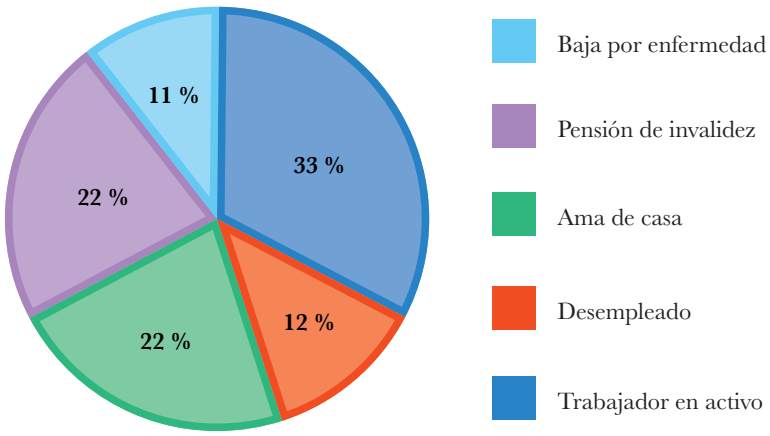

Figura 2. Estado laboral de los pacientes con fibromialgia en España. Fuente: Collado, *et al.,* 2014 [36].

Existe un desconocimiento por parte de la sociedad en general y una incomprensión del FMS [15,38]. Su reconocimiento social es limitado, lo que conduce al aislamiento y a una disminución de las relaciones interpersonales. A esto hay que añadir que numerosos profesionales dudan de su existencia o creen que hay una simulación por parte de las/los pacientes [38,39].

Además, afecta a su entorno familiar; muchos de las/los pacientes que padecen el FMS, tienen dificultades en sus relaciones de pareja, no pueden realizar las tareas del hogar, asumiéndolo otro miembro de la familia, que muchas veces, debe cambiar su actividad laboral normal para adaptarse y cuidar al paciente [37].

2. MÉTODOS DIAGNÓSTICOS. EVOLUCIÓN Y RETOS

2.1. Evolución

Actualmente no existe un método diagnóstico basado en pruebas anatomofisiológicas específicas, de imagen o bioquímicas, que diagnostiquen el FMS. Este hecho, genera controversia entre los profesionales, muchos de los cuales, como se ha adelantado, no creen en la existencia del síndrome [38,39]. Además, algunos de sus síntomas tienen un componente de somatización y se confunden con otras enfermedades como mialgias, artralgias, fatiga y trastornos del sueño, entre otras; siendo difícil su diagnóstico diferencial [40].

Criterios diagnósticos 1990

Como se ha mencionado anteriormente, en 1990 nacieron los primeros criterios rigurosos de clasificación del FMS [18]. La ACR llevó a cabo un estudio multicéntrico y junto con un comité de expertos reumatólogos determinó que se basaba en la presencia de [18]:

- Historia de dolor generalizado o difuso de más de tres meses de duración en ambos lados del cuerpo, por encima y por debajo de la cintura y en esqueleto axial, refiriéndose a la columna cervical, dorsal, lumbar y la pared torácica anterior.

- Dolor a la presión, como mínimo en 11 de los 18 puntos anatómicos identificados, (en realidad 9 simétricos), denominado puntos sensibles o *tender points*, que se identifican con un umbral de dolor bajo, que se activan al estímulo mecánico, mediante una presión digital de unos 4kg/cm^2, Figura 3. Esta presión equivaldría al momento en que el dedo del explorador cambia de color subungueal [41].

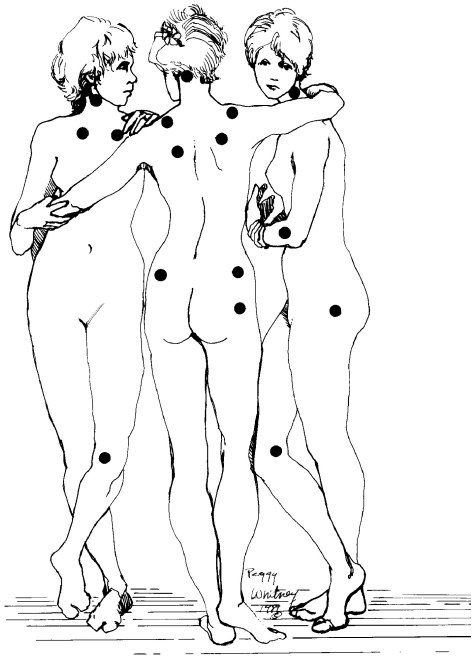

Figura 3. Localización anatómica de los puntos sensibles utilizados en los criterios diagnóticos de ACR de 1990[18].

La localización de los dieciochos puntos dolorosos es:

1. Occipucio: entre las inserciones de los músculos suboccipitales (apófisis mastoide y protuberancia occipital externa)
2. Cervical inferior: en la cara anterior de los espacios intertransversos a la altura de C5-C7
3. Trapecio: en el punto medio del borde superior y posterior
4. Supraespinoso: borde medial de la espina de la escápula
5. Segunda costilla: en la unión costocondral
6. Epicóndilo lateral del brazo: se ubica a 2 cm en dirección distal

7. Glúteo: en el cuadrante superoexterno de la nalga
8. Trocánter mayor: en la parte posterior de la prominencia trocantérea
9. Rodilla: en la almohadilla grasa medial próxima a la línea articular

Para que un punto se considere positivo, la persona debe expresar que es un punto doloroso a la exploración, no se considera si solo se percibe de forma sensible.

Estos criterios presentaron una sensibilidad del 88,4 % y una especificidad del 81,1 % [18]. Como aspecto positivo de estos criterios, fueron los primeros que de forma rigurosa legitimaron el FMS, permitiendo el reconocimiento de las/los pacientes así como el auge de la investigaciones, el desarrollo de medicación y tratamiento no farmacológico [42]. Pero su implantación presentó ciertas dificultades y críticas. Las limitaciones que aparecieron fueron que se basaba en un diagnóstico con el síntoma subjetivo de dolor que referían los pacientes. Se observó que en atención primaria, pocas veces se utilizaba la palpación de los 18 puntos o no se exploraban correctamente [43], existía mucha variabilidad en la localización por parte del examinador [42], con lo que cada vez más, el diagnóstico se realizaba a través de los síntomas que relataban los pacientes en consulta. También el hecho de haber seleccionado unos puntos sensibles con una localización específica y haber determinado un punto de corte, 11 de 18, siendo totalmente arbitrario y dicotómico, pues el hecho de tener 10 puntos de 18, conllevaba ser considerado como completamente normal [41,44]. Además se demostró que las mujeres presentaban más puntos sensibles que los hombres al aplicar el estímulo mecánico de 4kg/cm^2 [45], por lo que había un sesgo de sexo en el diagnóstico. Por último, no se había tenido en cuenta otra clase de síntomas, que caracterizan al síndrome, como son la fatiga, las alteraciones cognitivas, los trastornos de sueño o los cambios en el estado anímico [42]. Finalmente, se determinó que no se podía diagnosticar por presencia o ausencia de los síntomas, si no por un abanico de alteraciones con un rango variable de intensidad [1].

Criterios diagnósticos 2010

Veinte años después, con el avance de los conocimientos sobre el síndrome y en pro de vencer estas limitaciones, en el 2010 el ACR publicó unos nuevos criterios diagnósticos preliminares, eliminando la exploración de los puntos sensibles e identificando síntomas y características comunes, que fueron validados al español [46,47].

Los nuevos criterios incluían:

- Un índice de dolor generalizado (*Widespread Pain Index - WPI*).
- Una escala de severidad de los síntomas (*Symptom Severity Score, SS Score*).
- Y que el paciente no presente otra patología o enfermedad que explique el dolor.

El índice de dolor generalizado (*Widespread Pain Index - WPI*) incluía 19 localizaciones. Su puntuación era de 0 a 19 puntos en función del número de áreas identificadas. El paciente debía indicar cuáles le habían dolido durante la última semana, (Figura 4 y Tabla 3):

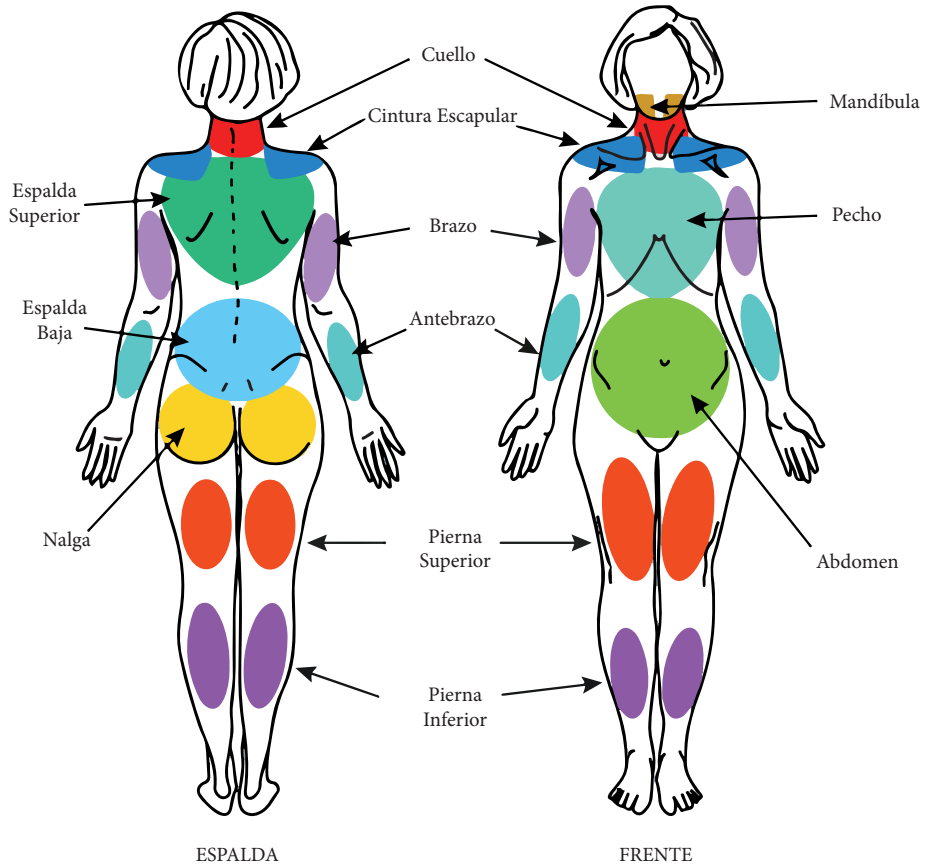

Figura 4. Áreas del cuerpo que aparecen en el Índice de dolor generalizado. Fuente: Segura, *et al.*, 2014 [46].

Tabla 3. Índice de dolor generalizado, validado al español de los criterios preliminares diagnósticos de 2010.

Hombro izquierdo	Hombro derecho
Lado izquierdo de la cadera	Lado derecho de la cadera
Parte superior del brazo izquierdo	Parte superior del brazo derecho
Parte inferior del brazo izquierdo Parte superior pierna izquierda	Parte inferior del brazo derecho Parte superior pierna derecha
Parte inferior pierna izquierda	Parte inferior pierna derecha
Lado izquierdo de la mandíbula	Lado derecho de la mandíbula
Pecho	Abdomen
Parte superior espalda	Parte inferior espalda
Cuello	

Fuente: Carrillo-de-la-Peña, *et al.,* 2015 [47].

La escala de Severidad de los Síntomas (*SS Score*), constaba de dos apartados. Una primera parte (*SS Score 1*), donde el paciente debía indicar de 0 a 3 puntos, el nivel de intensidad en el que había padecido los siguientes síntomas durante los últimos siete días:

- Fatiga
- Sueño no reparador
- Síntomas cognitivos

Se puntuaba cada uno de ellos, siguiendo la graduación:

0 = Sin problemas

1 = Problemas leves, generalmente leves o intermitente

2 = Moderado, produce problemas considerables, a menudo presentes y/o en un nivel moderado

3 = Severo, grave, persistente, afectación continua, gran afectación de la calidad de vida

Asimismo, existía una segunda parte (*SS Score 2*), donde se indicaban otros síntomas experimentados durante la semana anterior, tal y como se muestra en la Tabla 4.

Tabla 4. Escala de severidad de los síntomas, segunda parte; síntomas experimentados durante la semana anterior. Criterios 2010 ACR.

Dolor muscular	Pitidos al respira (sibilancias)
Síndrome del Colon Irritable	Fenómeno de Raynaud
Fatiga / agotamiento	Urticaria
Problemas de comprensión o memoria	Zumbidos en los oídos
Debilidad muscular	Vómitos
Dolor de cabeza	Acidez de estómago
Calambres en el abdomen	Aftas orales (úlceras)
Entumecimiento / hormigueos	Pérdida o cambios en el gusto
Mareos	Convulsiones
Insomnio	Ojo seco
Depresión	Respiración entrecortada
Estreñimiento	Pérdida de apetito
Dolor en la parte alta del abdomen	Erupciones
Nauseas	Intolerancia al sol
Ansiedad	Trastornos auditivos
Dolor torácico	Moretones frecuentes (hematomas)
Visión borrosa	Caída del cabello
Diarrea	Micción frecuente
Boca seca	Micción dolorosa
Picores	Espasmos vesicales

Fuente: Carrillo-de-la-Peña, *et al.*, 2015 [47].

Este apartado también se puntuaba de 0 a 3 atendiendo a los siguientes criterios:

0 = Asintomático (0 síntomas)

1 = Pocos síntomas (entre 1 y 10)

2 = Un número moderado de síntomas (entre 11 y 24)

3 = Un gran acúmulo de síntomas (25 o más)

Para obtener una valoración general, se sumaban las puntuaciones finales del Índice de dolor generalizado (*WPI*) y de la escala de severidad de los síntomas *(SS Score 1 and 2)*.

- Índice de dolor generalizado (WPI): 0 a 19 puntos
- Escala de severidad de los síntomas (*SS Score 1 and 2)* de 0 a 12 puntos

La suma de las dos partes de la Escala de severidad de los síntomas se obtenía de la siguiente forma:

En la primera parte (*SS Score 1*), el rango de las puntuaciones que se obtenían iba de 0 hasta 9 puntos mientras que en la segunda parte (*SS Score 2*), el rango iba de 0 a 3 puntos. A continuación, se sumaban ambas partes (*SS Score 1 and 2*), de forma que la escala de severidad de los síntomas tenía un rango de puntuación de 0 a 12 puntos.

Los criterios diagnósticos se satisfacían si los síntomas habían estado presentes durante al menos 3 meses y si se cumplían una de las siguientes opciones [1]:

- WPI ≥ 7 y SS Score ≥ 5
- WPI entre 3-6 y SS Score ≥ 9

Estos nuevos criterios clasificaban el 88,1 % de los casos diagnosticados con los criterios de 1990 y pretendían ser adecuados para su uso en atención primaria y especializada sin necesitar un examen físico [1]. Se demostró en un estudio del 2014, que su evaluación era más sencilla que los criterios anteriores, de fácil manejo y su uso se realizaba correctamente en atención primaria [48]. Oncu *et al.,* sugirieron que los criterios de 2010 eran más sensibles para su uso en el primer diagnóstico [49].

Criterios diagnósticos 2011

En el 2011, Wolfe *et al.,* modificaron los criterios de 2010, conformando los de 2011, creando una nueva escala de síntomas para el FMS [50]. Pretendían conseguir diagnosticar a pacientes que no satisfacían los criterios de 1990 o 2010. Los criterios de 2011, obtuvieron una sensibilidad del 96,6 % y especificidad del 91,8 %; pero tanto los criterios de 2010 como los del 2010 modificados, fueron criticados, por su falta de precisión y por ser un diagnóstico de exclusión [42].

Una ventaja de los criterios modificados del 2010 es que eran 100 % autoadministrables y no se necesitaba un entrevistador. Wolfe y su equipo, llamaron a estos cambios, *Fibromyalgianess scale* tratándose de una escala que puntuaba de 0

a 31 puntos en la cual se mantenía intacto el Índice de dolor generalizado (WPI) y la primera parte de la Escala de Severidad de los Síntomas (*SS Score 1*). La segunda parte, la que se refería a los síntomas se substituyeron los que había por:

- Dolores de cabeza
- Dolor o calambres en la parte baja del abdomen
- Depresión

La puntuación oscilaba entre 0 y 3 puntos, igual que anteriormente: anotando de 0 a 1 punto cada uno de los 3 síntomas; siempre y cuando, los hubieran padecido en los últimos seis meses.

Con lo cual, la puntuación final no difería, seguía siendo una asignación de 0 a 3. La particularidad era que, en lugar de preguntar por una gran variedad de síntomas, se acotó a tres posibles.

El diagnóstico se establecía igual que en los criterios de 2010, es decir, si:

- WPI ≥ 7 y SS Score ≥ 5
- WPI entre 3-6 y SS Score ≥ 9

Finalmente, para diagnosticar a una persona con FMS, requería tener una puntuación mínima, en la *Fibromyalgianess scale,* de 12 puntos. Así, se podía explorar y trazar un continuo observando la evolución del síndrome [22]. Estos criterios fueron traducidos y validados al español [47].

Criterios diagnósticos de 2016

En el 2016, se han publicado los últimos criterios diagnósticos por el equipo de Wolfe, que modifican y combinan los criterios anteriores [51]. Con estos criterios, una/un paciente es diagnosticado de FMS si se cumplen las siguientes 3 condiciones:

1. Índice de dolor generalizado (WPI) ≥ 7 y puntaje de la escala de gravedad de los síntomas (SSS) ≥ 5 O WPI de 4-6 y puntaje de SSS ≥ 9.
2. Dolor generalizado, definido como dolor presente en al menos 4 de las 5 regiones. El dolor mandibular, torácico y abdominal no se incluye en la definición generalizada del dolor.

3. Síntomas generalmente presentes durante al menos 3 meses.
4. El diagnóstico de fibromialgia es válido independientemente de otros diagnósticos. Además, el diagnóstico de fibromialgia no excluye la presencia de otras enfermedades clínicamente importantes.

Como se ha indicado, respecto al Índice de dolor generalizado (WPI), la modificación que presenta es que se debe percibir dolor en al menos 4 regiones de las 5 definidas. Estas cinco regiones que se consideran en la definición del dolor generalizado son:

- Región 1: zona superior izquierda.
- Región 2: zona superior derecha.
- Región 3: zona inferior izquierda.
- Región 4: zona inferior derecha.
- Región 5: región axial.

De esta forma, se elimina la condición de cumplir WPI entre 3-6 y *SS Score* ≥ 9, de manera que se establece:

WPI ≥ 7 y SS Score ≥ 5 ó WPI entre 4-6 y SS Score ≥ 9, ya que no da la opción de tener en cuenta una puntuación en el índice de dolor generalizado menor de 4 regiones corporales.

Con este cambio, pretenden evitar que personas con el síndrome de dolor regional complejo satisfagan los criterios del FMS [52]. Por un lado, se separaron las regiones, para que no quedaran superpuestas como en los criterios de 1990, donde un mismo dolor aparecía en dos regiones [52]. Asimismo, añadieron el nombre de la Escala de Severidad de la Fibromialgia *(FS Scale),* siendo la suma del WPI y del *SS Score*. Esta escala, también recibe el nombre de Escala de Distrés Polisintomático (PSD).

A continuación, se muestran en la Tabla 5 las cinco regiones del cuerpo que aparecen en el índice de dolor generalizado de los criterios de 2016 [51].

Tabla 5. Criterios 2016 ACR, las 5 regiones de dolor generalizado.

Región 1: zona superior hombro izquierda	**Región 2: zona superior hombro derecha**	**Región 5: región axial**
Mandíbula izquierda	Mandíbula derecha	Cuello
Hombro izquierdo	Hombro derecho	Parte superior espalda
Brazo superior izquierdo	Brazo superior derecho	Parte inferior espalda
Brazo inferior izquierdo	Brazo inferior derecho	Costilla
Región 3: zona inferior izquierda:	**Región 3: zona inferior derecha:**	Abdomen
Cadera izquierda	Cadera derecha	
Pierna superior izquierda	Pierna superior derecha	
Pierna inferior izquierda	Pierna inferior derecha	

Fuente: Wolfe *et al.*, 2016 [51].

Además, con esta versión se modifica el criterio excluyente de que una/un paciente con otra entidad clínica no podía padecer el FMS. Incluyendo que, de esta forma, pueden presentar comorbilidades, con clínica similar.

La revisión de 2016 garantiza que las/los pacientes con síndromes regionales de dolor no se clasifiquen erróneamente como FMS, al considerar que casi el 14 % de las/los pacientes diagnosticados previamente con los criterios de 2011, estaban diagnosticados incorrectamente [52]. Su sensibilidad es del 86 % y su especificidad del 90 % [51]. Pero con estos criterios, no se consigue vencer ni la barrera de que sigue siendo un diagnóstico intrínsecamente subjetivo, ni la baja credibilidad ni legitimación a nivel social, que abarca incluso problemas para evaluar la discapacidad o dificultades con los seguros médicos, al ser a través de una evaluación por síntomas autoinformados [39,52,53]. Todo esto redunda en una desconfianza y preocupación por parte de las/los pacientes en cuanto a las opciones terapéuticas pautadas por los profesionales sanitarios y que repercute en la adherencia a los tratamientos [54].

2.2. Retos

El problema del diagnóstico del FMS es que no existe un estándar de oro que defina el FMS y con el que se puedan comparar los criterios de FMS. El hecho de que su diagnóstico siga siendo clínico, sin biomarcadores objetivos, reta a la

comunidad científica a intentar desarrollar posibles herramientas de detección para ayudar a evaluar los dominios de sus síntomas, su severidad y la presencia de comorbilidades [42,52]. Se recomiendan pruebas simples de laboratorio para descartar posibles enfermedades, que confunden en el diagnóstico; tales como enfermedades reumáticas, neurológicas, trastornos de salud mental y efectos adversos a las drogas. Además, algunas enfermedades reumáticas preclínicas, (artritis reumática preclínica, espondiloartritis inflamatoria) y otros trastornos (trastornos metabólicos, enfermedades gastrointenstinales o infecciosas) cursan también en sus inicios con dolor, fatiga y/o debilidad muscular, todo ello antes de tener diagnóstico positivo con pruebas de laboratorio [55], que puede llevar a confusión y realizar un diagnóstico erróneo.

Muchos profesionales de la salud son escépticos con el síndrome, probablemente por desconocimiento de las cada vez más numerosas pruebas objetivas que ayudan en la caracterización del síndrome [56]. El tiempo en establecer el diagnóstico a menudo lleva años, de hecho, el promedio desde el inicio de los primeros síntomas hasta el diagnóstico es de 6,5 años [57], con incontables visitas clínicas y consultas a especialistas, comportando una gran carga personal, social y de recursos sanitarios [55,56,58].

Al ser la etiología desconocida, sus aproximaciones siguen siendo poco claras, no obstante, cada vez se tiene más conocimiento sobre el FMS. Ha habido investigaciones que han analizado la influencia de la inflamación de pequeñas fibras periféricas sobre la aparición de los síntomas [59]. La literatura sugiere que, en personas con FM, hay una falta de regulación de las citoquinas IL-1, IL-6 e IL-8 [60]. Se sabe que la presencia de diversas citoquinas que inducen síntomas inflamatorios, están relacionados con la modulación de la hiperalgesia, la fatiga, los trastornos del sueño y el dolor entre otros.

Otra línea ha relacionado el dolor experimentado con la falta de condición física de quienes lo padecen [61,62]. Pero sin duda, la característica del síndrome y que tiene una mayor aceptación es la que atribuye su aparición a un problema de sensibilización central [15]. Existen cambios en el procesamiento central de la señal nociceptiva, que, a su vez, producen una alteración de los mecanismos encargados de regular la sensación de dolor, con una amplificación de la entrada nociceptiva y una perpetuación de los estímulos dolorosos [63]. De hecho, hay estudios que han

observado una hiperperfusión en regiones cerebrales encargadas de la dimensión sensorial del procesamiento del dolor y una hipoperfusión en áreas relacionadas con la dimensión afectivo-atencional [64,65]. El dolor, en el caso de estas personas, está relacionado con la sensibilización central que ocasiona una serie de cambios en el procesamiento de la información del Sistema Nervioso Central (SNC) que altera los mecanismos que regulan la sensación de dolor [63], y esto lleva asociados cambios como ejemplo la disminución de la actividad de la corteza cingulada anterior y otras área frontales que perpetúan la sensación dolorosa [15,66].

Otra línea de investigación, es la predisposición genética a sufrir el FMS [67]. Se ha descubierto que los eventos de la vida temprana, incluidos el trauma físico y los estresores psicosociales, influyen en su expresión génica y, por lo tanto, contribuyen a la aparición del FMS. No obstante, el medio ambiente también puede estar involucrado en el desarrollo del síndrome [68]. Asimismo, los eventos adversos durante la vida neonatal e infantil, como el nacimiento prematuro, abuso físico y sexual; posiblemente contribuyen a una alteración del umbral de dolor en la edad adulta y al desarrollo de la aparición del FMS.

Se trata de un síndrome caracterizado por múltiples signos y síntomas que, además, evolucionan y se modifican con el tiempo pudiendo no coincidir con los observados clínicamente en una etapa prodrómica. Esto lleva a las personas con FMS a la incertidumbre de no saber cuál va a ser su evolución. En esta línea ha habido diversos intentos para determinar tipos de FMS distintos en función de los síntomas con la intención de orientarse hacia la investigación traslacional que beneficie en mayor medida la funcionalidad y la calidad de vida de las/los pacientes. De Souza *et al.,* determinaron 2 subgrupos de FMS. Un tipo I, en el que predominaba un alto grado de dolor, fatiga y rigidez y un tipo II, en el que además de predominar el dolor, la fatiga y la rigidez, existía un elevado nivel de cansancio acompañado de ansiedad y depresión [69]. Por otro lado, en un estudio observacional, con 3.035 pacientes con FMS, encontraron 5 subtipos con diferentes características clínicas que se indican a continuación [70].

1. Hipersensibilidad a los estímulos térmicos
2. Dolor térmico y sensibilidad mecánica casi ausentes, pero con sensación de picor de moderada a fuerte

3. Dolor intenso a la presión acompañado de dolor intenso al tacto
4. Ataques de dolor severo y fuertes dolores por presión
5. Niveles más altos de ansiedad y depresión, que dominaban el cuadro clínico

Por todo lo anteriormente expuesto, es importante determinar más características clínicas que puedan caracterizar a las/los pacientes con FMS pues la etiología y la patogénesis del FMS aún se desconocen [71]. De lo que no hay duda es de que se trata de un síndrome multifactorial [15] y, por lo tanto, para poder mejorar su manejo, determinar cambios en la severidad de los síntomas y planificar programas de tratamiento, se deben contemplar diferentes enfoques para mejorar el bienestar y la calidad de vida de las personas con FMS.

3. REPERCUSIÓN FUNCIONAL DEL SÍNDROME DE LA FIBROMIALGIA

3.1. Concepto de capacidad física

La condición física es un componente del estado de rendimiento de una persona y depende de sus capacidades psico-físicas. Sus capacidades físicas, también se denominan cualidades o habilidades motrices [72]. Son habilidades comunes en todos los individuos, y se relacionan con tres acciones distintas: la locomoción, el control corporal y la manipulación de objetos. Las capacidades físicas básicas están determinadas genéticamente, son condiciones internas de cada organismo que permiten realizar actividades motoras. Estas capacidades físicas o habilidades motrices se dividen en capacidades motrices condicionales o coordinativas [73].

Las capacidades físicas condicionales, son las habilidades físicas básicas de un individuo, aquellas innatas en el individuo, factibles de medida y mejora, que permiten el movimiento y el tono postural, como son [72,74]:

- Fuerza
- Resistencia
- Velocidad
- Flexibilidad

Las capacidades coordinativas, son las cualidades perceptivo motrices y se asocian a la disposición ordenada de las acciones para cumplir un objetivo. Estas son:

- Coordinación
- Equilibrio
- Percepción

3.2. Capacidad física en fibromialgia

Se sabe, que las mujeres con FMS presentan una condición física general deteriorada y más reducida que las mujeres sanas de su misma edad [75-77] y presentan una reducción de su capacidad de rendimiento físico [78]. En varios de los estudios previos que han centrado su atención en su evaluación en personas con fibromialgia, también denominan a la capacidad física como aptitud física [76,79].

Por un lado, parece ser que las mujeres con FMS realizan menos actividad física y son más sedentarias a causa de su sintomatología, refieren necesitar un mayor descanso y reposo [80]. Por otro lado, la baja condición física se ha observado que aumenta la fatiga, la rigidez y el riesgo de caída [79,81]. Además, se ha asociado el dolor y la ansiedad con un peor estado físico, en concreto, con una disminución de la fuerza, la aptitud cardiorrespiratoria y la flexibilidad superior del cuerpo [77,82].

Esta alteración que se produce en las personas con FMS, está en línea con lo que ocurre con las personas con dolor crónico que, en general, presentan una peor capacidad física, lo cual, repercute en sus actividades diarias y en su capacidad para gestionarla [83,84]. A continuación, se expone brevemente el estado del arte de las diferentes capacidades físicas en FMS.

Fuerza

Existe controversia respecto al nivel de fuerza que presentan. El estudio de Häkkinen *et al.,* no encuentra diferencias a nivel de fuerza isométrica entre las mujeres con FMS y sus homólogas sanas [85]. En cambio, otros estudios sí que observan una reducción de su fuerza tanto a nivel de miembros superiores [75,86], miembros inferiores [87] y fuerza de agarre [75,76,86], siendo su fuerza similar al de mujeres adultas mayores sanas [88,89], relacionado con el aumento del riesgo de sufrir discapacidad asociada a la edad [90] y una menor independencia relacionada con el trabajo [87].

Resistencia

El aumento de la fatiga muscular es un síntoma del FMS que limita el rendimiento físico de las personas que lo padecen [91]. Varios estudios han evaluado el rendimiento muscular en personas con FMS, encontrando una disminución de este parámetro [91-95]. En cambio, en otros estudios no se observaron diferencias en la activación neuromuscular durante el ejercicio de resistencia fatigante entre mujeres con FMS y controles sanas, aunque las mujeres con FMS sí que informaron que experimentaron niveles más altos de fatiga autoinformada [85,96]. Estos resultados sugieren que la fatiga que experimentan es debido a un componente de sensibilización central [66]. Por otro lado, sí que se encontró una distribución alterada del tamaño de las fibras musculares y la disminución de la densidad capilar, que podría repercutir en la fatiga post-esfuerzo de las mujeres con FMS [96].

Velocidad

Las/los pacientes con FMS muestran velocidades de marcha alteradas tanto en la marcha confortable como en la marcha a máxima velocidad. Asimismo, hay una alteración de la cadencia, la zancada, la longitud de paso, las fases de oscilación y la base de apoyo [14,97]. Una investigación previa ha sugerido que la marcha confortable, en estos pacientes, se realiza preferentemente usando sus músculos flexores de cadera en lugar de sus flexores plantares de tobillo, aumentando su fatiga [98]. Todo ello concuerda con la investigación de Góes *et al.*, quienes han comprobado que su patrón de marcha es similar al de mujeres adultas mayores [99].

Flexibilidad

La flexibilidad se ha estudiado poco en la población con FMS; se sabe que está asociada al dolor [82] y se usa en los protocolos de entrenamiento para las personas con FMS [100]. Existe evidencia de que entrenar la flexibilidad junto con otras actividades físicas conlleva un envejecimiento saludable y se utiliza en el manejo de enfermedades crónicas como la osteoartritis, la diabetes mellitus o la obesidad [101]. Nuestro estudio analiza la flexibilidad de estas personas y su relación con otras variables.

Equilibrio

Las personas con FMS presentan un control postural alterado. De hecho, se calcula que aproximadamente el 45 % presentan dificultades en el equilibrio [102]. Se ha observado que presentan una mayor velocidad en el centro de presión y una estabilidad postural alterada [103,105,106]. Asimismo, algunos estudios han tratado de determinar, utilizando diferentes pruebas, qué entradas sensoriales estaban afectadas y eran responsables del control postural en esta población [103-105]. Algunos estudios sugieren que el equilibrio en personas con FMS puede depender de otros factores como la ansiedad, la depresión, la fatiga o por una disminución de la fuerza en miembros inferiores aunque no existe un consenso al respecto [107,108]. Como consecuencia directa de esta alteración del equilibrio en FMS, se ha asociado a un mayor riesgo de caídas [12].

4. OBJETIVOS

Por todo lo expuesto en el contexto del marco teórico, en esta sección se detallan los objetivos del presente trabajo de investigación.

4.1. Objetivo general

Determinar aquellos componentes biomecánicos y psicológicos, que influyen en la capacidad funcional de las mujeres con FMS y repercuten en su calidad de vida.

4.2. Objetivos específicos

Estudio 1

1. Determinar si las mujeres con FM sufren un deterioro del control postural en comparación con sus homólogas sanas.

2. Estudiar la contribución sensorial del control postural en esta población.

3. Analizar el impacto de la ansiedad autoinducida en el control postural. Explorar la relación entre el control postural y la fuerza de la extremidad inferior.

Nuestra hipótesis es que las mujeres con FMS muestran un control postural intrínseco más deficiente que las mujeres sanas de la misma edad. Asimismo, esta alteración no está mediada por la capacidad de desarrollar fuerza ni por la alteración emocional que padecen.

Estudio 2

1. Analizar la postura de tronco en mujeres con FMS en comparación con mujeres sanas.

2. Explorar el impacto del comportamiento sedentario en la postura del tronco.

Nuestra hipótesis es que las mujeres con FMS tienen una deficiente capacidad para mantener una postura correcta y que no está mediada por su falta de actividad física.

Estudio 3

1. Identificar factores predictores de la calidad de vida relacionados con la condición física y la ansiedad autoinducida.

2. Determinar las diferencias en la condición física de las mujeres con FMS en comparación con sus contrapartes saludables.

Nuestra hipótesis es que, las mujeres con FMS presentan una peor condición física que, a su vez, repercute en su calidad de vida.

SECCIÓN SEGUNDA

PROCEDIMIENTO GENERAL

PROCEDIMIENTO GENERAL

1. PROYECTO FIBROVAL

1.1. Petición del proyecto

En primer lugar, se redactó el proyecto "Desarrollo de una metodología de valoración del síndrome de fibromialgia (FIBROVAL)", para la convocatoria de proyectos de I+D para grupos de investigación emergentes de la Generalitat Valencia del año 2016. Fue concedido un presupuesto de 6.200 euros para la consecución de la investigación con código GV/2016/140, siendo la investigadora principal la Dra. Pilar Serra Añó, del grupo, Unidad de Biomecánica Clínica (*UBIC)*. La duración del proyecto fue de dos años, desde enero de 2016 hasta diciembre de 2017.

La finalidad del proyecto era desarrollar un índice que contemplara diferentes pruebas de valoración objetivas asignando un peso específico a cada una de ellas, de forma que se facilitara la identificación de las personas que sufren el FMS. Más específicamente, los objetivos del proyecto fueron:

- Conocer la repercusión del síndrome sobre la capacidad para mantener el equilibrio, tanto en tareas simples como en tareas duales.
- Valorar la influencia del síndrome en la capacidad para desarrollar una acción isométrica de las extremidades.
- Averiguar la capacidad funcional general de las participantes y el impacto del síndrome en su calidad de vida.
- Saber la actitud postural en las personas con FMS y su repercusión sobre la movilidad del raquis.
- Estudiar la fiabilidad y validez de las pruebas de valoración.
- Analizar la sensibilidad y la especificidad de las herramientas diseñadas.

Al mismo tiempo, se presentó la propuesta de proyecto, junto con su correspondiente solicitud, a la *Comissió d'Ètica en Investigació Experimental de la Universitat de València* para su aprobación. Los procedimientos descritos en la propuesta cumplían con los requisitos impuestos en la declaración de Helsinki de 1975, con la posterior revisión en el año 2013.

Para la recogida de los datos y la realización de las pruebas, se adoptaron las medidas oportunas para garantizar la completa confidencialidad de los datos personales de los sujetos de experimentación que participaron en este proyecto, de acuerdo con la Ley Orgánica 3/2018, de 5 de diciembre, de Protección de Datos de Carácter Personal y garantías de derechos digitales (en adelante, LOPD) y el Reglamento (UE) 2016/679, del Parlamento y del Consejo, de 27 de abril, relativo a la protección de las personas físicas en lo que respecta al tratamiento de datos personales y a la libre circulación de estos datos.

1.2. Reunión con los responsables de los centros de fibromialgia y búsqueda de participantes

Después de ser aprobada la propuesta de investigación por la *Comissió d'Ètica en Investigació Experimental de la Universitat de València* , (Anexo I), se empezó con la búsqueda de participantes. Con esta finalidad, se preparó la documentación necesaria sobre el estudio, para conseguir obtener la máxima difusión posible, con el objetivo de reclutar a la mayor cantidad de mujeres tanto con FMS como sanas para la muestra. Así pues, se organizaron varias entrevistas, por un lado, con el reumatólogo de gran relevancia internacional, el Dr. Eliseo Pascual Gómez, y con los máximos responsables de varias asociaciones de Fibromialgia:

- La Asociación Valenciana de Afectados de Fibromialgia (Avafi).
- La Asociación de Afectados de Fibromialgia Almussafes (Afaal).
- La Asociación de Fibromialgia y fatiga crónica (Adafir).
- La Asociación de Fibromialgia Alcoy (Asfial).
- La Asociación de Afectados de Fibromialgia Valencia Norte (Afivam).
- La Asociación de enfermos de Fibromialgia de Ontinyent.

Todas estas entidades colaboraron en la divulgación del proyecto mediante el envío de la información a todas las personas que estos organismos tenían en sus bases de datos, enviando emails de difusión y cartas por correo ordinario. Para ello se redactó un escrito descriptivo de la investigación (Anexo II), con los objetivos de la misma, los criterios de inclusión y exclusión, los datos de contacto del equipo investigador, y especificando que, al finalizar la investigación, se les facilitaría un informe sobre su estado de salud, basado en los datos obtenidos de su evaluación, en relación a sus resultados y en comparación a las sujetas sanas.

Por otro lado, para poder contactar con un mayor número de personas con FMS se realizó una búsqueda en internet de médicos reumatólogos y de todo tipo de asociaciones que tuvieran relación con la FMS. Según la información disponible de contacto, se les enviaba por escrito o se les comunicaba telefónicamente, los detalles y objetivos del proyecto, y la forma de realización.

Además, el reclutamiento de mujeres también se consiguió mediante el envío masivo de un mensaje de texto vía la aplicación gratuita *WhatsApp*, (Anexo III), a través de los contactos de las asociaciones, de reumatólogos, de los compañeros del *Departament de Fisioteràpia* de la *Universitat de València* y con la difusión del mensaje por fisioterapeutas de la red de salud de la *Conselleria de Sanitat Universal i Salut Pública de la Generalitat Valenciana*, con el fin de hacer llegar la información del proyecto a mujeres con FMS y mujeres que formaran parte del grupo control.

A través de este mensaje vía *WhatsApp*, contactaron con el equipo de investigación varias mujeres de Villar del Arzobispo, interesadas en colaborar. Por ese motivo, se organizó una reunión con un representante del Ayuntamiento de esta localidad. Después de esta entrevista, se preparó un bando para su difusión (Anexo IV).

Al mismo tiempo, desde este Ayuntamiento, se facilitó un espacio que fuese adecuado y reuniera las características específicas para poder realizar allí las mediciones, de forma que las mujeres no tuvieran que desplazarse a Valencia. El equipo de investigación se desplazó a esta población para examinar a las participantes que finalmente quisieron colaborar.

En la ciudad de Alcoi, la *Colla de Dolçaines i Tabal de Barxell*, cedió su local, pues disponían de un espacio con las características idóneas para instalar los aparatos de valoración y se adecuó para su uso.

Además, desde varias asociaciones, concretamente Adafir, Afaal, Avafi y Aefo, se organizó una reunión con las socias sobre el proyecto de investigación, en cada uno de los cuatro centros, para que las mujeres resolvieran dudas. Y en las localidades de Ontinyent, Almusafes y Alzira se facilitó un local para poder efectuar las mediciones de cada participante. Estos espacios fueron previamente acondicionados para asegurar la óptima ejecución de las pruebas.

Las mujeres de la zona de Valencia acudieron al *laboratori d'avaluació i recuperació funcional del Departament de Fisioteràpia de la Universitat de València*, donde se realizaba su evaluación.

En todas las salas donde se iban a llevar a cabo las valoraciones, se comprobó el correcto funcionamiento de todos los aparatos de evaluación. Además, previamente, el equipo de investigación simuló una secuencia de las distintas mediciones físicas y funcionales, así como de la batería de escalas, para comprobar los tiempos requeridos cada valoración, de manera que fuese viable llevarlo a cabo en una única sesión.

A continuación, en la Tabla 1, se muestran las diferentes formas de captación de las participantes y el número de mujeres con FMS que finalmente accedieron:

Tabla 1. Medios de captación de las participantes con FMS.

Formas de captación a través de:	**Lugar**	**Mujeres**
Asociación Valenciana de Afectados de Fibromialgia (Avafi)	Valencia	45 (57)
Asociación de Afectados de Fibromialgia Almussafes (Afaal)	Almussafes	17 (25)
Asociación de Fibromialgia y fatiga crónica (Adafir)	Alzira	12 (17)
Asociación de Fibromialgia Alcoy (Asfial)	Alcoy	8 (19)
Asociación de Afectados de Fibromialgia Valencia Norte (Afivam)	Valencia	12 (15)
Asociación de enfermos de Fibromialgia de Ontinyent (Aefo)	Ontinyent	7(13)
Villar del Arzobispo	Villar del Arzobispo	3 (3)

Entre paréntesis aparecen las mujeres con FMS que mostraron su voluntad de participar pero que, finalmente, no formaron parte del proyecto por no estar interesadas o por no cumplir los criterios de inclusión y exclusión.

En la siguiente tabla, (Tabla 2) se exponen las diversas vías que sirvieron para obtener mujeres sin FMS y el número de ellas que finalmente aceptó:

Tabla 2. Medios de captación de las participantes sin FMS.

Formas de captación a través de:	**Lugar**	**Mujeres**
Asociación Valenciana de Afectados de Fibromialgia (Avafi)	Valencia	3 (7)
Asociación de Fibromialgia Alcoy (Asfial)	Alcoy	2 (5)
Asociación de enfermos de Fibromialgia de Ontinyent (Aefo)	Ontinyent	3 (8)
Universitat de València	València	8 (13)
Villar del Arzobispo	Villar del Arzobispo	27 (38)
Fisioterapeutas *Conselleria de Sanidad*	Valencia	19 (1)
Mensaje vía WhatsApp	Varias localidades	56 (65)

Entre paréntesis aparecen las mujeres con FMS que mostraron su voluntad de participar pero que finalmente no formaron parte del proyecto por no estar interesadas o por no cumplir los criterios de inclusión y exclusión.

Posteriormente, y a medida que se iban produciendo las respuestas manifestando voluntad de participación, se contactó por teléfono para dar una explicación más detallada del estudio, comentar los requisitos para participar en el mismo y solucionar posibles dudas. Una vez confirmada la disponibilidad de las participantes, se les citó personalmente en la *Universitat de València* o en los diferentes pueblos y ciudades donde se iban a llevar a cabo las evaluaciones.

Durante la entrevista personal, de nuevo, se explicó el tipo de valoraciones y pruebas que se realizarían, así como se resolvieron dudas que tuviesen al respecto y a continuación se les proporcionó el consentimiento informado (Anexo V) para su aclaración, discusión y firma, mostrando su conformidad en participar en el estudio y el consentimiento del uso de la imagen (Anexo VI). Se recogieron los datos básicos necesarios para conocer el cumplimiento de los criterios de inclusión o exclusión. Una vez obtenida la participación voluntaria, se dio comienzo a la sesión de evaluación, con un evaluador, que anotó en el cuaderno de recogida de datos los resultados de los distintos cuestionarios, los datos sociodemográficos y los diferentes resultados del protocolo de evaluación.

Entre el periodo de enero a diciembre de 2017 se realizaron las mediciones. El protocolo de mediciones consistía en: i. recogida de datos sociodemográficos, ii. administración del cuestionario de calidad de vida relacionada con la salud (SF-

36) y las escalas de ansiedad de Hamilton y la escala visual analógica del dolor iii. medición de la composición corporal, iv. valoración del equilibrio, v. medición de la fuerza isométrica de prensión y de miembro superior e inferior, vi. medición de la flexibilidad, vii. análisis de la postura y viii. evaluación del umbral de dolor.

Una vez concluida la fase de recogida de datos, se les hizo entrega del informe de su estado de salud.

2. PARTICIPANTES

Para reclutar a las mujeres, se realizó un muestreo no probabilístico, con la combinación de un muestreo incidental junto con un muestreo tipo bola de nieve. En el primer caso, se contactó, por un lado, con mujeres con FMS y por otro, con mujeres sanas, las cuales cumplían todos los criterios de inclusión, y que habían participado en investigaciones de características similares planteados por el equipo investigador. De estas, sólo 16 mostraron su disponibilidad para participar en el estudio. De las mujeres contactadas en la mayoría de asociaciones, aproximadamente el 40 % de todas las mujeres con FMS que cumplían los requisitos para participar, lo hicieron. El muestreo tipo bola de nieve se dio en un porcentaje muy alto de casos pues cuando la información del estudio llegaba a una mujer de una asociación o ciudad, y esta participaba en el estudio, posteriormente lo hacían otras mujeres cercanas y conocidas de la primera.

El tamaño muestral se estimó estableciendo un tamaño del efecto medio (f^2=0.063), una potencia de 80 % y un error de tipo I de un 5 %. Asimismo, se contempló la posibilidad de hacer tres agrupaciones, contando con el grupo de mujeres sin fibromialgia y dos hipotéticos grupos de gravedad del FMS. Asimismo, dado que el estudio pretendía caracterizar la capacidad funcional general de este tipo de personas, se determinó un cálculo a priori de 20 variables dependientes. Con estos condicionantes, el tamaño requerido fue de 237 personas. El número final de mujeres que se incluyeron en el estudio fue de 250. De los 250 registros iniciales, finalmente quedaron 235. Para cada estudio se hizo un cálculo de tamaño muestral específico, como se verá más adelante, en el apartado de cada estudio, donde se describen las características específicas de las participantes.

Los criterios de inclusión que debían reunir las participantes fueron los siguientes: i. mujeres entre 43 a 70 años, ii. si eran del grupo de Fibromialgia (FMG) debían estar diagnosticadas conforme a los criterios del 2010 de la *American College of Rheumatology*. Como criterios de exclusión se tuvieron en cuenta: i. presentar una enfermedad reumática, ii. alteraciones neurológicas, iii. que sufrieran alguna enfermedad aguda y terminal, iv. trastornos del oído interno, v. vértigos o mareos actuales, vi. enfermedad del sistema visual que pudiera limitar de forma significativa la visión (cataratas con pérdida de visión o glaucoma con reducción del campo de visión), vii. neuropatía periférica, viii. cirugía previa durante el año anterior que causara déficit de equilibrio, ix. historial de fracturas o cirugía de la columna vertebral, x. enfermedades del aparato locomotor que impidiesen una correcta bipedestación, deambulación o la imposibilidad de sentarse en el suelo, xi. dificultades cognitivas o con insuficiente dominio de los dos idiomas oficiales de la Comunidad Valenciana que -a juicio del profesional sanitario que realizaba el reclutamiento- dificultaba la comprensión de las distintas evaluaciones y xii. que participaran en otros estudios similares durante las valoraciones.

A cada consentimiento informado firmado se le asignó un código alfanumérico, que lo identificaba, asegurando la confidencialidad de los datos personales tal como estipula la ley Orgánica 15/1999, de 13 de diciembre, de Protección de Datos de Carácter Personal, siendo custodiado este documento por separado de los datos obtenidos del estudio.

3. MATERIAL Y MÉTODOS

Para el desarrollo del protocolo de mediciones del presente estudio, se detallan a continuación las herramientas y los materiales utilizados. Se describe el formulario de registro, los diferentes cuestionarios y escalas que fueron empleados para determinar el umbral de dolor, la capacidad funcional y la calidad de vida. Asimismo, se describen las herramientas biomecánicas objetivas utilizadas para medir la fuerza, el equilibrio, la flexibilidad, la antropometría y la postura.

3.1. Formulario de registro

En el formulario de registro se anotó, a modo de cuaderno de recogida de datos, toda la información relacionada con la valoración del cumplimiento de sus datos sociodemográficos, los criterios de inclusión de las participantes y el formulario de cumplimentación de la historia clínica del paciente. (Anexo vii)

Además, de forma adicional, se hizo una entrevista semiestructurada sobre sus hábitos sedentarios y si realizaba actividad física. Se clasificó a las participantes en tres grupos según si eran completamente inactivas, si realizaban ejercicio físico o deporte de forma esporádica u ocasional o si lo practicaban de forma regular. Asimismo, se registró cuánto tiempo lo realizaban a la semana.

3.2. Cuestionarios y escalas utilizados para la valoración de las participantes.

Una vez detallado el cuestionario de recogida de datos, se presentan en este apartado las escalas y cuestionarios utilizados para la valoración de las participantes.

Cuestionario SF-36, versión española (SF-36).

Este cuestionario es genérico, la escala es también autoadministrada y evalúa la calidad de vida relacionada con la salud, sirve tanto para pacientes como para la población en general [109]. Está compuesto por 36 ítems que evalúan aspectos negativos y positivos de la salud, dividiéndose en 8 escalas que representan distintas dimensiones relacionadas con la salud: función física, rol físico, dolor corporal, salud general, vitalidad, función social y salud mental. Adicionalmente, incluye una pregunta de transición sobre el cambio en el estado de salud general con respecto al año anterior. Se puntúa del 0 al 100, siendo una mayor puntuación indicativo de un mejor estado de salud y/o una mejor calidad de vida. Además, el cuestionario permite el cálculo de dos puntuaciones resumen, física y mental, mediante la suma ponderada de las puntuaciones de las ocho dimensiones principales [110].

- Función física: se refiere a la capacidad o limitación para realizar todas las actividades físicas desde las actividades básicas de la vida diaria como bañarse o vestirse hasta las más vigorosas, debido a la salud.

- Rol físico: indica si existen o no problemas con el trabajo u otras actividades diarias como consecuencia de la salud física.
- Dolor: se relaciona con la percepción de la sensación de dolor que tiene el paciente.
- Salud general: se refiere a su creencia sobre si su salud es mala y empeorará o es excelente.
- Vitalidad: evalúa la sensación de fatiga, cansancio y agotamiento que siente todo el tiempo o bien si refiere entusiasmo y energía.
- Función social: examina la capacidad de realizar actividades sociales normales o ausencia debido a problemas emocionales o físicos.
- Rol emocional: analiza la existencia de dificultades en el trabajo u otras actividades diarias como resultado de problemas emocionales.
- Salud mental: indica cuál es su estado mental analizando si existe una sensación de nerviosismo, depresión o todo lo contrario, de paz, calma, felicidad…

La puntuación se obtiene homogeneizando la dirección de las respuestas mediante la recodificación de los 10 ítems que se deben ordenar, con la finalidad de que todos los ítems sigan el rango de "a mayor puntuación, mejor estado de salud". A continuación, se suman los ítems que componen la escala y luego se requiere una transformación lineal de las puntuaciones para obtener puntuaciones en una escala de 0 a 100, obteniendo las puntuaciones transformadas de la escala. Así pues, para cada dimensión, los ítems han sido codificados, agregados y transformados en una escala que tiene un recorrido desde 0 (el peor estado de salud) y 100 (el mejor estado de salud) [111].

Las características que definen esta escala se detallan a continuación:

- Carga administrativa: el tiempo que emplean los sujetos en la contestación de la escala es menor de 15 minutos.
- Fiabilidad (test-retest): el ICC toma valores desde 0,58 hasta 0,99 [112].
- Consistencia Interna: el Alfa de Cronbach es elevado, con un rango desde 0,71 a 0,94, excepto para la escala de Funcionamiento Social (alfa = 0,45).

- Validez: se correlaciona con la Escala Visual Analógica del dolor con una puntuación de r = 0,90 (p<0,01).

Hamilton Anxiety Rating Scale (HARS)

Esta escala es heteroadministrada está compuesta por 14 ítems que evalúan el estado de ansiedad con 5 opciones de respuesta ordinal (0: ausencia del síntoma; 4: síntoma muy grave o incapacitante). La puntuación total del instrumento, que se obtiene por la suma de las puntuaciones parciales de los 14 ítems, puede oscilar en un rango de 0 puntos (ausencia de ansiedad) a 56 (máximo grado de ansiedad) [113,114].

Las características que definen esta escala se detallan a continuación:

- Carga administrativa: el tiempo que emplean los sujetos en la contestación de la escala es menor de 7 minutos.
- Fiabilidad (test-retest): coeficiente de correlación intraclase superior a 0,92.
- Consistencia Interna: el Alfa de Cronbach es de 0,89.

Escala visual analógica del dolor (EVA)

La escala visual analógica (EVA) sirve para medir la intensidad del dolor percibido. Es una escala de calificación de 11 puntos, con una línea continua entre dos puntos, desde el 0 al 10, (0= sin dolor a 10 = el dolor más intenso imaginable)[115].

Las características que definen esta escala se detallan a continuación:

- Carga administrativa: el tiempo que emplean los sujetos en la contestación de la escala es menor de 3 minutos.
- Fiabilidad (test-retest): el ICC está entre desde 0,97 hasta 0,99 [116].
- Consistencia Interna: el Alfa de Cronbach es de 0,87 - 0,89 [117].

3.3. Pruebas clínicas de condición física

Test V- Sit and reach (VSR)

La flexibilidad global de la cadena posterior se midió con el *test V- Sit and reach* (VSR) que se corresponde con una versión modificada del test sit and reach clásico [118]. Requiere de procedimientos más simples y sin necesidad de usar un equipamiento específico, en comparación a la prueba *Sit and Reach*. Se coloca el sujeto sentado en el suelo con las piernas en V separadas a 30 cm y una cinta métrica en medio que marque los 23 cm a partir de la línea del talón. Posee una moderada validez para estimar la flexibilidad isquiosural y una elevada fiabilidad relativa intraexaminador [119].

Test dos minutos marcha

La prueba de caminata de dos minutos (2MWT, de las siglas en inglés) se utilizó para medir la capacidad funcional. Este test se utilizó por primera vez en 1982, para personas con trastornos respiratorios [120]. Se llevó a cabo siguiendo las instrucciones del estudio realizado por Johnston y colegas [121]. Esta prueba consiste en determinar la distancia máxima (en metros) que se puede caminar en 2 min. Esta prueba muestra una buena correlación con la prueba de caminata de seis minutos (6MWT), que se utilizó ampliamente como una medida confiable de la capacidad funcional en individuos con diferentes características [122,123], incluidos los individuos con fibromialgia [82]. Sin embargo, esta prueba es menos fatigante y mejor tolerada [124].

Equilibrio

La valoración del equilibrio se realizó mediante la plataforma dinamométrica *Wii Balance Board* (WBB) (Nintendo, Kyoto, Japón). Estudios previos habían validado este instrumento para analizar el control postural en bipedestación [125,126]. Se usó esta plataforma móvil para poder realizar las valoraciones *in-situ* en las diferentes asociaciones de FMS y locales cedidos, pues el uso de una plataforma de equilibrio encastrada en el suelo hubiera requerido de una valoración centralizada. Por este motivo se tuvo que diseñar un software en el entorno de Matlab R2007 (Mathworks Inc, Natick, EEUU) con la finalidad de poder adquirir las señales y guardarlas en

formato .txt. para su posterior análisis. En la Figura 1 se observa el entorno gráfico de la aplicación de adquisición de la señal.

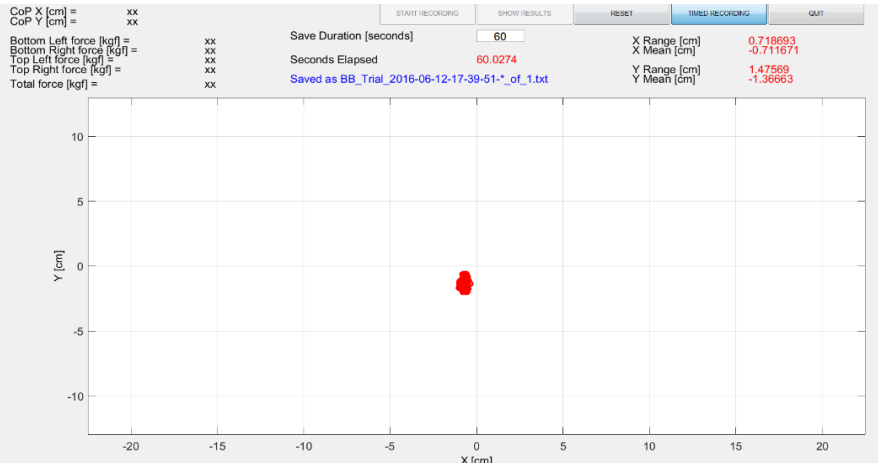

Figura 1. Entorno gráfico del software de adquisición de la señal posturográfica. En rojo se observa el estatocinesiograma de un sujeto participante.

La plataforma fue colocada siempre en una superficie estable en el suelo para evitar la distorsión de la señal y el ruido. Se les mostraba a las mujeres donde debían colocar sus pies, de forma que quedaran separados a la altura de las caderas, los dedos apuntando hacia adelante y los brazos relajados a los lados. Para las pruebas se situó delante de la persona un punto de referencia a 2 metros de distancia a la altura de los ojos. A continuación, se les informaba sobre la importancia de mantener esta posición y que evitaran en la medida de lo posible, realizar cualquier movimiento del cuerpo. Se realizaron cinco pruebas, de cada una se hicieron dos repeticiones consecutivas de 60 segundos [127], descansando durante 30 segundos entre pruebas y repeticiones, excepto si necesitaban un tiempo extra. Las pruebas realizadas fueron:

- Ojos abiertos
- Ojos cerrados
- Tarea *Dual Task*, consistía en describir un día estresante que hubieron vivido.
- Ojos abiertos de pie encima de una goma espuma de 45 x 27 x 9 cm y la densidad de la cual era de 56,7 kg/m^3.
- Ojos cerrados de pie sobre la goma espuma.

Para el análisis de los datos se tuvo, en primer lugar, que acondicionar la señal posturográfica obtenida del desplazamiento del centro de presiones (CDP). Para ello se diseñó un programa en el entorno Matlab, mediante el cual los desplazamientos en el plano mediolateral (ML) y anteroposterior (AP) del CDP se filtraron digitalmente con un filtro de paso bajo Butterworth con una frecuencia de corte 12 Hz. Como la estabilización retardada había sido reportada previamente, los primeros 10 segundos de cada ensayo fueron excluidos del análisis. Las señales se registraron a una frecuencia de 40 Hz. Del análisis de la señal posturográfica se decidió utilizar una serie de variables dependientes cuya justificación se fundamenta en la Tabla 3 [125,128].

Tabla 3. Justificación de las variables posturográficas.

Variable	Justificación
Elipse	El área de la elipse se utilizó como la principal medida de la estabilidad postural. El tamaño total de la elipse resume la cantidad de movimiento en general, y la orientación relativa de la elipse es una indicación de la medida en que están correlacionados los movimiento de las caderas y los tobillos [129].
RMS	Cuantifica la variabilidad alrededor de la trayectoria media del centro de presiones (CDP). Esta variable es sensible a la alteración [130]. Cuando la retroalimentación somatosensorial responsable de la postura y la propiocepción se retrasa, lo que resulta en un aumento de esta variable [131].
Entropía muestral	Indica la regularidad del CDP y podría ser interpretado como la automaticidad del control postural [132].

Fuerza

Mediante el dinamómetro portátil NedVEP/IBV (Instituto de Biomecánica de Valencia, Valencia, España) se midió la fuerza de agarre de las participantes. A continuación, se midió la fuerza de bíceps y de miembros inferiores, concretamente cuádriceps e isquiotibiales, realizando una contracción isométrica con el dinamómetro portátil NedDFM / IBV (Instituto de Biomecánica de Valencia, Valencia, España). Se realizaron tres repeticiones de cada medición consecutivamente con un descanso de 30 segundos entre ellas. Se calculó la media entre las repeticiones. Como estos dinamómetros portátiles no habían sido validados con anterioridad, previamente se realizó un estudio de fiabilidad con 15 mujeres sanas, que fueron evaluadas en dos sesiones diferentes (con ocho días de diferencia) por dos fisioterapeutas. La fiabilidad interna e interobservador se determinó comparando los valores obtenidos por los dos evaluadores diferentes el

mismo día. La fiabilidad entre días e intraobservadores se determinó comparando los resultados de dos evaluaciones repetidas por el mismo evaluador, con al menos ocho días de diferencia. La fiabilidad entre días y entre observadores se determinó comparando los resultados de dos evaluaciones realizadas por los dos evaluadores diferentes con ocho días de diferencia.

3.4. Valoración de la postura

Paralelamente a las medidas de la condición física, se evaluaron otros elementos de la biomecánica corporal, como la postura.

Test medición cifosis torácica

Para medir el grado de cifosis torácica, se siguió el protocolo de medición establecido por Lewis y Valentine [133]. Las participantes mantenían una postura cómoda, erguida, mirada al frente. Se les colocaban unos marcadores adhesivos en las espinosas de las vértebras dorsales T1, T2 y T12 y en la de la primera vértebra lumbar (L1). A continuación, se apoyaban en esas dos regiones formadas por T1 y T2 y por T12 y L1, dos inclinómetros de burbuja (*Fabrication Enterprises, Inc, White Plains, NY*). Se realizaron tres repeticiones y se calculó su media para análisis posteriores.

Prueba del ángulo cráneovertebral

La medición del ángulo craneovertebral se realizó mediante el protocolo de Falla *et al.*[134], para averiguar si las mujeres con FMS presentaban la cabeza adelantada [135]. Se sentaron en una silla sin respaldo, con las rodillas y las caderas flexionas a noventa grados, los pies apoyados en el suelo y con la cabeza fija mirando hacia delante. A continuación, se colocaron unos marcadores adhesivos en las apófisis espinosas de la séptima vértebra cervical, la séptima vértebra dorsal y, por último, en la región anatómica del trago de la oreja, como se observa en la Figura 2.

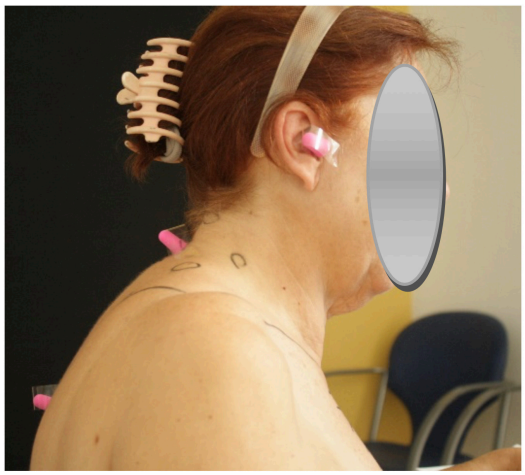

Figura 2. Determinación del ángulo cráneovertebral de una participante.

En el laboratorio, perpendicular al plano sagital y a 80 cm de cada paciente, se colocaba una cámara digital, Canon EOS 1200D (18 Mpx), para tomar una foto. A continuación, esos datos fotográficos fueron analizados con el software ImageJ [136]. Para medir el ángulo cráneovertebral, se trazó una línea desde el trago hasta la apófisis espinosa de C7 y se obtuvo el ángulo de esta línea con la intersección con la línea horizontal.

Test de protracción del hombro

La medición de la protracción basal del hombro se midió utilizando el protocolo para el pectoral menor de Lewis y Valentine [137]. Se colocó a las participantes en decúbito supino sobre una camilla con una superficie dura, y se les indicó que estuvieran relajadas, con las manos apoyadas cómodamente sobre su abdomen. A continuación, se procedió a medir la distancia lineal en centímetros usando una escuadra estándar de plástico rígido, con una altura de 17 cm y una base de 14 cm. Sin ejercer ninguna presión sobre la camilla, la base de la escuadra se colocó en la camilla y el lado vertical sobre el lado de la cara lateral del acromion y se midió la distancia en cm.

Para la medición máxima de la protracción de hombro, manteniendo la misma posición, se pidió que levantaran el hombro hacia arriba tanto como les fuera posible, en un plano anatómico transversal manteniendo los codos en contacto con la camilla.

Se repitieron tres veces ambas mediciones y se calculó la media para cada uno de los test, la basal y la medición máxima.

Prueba de postura sentada

Con esta prueba, se evaluó la capacidad de mantener la postura del tronco erguida durante cinco minutos, evaluando el ángulo cervical y torácico. Las participantes estaban sentadas en la misma posición descrita en la prueba del ángulo cráneovertebral, pero esta vez, delante de un ordenador. Este, estaba colocado en frente de ellas, con el borde superior de la pantalla justo debajo de la altura de sus ojos, para asegurar que mantenían la mirada fija con una posición neutra de la cabez. Llevaban unos marcadores adhesivos en el trago y en las espinosas de las vértebras C7 y T7, tal y como se ha explicado previament [134]. Luego, debían leer una novela en el ordenador durante 5 minutos, de forma que las mujeres estuvieran distraídas. La mano dominante manejaba el ratón para pasar las páginas, y la otra, descansaba inmóvil encima del escritorio. Se tomaron 6 fotografías, una en el momento inicial y a continuación una cada minuto, para observar si existía un cambio en la postura, usando el mismo procedimiento de la prueba del ángulo cráneovertebral, (Figura 2). A continuación, las imágenes también fueron analizadas con el ImageJ [136]. El ángulo cervical se formó con la intersección de la línea trazada desde el trago a la espinosa de la vértebra C7 con la línea horizontal; mientras que el ángulo torácico se formó con la intersección de la línea dibujada de la espinosa de C7 a la apófisis espinosa de la vértebra T7 con la línea horizontal.

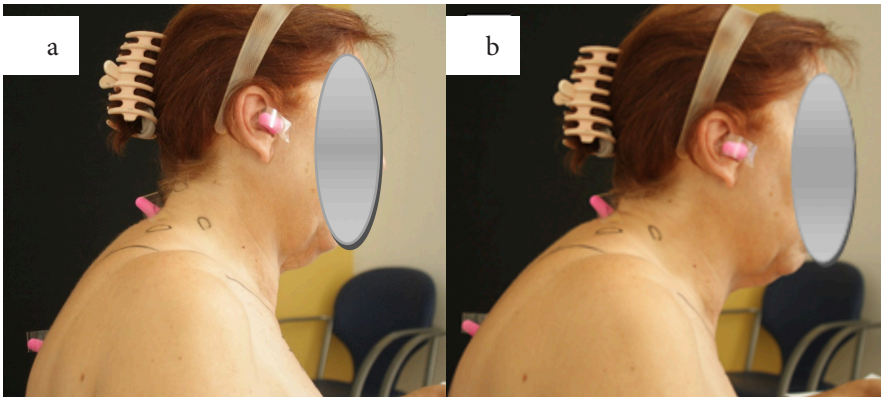

Figura 3. Prueba del mantenimiento de la postura del tronco. a) Postura al inicio del test; b) postura al finalizar el test.

3.5. Valoración del umbral de presión al dolor

El umbral de presión al dolor se midió con un algómetro Wagner FPK 20 (Wagner Instruments, Greenwich, CT, EE. UU.) Con un área de contacto de 1 cm^2 aplicada perpendicularmente a la piel siguiendo el protocolo de Slater y colaboradores [138]. Se midió el músculo trapecio, ubicando el algómetro en el área del trapecio superior en el punto medio entre la apófisis espinosa de C7 y el acromion. Se realizaron tres repeticiones de la medición, de forma consecutiva, con un descanso de 60 segundos entre ellas, y se calculó la media de las repeticiones.

REFERENCIAS BIBLIOGRÁFICAS

REFERENCIAS BIBLIOGRÁFICAS

1. Wolfe F, Clauw DJ, Fitzcharles MA, Goldenberg DL, Katz RS, Mease P. The American College of Rheumatology preliminary diagnostic criteria for fibromyalgia and measurement of symptom severity. Arthritis Care Res. 2010;62:600-10.

2. Talotta R, Bazzichi L, Di Franco M, Casale R, Batticciotto A, Gerardi MC, et al. One year in review 2017: fibromyalgia. Clin Exp Rheumatol. 2017;35Suppl105(3):6-12.

3. Schweiger V, Del Balzo G, Raniero D, De Leo D, Martini A, Sarzi-Puttini P, et al. Current trends in disability claims due to fibromyalgia syndrome. Clin Exp Rheumatol. 2017;35Suppl 105(3):119-26.

4. Rasouli O, Stensdotter A-K, Van der Meer ALH. TauG-guidance of dynamic balance control during gait initiation in patients with chronic fatigue syndrome and fibromyalgia. Clin Biomech Bristol Avon. 2016;37:147-52.

5. Heidari F, Afshari M, Moosazadeh M. Prevalence of fibromyalgia in general population and patients, a systematic review and meta-analysis. Rheumatol Int. 2017;37(9):1527-39.

6. Wolfe F, Ross K, Anderson J, Russell IJ. Aspects of fibromyalgia in the general population: sex, pain threshold, and fibromyalgia symptoms. J Rheumatol. 1995;22(1):151-6.

7. Nielsen LA, Henriksson K. G. Pathophysiological mechanisms in chronic musculoskeletal pain (fibromyalgia): the role of central and peripheral sensitization and pain disinhibition. Best Pract Res Clin Rheumatol. 2007;21(3):465-80.

8. Meeus M, Nijs J. Central sensitization: a biopsychosocial explanation for chronic widespread pain in patients with fibromyalgia and chronic fatigue syndrome. Clin Rheumatol. 2007;26(4):465-73.

9. Sluka K.A, Clauw DJ. Neurobiology of fibromyalgia and chronic widespread pain. Neuroscience. 2016;338:114-29.

10. Smith HS, Bracken D, Smith JM. Duloxetine: A Review of Its Safety and Efficacy in the Management of Fibromyalgia Syndrome. J Cent Nerv Syst Dis. 2010;2:57-72.

11. Chinn S, Caldwell W, Gritsenko, K. Fibromyalgia Pathogenesis and Treatment Options Update. Curr Pain Headache Rep. 2016;20(4):25.

12. Jones KD, Horak FB, Winters-Stone K, Irvine JM, Bennett RM. Fibromyalgia is associated with impaired balance and falls. J Clin Rheumatol. 2009;15(1).

13. Noehren B, Dailey DL, Rakel BA, Vance CG, Zimmerman MB, Crofford LJ, et al. Effect of transcutaneous electrical nerve stimulation on pain, function, and quality of life in fibromyalgia: a double-blind randomized clinical trial. Phys Ther. 2015;95(1):129-40.

14. Costa I da S, Gamundí A, Miranda JGV, França LGS, De Santana CN, Montoya P. Altered Functional Performance in Patients with Fibromyalgia. Front Hum Neurosci. 2017;11:14.

15. Clauw DJ. Fibromyalgia a clinical review. Jama. 2014;311(15):1547-55.

16. Cardoso F de S, Curtolo M, Natour J, Lombardi Júnior I. Assessment of quality of life, muscle strength and functional capacity in women with fibromyalgia. Rev Bras Reum. 2011;51(4):338-43,349-50.

17. López Espino M, Mingote Adán JC. Fibromialgia. Clínica y Salud. 2008;19(3):343-58.

18. Wolfe F, Smythe HA, Yunus MB, Bennett RM, Bombardier C, Goldenberg DL, et al. The American College of Rheumatology 1990 Criteria for the Classification of Fibromyalgia. Report of the Multicenter Criteria Committee. Arthritis Rheum. 1990;33(2):160-72.

19. WHO. Quitner, International Statistical Classification of Diseases and Related Problems. ICD-10. 1992.

20. Ministerio de Sanidad, Política Social e Igualdad. Fibromialgia [Internet]. Ministerio de Sanidad, Política Social e Igualdad; 2011. Disponible en: https://www.mscbs.gob.es/profesionales/prestacionesSanitarias/publicaciones/docs/fibromialgia.pdf

21. WHO. ICD-11 [Internet]. Disponible en: https://icd.who.int/en/

22. Wolfe F, Brähler E, Hinz A, Häuser W. Fibromyalgia prevalence, somatic symptom reporting, and the dimensionality of polysymptomatic distress: results from a survey of the general population. Arthritis Care Res (Hoboken). 2013;65(5):777-85.

23. Branco JC, Bannwarth B, Failde I, Abello Carbonell J, Blotman F, Spaeth M, et al. Prevalence of fibromyalgia: a survey in five European countries. In: Seminars 385 in Arthritis and Rheumatism. Vol. 39. Elsevier; 2010: pp. 448- 386 453. Semin Arthritis Rheum. 2010;39 (6):448-53.

24. Queiroz LP. Worldwide Epidemiology of Fibromyalgia. Curr Pain Headache Rep. 2013;17(8).

25. Cabo-Meseguer A, Cerdá-Olmedo G, Trillo-Mata JL. Fibromyalgia: Prevalence, epidemiologic profiles and economic costs. Med Clin (Barc). 2017;149(10):441-8.

26. Carmona L, Ballina J, Gabriel R, Laffon A. EPISER Study Group. The burden of musculoskeletal diseases in the general population of Spain: results from a national survey. Ann Rheum Dis. 2001; 60: 1040-5.

27. Jones GT, Atzeni F, Beasley M, Flüß E, Sarzi-Puttini P, Macfarlane GJ. The prevalence of fibromyalgia in the general population: a comparison of the American College of Rheumatology 1990, 2010, and modified 2010 classification criteria. Artritis Reumatol. 2015;67(2):568-75.

28. Gmuca S, Xiao R, Sherry DD. Patient-proxy agreement on health-related quality of life in juvenile fibromyalgia syndrome. Pediatr Rheumatol Online J. 2019;17:21.

29. Ghavidel-Parsa B, Bidari A, Amir Maafi A, Ghalebaghi B. The Iceberg Nature of Fibromyalgia Burden: The Clinical and Economic Aspects. Korean J Pain. 2015;28(3):169-76.

30. Ugur Bilge, 1 Yunus Emre Sari, 2 Hüseyin Balcioglu, 3 Nazife Sule Yasar Bilge, 4 Timucin Kasifoglu, 5 Mehmet Kayhan, et al. Prevalence of comorbid diseases in patients with fibromyalgia: A retrospective cross-sectional study. J Pak Med Assoc. 2018;68(5):729-32.

31. Lichtenstein A, Tiosano S. The complexities of fibromyalgia and its comorbidities. Curr Opin Rheumatol. 2018;30(1):94-100.

32. Weir PT, Harlan GA, Nkoy FL, Jones SS, Hegmann KT, Gren LH, et al. The Incidence of Fibromyalgia and Its Associated Comorbidities: A Population-Based Retrospective Cohort Study Based on International Classification of Diseases, 9th Revision Codes. JCR J Clin Rheumatol. 2006;12(3):124-8.

33. Collin SM, Bakken IJ, Nazareth I, Crawley E, White PD. Trends in the incidence of chronic fatigue syndrome and fibromyalgia in the UK, 2001-2013: A Clinical Practice Research Datalink study. J R Soc Med. 2017;110(6):231-44.

34. Annemans L, Le Lay K, Taïeb C. Societal and Patient Burden of Fibromyalgia Syndrome: PharmacoEconomics. 2009;27(7):547-59.

35. Skaer TL. Fibromyalgia: Disease Synopsis, Medication Cost Effectiveness and Economic Burden. PharmacoEconomics. 2014;32(5):457-66.

36. Seoane-Mato D, Sánchez-Piedra C, Silva-Fernández L, Sivera F, Blanco FJ, Pérez Ruiz F, et al. Prevalencia de enfermedades reumáticas en población adulta en España (estudio EPISER 2016). Objetivos y metodología. Reumatol Clínica. 2019;15(2):90-6.

37. Collado A, Gomez E, Coscolla R, Sunyol R, Solé E, Rivera J, et al. Work, family and social environment in patients with Fibromyalgia in Spain: an epidemiological study: EPIFFAC study. BMC Health Serv Res. 2014;14(1).

38. Briones-Vozmediano E. The social construction of fibromyalgia as a health problem from the perspective of policies, professionals, and patients. Glob Health Action. 2017;10(1):1275191.

39. Homma M, Ishikawa H, Kiuchi T. Illness perceptions and negative responses from medical professionals in patients with fibromyalgia: Association with patient satisfaction and number of hospital visits. Patient Educ Couns. 2018;101(3):532-40.

40. Borchers AT, Gershwin ME. Fibromyalgia: A Critical and Comprehensive Review. Clin Rev Allergy Immunol. 2015;49(2):100-51.

41. Collado A, Alijotas J, Benito P, Alegre C, Romera M, Sañudo I, et al. Documento de consenso sobre el diagnóstico y tratamiento de la fibromialgia en Cataluña. Med Clínica. 2002;118(19):745-9.

42. Wang S-M, Han C, Lee S-J, Patkar AA, Masand PS, Pae C-U. Fibromyalgia diagnosis: a review of the past, present and future. Expert Rev Neurother. 2015;15(6):667-79.

43. Fitzcharles M-A. Inaccuracy in the diagnosis of fibromyalgia syndrome: analysis of referrals. Rheumatology. 2003;42(2):263-7.

44. Harden RN, Revivo G, Song S, Nampiaparampil D, Golden G, Kirincic M, et al. A Critical Analysis of the Tender Points in Fibromyalgia. Pain Med. 2007;8(2):147-56.

45. Vincent A, Lahr BD, Wolfe F, Clauw DJ, Whipple MO, Oh TH, et al. Prevalence of Fibromyalgia: A Population-Based Study in Olmsted County, Minnesota, Utilizing the Rochester Epidemiology Project: Estimation of the Prevalence of FM in a Defined Population. Arthritis Care Res. 2013;65(5):786-92.

46. Segura-Jiménez V, Aparicio VA, Álvarez-Gallardo IC, Soriano-Maldonado A, Estévez-López F, Delgado-Fernández M, et al. Validation of the modified 2010 American College of Rheumatology diagnostic criteria for fibromyalgia in a Spanish population. Rheumatology. 2014;53(10):1803-11.

47. Carrillo-de-la-Peña MT, Triñanes Y, González-Villar A, Romero-Yuste S, Gómez-Perretta C, Arias M, et al. Convergence between the 1990 and 2010 ACR diagnostic criteria and validation of the Spanish version of the Fibromyalgia Survey Questionnaire (FSQ). Rheumatol Int. 2015;35(1):141-51.

48. Moyano S, Kilstein JG, Alegre de Miguel C. Nuevos criterios diagnósticos de fibromialgia: ¿vinieron para quedarse? Reumatol Clínica. 2015;11(4):210-4.

49. Oncu J, Iliser R, Kuran B. Do new diagnostic criteria for fibromyalgia provide treatment opportunity to those previously untreated? J Back Musculoskelet Rehabil. 2013;26(4):437-43.

50. Wolfe F, Clauw DJ, Fitzcharles M-A, Goldenberg DL, Häuser W, Katz RS, et al. Fibromyalgia Criteria and Severity Scales for Clinical and Epidemiological Studies: A Modification of the ACR Preliminary Diagnostic Criteria for Fibromyalgia. J Rheumatol. 2011;38(6):1113-22.

51. Wolfe F, Clauw DJ, Fitzcharles M-A, Goldenberg DL, Häuser W, Katz RL, et al. 2016 Revisions to the 2010/2011 fibromyalgia diagnostic criteria. Semin Arthritis Rheum. 2016;46(3):319-29.

52. Ablin JN, Wolfe F. A Comparative Evaluation of the 2011 and 2016 Criteria for Fibromyalgia. J Rheumatol. 2017;44(8):1271-6.

53. Mengshoel AM, Sim J, Ahlsen B, Madden S. Diagnostic experience of patients with fibromyalgia - A metaethnography. Chronic Illn. 2018;14(3):194-211.

54. Dobkin PL, Sita A, Sewitch MJ. Predictors of Adherence to Treatment in Women With Fibromyalgia: Clin J Pain. 2006;22(3):286-94.

55. Häuser W, Sarzi-Puttini P, Fitzcharles M-A. Fibromyalgia syndrome: under-, over- and misdiagnosis. Clin Exp Rheumatol. 2019;37Suppl 116(1):90-7.

56. Clauw DJ, D'Arcy Y, Gebke K, Semel D, Pauer L, Jones KD. Normalizing fibromyalgia as a chronic illness. Postgrad Med. 2018;130(1):9-18.

57. Kwiatkowska B. Diagnostic and therapeutic challenge - fibromyalgia. Reumatologia/Rheumatology. 2018;56(5):273-4.

58. Kumbhare D, Ahmed S, Sander T, Grosman-Rimon L, Srbely J. A Survey of Physicians' Knowledge and Adherence to the Diagnostic Criteria for Fibromyalgia. Pain Med. 2018;19(6):1254-64.

59. Üçeyler N, Zeller D, Kahn AK, Kewenig S, Kittel-Schneider S, Schmid A, et al. Small fibre pathology in patients with fibromyalgia syndrome. Brain J Og Neurol. 2013;136:16857-1867.

60. Gür A, Karakoç M, Nas K, Remzi, Cevik, Denli A, et al. Cytokines and depression in cases with fibromyalgia. J Rheumatol. 2002;29(2):358-61.

61. Melian N, Branco J, Montemezzo D, Gonçalves R, Andrade A, Karsten M, et al. Relationship between handgrip strength, peripheral muscle strength and respiratory muscle endurance in patients with Fibromyalgia Syndrome (FMS)? Physiotherapists. European Respiratory Society; 2017. p. PA2578.

62. Okifuji A, Donaldson GW, Barck L, Fine PG. Relationship Between Fibromyalgia and Obesity in Pain, Function, Mood, and Sleep. J Pain. 2010;11(12):1329-37.

63. Cagnie B, Coppieters I, Denecker S, Six J, Danneels L, Meeus M. Central sensitization in fibromyalgia? A systematic review on structural and functional brain MRI. Semin Arthritis Rheum. 2014;44(1):68-75.

64. Guedj E, Taieb D, Cammilleri S, Lussato D, de Laforte C, Niboyet J, et al. 99mTc-ECD brain perfusion SPECT in hyperalgesic fibromyalgia. Eur J Nucl Med Mol Imaging. 2007;34(1):130-4.

65. Guedj E, Cammilleri S, Niboyet J, Dupont P, Vidal E, Dropinski J-P, et al. Clinical Correlate of Brain SPECT Perfusion Abnormalities in Fibromyalgia. J Nucl Med. 2008;49(11):1798-803.

66. Efrati S, Golan, Haim, Bechor, Yair, Faran, Yifat, Daphna-Tekoah, Shir, Sekler, Gal, et al. Hyperbaric Oxygen Therapy Can Diminish Fibromyalgia Syndrome - Prospective Clinical Trial. PLoS ONE. 2015;1-25.

67. D'Agnelli S, Arendt-Nielsen L, Gerra MC, Zatorri K, Boggiani L, Baciarello M, et al. Fibromyalgia: Genetics and epigenetics insights may provide the basis for the development of diagnostic biomarkers. Mol Pain. 2019;15:174480691881994.

68. Al-Allaf AW. A case-control study examining the role of physical trauma in the onset of fibromyalgia syndrome. Rheumatology. 2002;41(4):450-3.

69. de Souza JB, Goffaux P, Julien N, Potvin S, Charest J, Marchand S. Fibromyalgia subgroups: profiling distinct subgroups using the Fibromyalgia Impact Questionnaire. A preliminary study. Rheumatol Int. 2009;29(5):509-15.

70. Rehm SE, Koroschetz J, Gockel U, Brosz M, Freynhagen R, Tolle TR, et al. A cross-sectional survey of 3035 patients with fibromyalgia: subgroups of patients with typical comorbidities and sensory symptom profiles. Rheumatology. 2010;49(6):1146-52.

71. Higgs JB. Fibromyalgia in Primary Care. Prim Care. 2018;45(2).

72. Córdova Martínez A. Fisiologia deportiva. Madrid: Síntesis; 2013.

73. García Manso JM, Navarro Valdivieso M, Ruiz Caballero JA. Bases teóricas del entrenamiento deportivo. Principios y aplicaciones. 1.ª ed. Grada Gymnos; 1996. 400 p.

74. García Manos JM, Navarro Valdivieso M, Ruiz Caballero JA. Pruebas para la valoración de la capacidad motriz en el deporte: evaluación de la condición física. Gymnos. 1996. 272 p.

75. Larsson A, Palstam A, Bjersing J, Löfgren M, Ernberg M, Kosek E, et al. Controlled, cross-sectional, multi-center study of physical capacity and associated factors in women with fibromyalgia. BMC Musculoskelet Disord. 2018;19:1-8.

76. Sener U, Ucok K, Ulasli AM, Genc A, Karabacak H, Coban NF, et al. Evaluation of health-related physical fitness parameters and association analysis with depression, anxiety, and quality of life in patients with fibromyalgia. Nternational J Rheum Dis. 2016;16:763-72.

77. Córdoba-Torrecilla S, Aparicio VA, Soriano-Maldonado A, Estévez-López F, Segura-Jiménez V, Álvarez-Gallardo I, et al. Physical fitness is associated with anxiety levels in women with fibromyalgia: the al-Ándalus project. Qual Life Res. 2016;25(4):1053-8.

78. Mannerkorpi K, Burckhardt CS, Bjelle A. Physical performance characteristics of women with fibromyalgia. Arthritis Care Res Off J Arthritis Health Prof Assoc. 1994;7(3):123-9.

79. Aparicio VA, Segura-Jiménez V, Álvarez-Gallardo IC, Soriano-Maldonado A, Castro-Piñero J, Delgado-Fernández M, et al. Fitness Testing in the Fibromyalgia Diagnosis: The al-Ándalus Project. Med Sci Sports Exerc. 2015;47(3):451-9.

80. McLoughlin MJ, Colbert LH, Stegner AJ, Cook DB. Are women with fibromyalgia less physically active than healthy women? Med Sci Sports Exerc. 2011;43(5):905-12.

81. Góes SM, Leite N, Shay BL, Homann D, Stefanello JMF, Rodacki ALF. Functional capacity, muscle strength and falls in women with fibromyalgia. Clin Biomech. 2012;27(6):578-83.

82. Soriano-Maldonado A, Ruiz JR, Aparicio VA, Estévez-López F, Segura-Jiménez V, Álvarez-Gallardo IC, et al. Association of Physical Fitness with Pain in Women with Fibromyalgia: The al-Ándalus Project: Physical Fitness and Pain in Fibromyalgia. Arthritis Care Res. 2015;67(11):1561-70.

83. World Health Organization. ICF: International Classification of Functioning, Disability and Health. Geneva: WHO; 2001.

84. Björnsdóttir S, Jónsson S, Valdimarsdóttir U. Functional limitations and physical symptoms of individuals with chronic pain. Scand J Rheumatol. 2013;42(1):59-70.

85. Häkkinen A, Häkkinen K, Hannonen P, Alen M. Force production capacity and acute neuromuscular responses to fatiguing loading in women with fibromyalgia are not different from those of healthy women. J Rheumatol. 2000;27(5):1277-82.

86. Alvarez-Gallardo IC, Carbonell-Baeza A, Segura-Jimenez V, Soriano-Maldonado A, Intemann T, Aparicio VA, et al. Physical fitness reference standards in fibromyalgia:The al-Andalus project. Scand J Med Sci Sports. 2017;27(11):1477-88.

87. Cerón-Lorente L, Valenza MC, Pérez-Mármol JM, García-Ríos M del C, Castro-Sánchez AM, Aguilar-Ferrándiz ME. The influence of balance, physical disability, strength, mechanosensitivity and spinal mobility on physical activity at home, work and leisure time in women with fibromyalgia. Clin Biomech. 2018;60:157-63.

88. Panton LB, Kingsley JD, Toole T, Cress ME, Abboud G, Sirithienthad P, et al. A comparison of physical functional performance and strength in women with fibromyalgia, age- and weight-matched controls, and older women who are healthy. Phys Ther. 2006;86:1479-88.

89. Latorre-Román PÁ, Segura-Jiménez V, Aparicio VA, Santos e Campos MA, García-Pinillos F, Herrador-Colmenero M, et al. Ageing influence in the evolution of strength and muscle mass in women with fibromyalgia: the al-Ándalus project. Rheumatol Int. 2015;35(7):1243-50.

90. Goes SM, Bento PCB, Stefanello JMF, El Tassa KOM, Homann D, Leite N, et al. Muscle and functional parameters of mid-age women with fibromyalgia and healthy elderly. JEPOnline. 2013;16(3):20-29.

91. Valkeinen H, Häkkinen A, Alen M, Hannonen P, Kukkonen-Harjula K, Häkkinen K. Physical Fitness in Postmenopausal Women with Fibromyalgia. Int J Sports Med. 2008;29(408-13).

92. Yetişgin A, Tiftik T, Kara M, Karabay İ, Akkuş S, Ersöz M. Isokinetic muscle performance of the hip and ankle muscles in women with fibromyalgia. Int J Rheum Dis. 2016;19(6):551-6.

93. Maquet D, Croisier J-L, Renard C, Crielaard J-M. Muscle performance in patients with fibromyalgia. Jt Bone Spine Rev Rhum. 2002;69(3):293-9.

94. Jacobsen S, Holm B. Muscle strength and endurance compared to aerobic capacity in primary fibromyalgia syndrome. Clin Exp Rheumatol. 1992;10(4):419-20.

95. Heredia Jiménez JM, Aparicio García-Molina VA, Porres Foulquie JM, Delgado Fernández M, Soto Hermoso VM. Spatial-temporal parameters of gait in women with fibromyalgia. Clin Rheumatol. 2009;28(5):595-8.

96. Srikuea R, Symons TB, Long DE, Lee JD, Shang Y, Chomentowski PJ, et al. Association of fibromyalgia with altered skeletal muscle characteristics which may contribute to postexertional fatigue in postmenopausal women. Arthritis Rheum. 2013;65(2):519-28.

97. Heredia-Jimenez J, Orantes-Gonzalez E, Soto-Hermoso VM. Variability of gait, bilateral coordination, and asymmetry in women with fibromyalgia. Gait Posture. 2016;45:41-4.

98. Pierrynowski MR, Tiidus PM, Galea V. Women with fibromyalgia walk with an altered muscle synergy. Gait Posture. 2005;22(3):210-8.

99. Góes SM, Leite N, de Souza RM, Homann D, Osiecki ACV, Stefanello JMF, et al. Características da marcha de mulheres com fibromialgia: um padrão prematuro de envelhecimento. Rev Bras Reumatol. 2014;54(5):335-41.

100. Kibar S, Yıldız HE, Ay S, Evcik D, Ergin ES. New Approach in Fibromyalgia Exercise Program: A Preliminary Study Regarding the Effectiveness of Balance Training. Arch Phys Med Rehabil. 2014;96(9):1576-82.

101. Lee PG, Jackson EA, Richardson CR. Exercise Prescriptions in Older Adults. Am Fam Physician. 2017;95(7):425-32.

102. Bennett RM, Jones J, Turk DC, Russell IJ, Matallana L. An internet survey of 2,596 people with fibromyalgia. BMC Musculoskelet Disord. 2007;8:27.

103. Jones KD, King LA, Mist SD, Bennett RM, Horak FB. Postural control deficits in people with fibromyalgia: a pilot study. Arthritis Res Ther. 2011;13(4):R127.

104. Russek LN, Fulk GD. Pilot study assessing balance in women with fibromyalgia syndrome. Physiother Theory Pract. 2009;25(8):555-65.

105. Trevisan DC, Driusso P, Avila MA, Gramani-Say K, Moreira FMA, Parizotto NA. Static postural sway of women with and without fibromyalgia syndrome: A cross-sectional study. Clin Biomech. 2017;44:83-9.

106. Muto LHA, Sauer JF, Yuan SLK, Sousa A, Mango PC, Marques AP. Postural control and balance self-efficacy in women with fibromyalgia: are there differences? Eur J Phys Rehabil Med. 2015;51(2):149-54.

107. Muto LHA, Sauer JF, Yuan SLK, Marques AP. Assessment of postural control, strength of lower limbs and pain in individuals with and without fibromyalgia. Annals of the rheumatic diseases. 2012;71(3):748.

108. Doumas M, Morsanyi K, Young WR. Cognitively and socially induced stress affects postural control. Exp Brain Res. 2018;236(1):305-14.

109. Ware JE. SF-36 health survey update. Spine. 2000;25(24):3130-9.

110. Vilagut G, Ferrer M, Rajmil L, Rebollo P, Permanyer-Miralda G, Quintana JM, et al. The Spanish version of the Short Form 36 Health Survey: a decade of experience and new developments. Gac Sanit. 2005;19(2):135-50.

111. Vilagut G, María Valderas J, Ferrer M, Garin O, López-García E, Alonso J. Interpretación de los cuestionarios de salud SF-36 y SF-12 en España: componentes físico y mental. Med Clínica. 2008;130(19):726-35.

112. Alonso J, Prieto L, Antó JM. [The Spanish version of the SF-36 Health Survey (the SF-36 health questionnaire): an instrument for measuring clinical results]. Med Clin (Barc). 1995;104(20):771-6.

113. Hamilton M. The assessment of anxiety states by rating. Br J Med Psychol. 1959;32(1):50-5.

114. Lobo A, Chamorro L, Luque A, Dal-Ré R, Badia X, Baró E, et al. Validación de las versiones en español de la Montgomery-Asberg Depression Rating Scale y la Hamilton Anxiety Rating Scale para la evaluación de la depresión y de la ansiedad. Med Clínica. 2002;118(13):493-499.

115. Carlsson AM. Assessment of chronic pain. I. Aspects of the reliability and validity of the visual analogue scale. Pain. 1983;16(1):87-101.

116. Williamson A, Hoggart B. Pain: a review of three commonly used pain rating scales: *Pain rating scales*. J Clin Nurs. 2005;14(7):798-804.

117. Herr KA, Spratt K, Mobily PR, Richardson G. Pain intensity assessment in older adults: use of experimental pain to compare psychometric properties and usability of selected pain scales with younger adults. Clin J Pain. 2004;20(4):207-19.

118. Plowman SA, Meredith MD. (Eds.). (2013). Fitnessgram/Activity gram Reference Guide (4th Edition). Dallas, TX: The Cooper Institute for Aerobics Research. The Prudential FITNESSGRAM test administration manual.

119. Ayala F, de Ste Croix M, Sainz de Baranda P, Santonja F. Fiabilidad y validez de las pruebas sit-and-reach: revisión sistemática. Rev Andal Med Deporte. 2012;5(2):57-66.

120. Butland RJ, Pang J, Gross ER, Woodcock AA, Geddes DM. Two-, six-, and 12-minute walking tests in respiratory disease. Br Med J Clin Res Ed. 1982;284:1607-8.

121. Johnston KN, Potter AJ, Phillips AC. Minimal important difference and responsiveness of 2-minute walk test performance in people with COPD undergoing pulmonary rehabilitation. Int J Chron Obstruct Pulmon Dis. 2017;12:2849-57.

122. Çimen ÖB, Deviren SD, Yorgancıoğlu ZR. Pulmonary Function Tests, Aerobic Capacity, Respiratory Muscle Strength and Endurance of Patients with Rheumatoid Arthritis. Clin Rheumatol. 2001;20(3):168-73.

123. Steffen TM, Hacker TA, Mollinger L. Age- and Gender-Related Test Performance in Community-Dwelling Elderly People: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and Gait Speeds. Phys Ther. 2002;82(2):128-37.

124. Alfano LN, Lowes LP, Dvorchik I, Yin H, Maus EG, Flanigan KM, et al. The 2-min walk test is sufficient for evaluating walking abilities in sporadic inclusion body myositis. Neuromuscul Disord. 2014;24(3):222-226.

125. Clark RA, Bryant AL, Yonghao P, McCrory P, Bennell K, Hunt M. Validity and reliability of the Nintendo Wii Balance Board for ass. Gait Posture. 2010;31(3):307-10.

126. Wikstrom EA. Validity and reliability of Nintendo Wii Fit balance scores. J Athl Train. 2012;47:306-313.

127. Carpenter MG, Frank JS, Winter DA, Peysar GW. Sampling duration effects on centre of pressure summary measures. Gait Posture. 2001;13(1):35-40.

128. Raymakers JA, Samson MM, Verhaar HJJ. The assessment of body sway and the choice of the stability parameter(s). Gait Posture. 2005;21(1):48-58.

129. Speers RA, Kuo AD, Horak FB. Contributions of altered sensation and feedback responses to changes in coordination of postural control due to aging. Gait Posture. 2002;16(1):20-30.

130. Niam S, Cheung W, Sullivan PE, Kent S, Gu X. Balance and physical impairments after stroke. Arch Phys Med Rehabil. 1999;80(10):1227-33.

131. Rocchi L, Chiari L, Horak FB. Effects of deep brain stimulation and levodopa on postural sway in Parkinson's disease. J Neurol Neurosurg Psychiatry. 2002;73(3):267-74.

132. Stins JF, Michielsen ME, Roerdink M, Beek PJ. Sway regularity reflects attentional involvement in postural control: Effects of expertise, vision and cognition. Gait Posture. 2009;30(1):106-9.

133. Lewis JS, Valentine RE. Clinical measurement of the thoracic kyphosis. A study of the intra-rater reliability in subjects with and without shoulder pain. BMC Musculoskelet Disord. 2010;11(1):39.

134. Falla D, Jull G, Russell T, Vicenzino B, Hodges P. Effect of neck exercise on sitting posture in patients with chronic neck pain. Phys Ther. 2007;87(4):408-17.

135. Nejati P, Lotfian S, Moezy A, Nejati M. The study of correlation between forward head posture and neck pain in Iranian office workers. Int J Occup Med Environ Health. 2015; 28(2):295-303.

136. Schneider CA, Rasband WS, Eliceiri KW. NIH Image to ImageJ: 25 years of image analysis. Nat Methods. 2012;9(7):671-5.

137. Lewis JS, Valentine RE. The pectoralis minor length test: a study of the intra-rater reliability and diagnostic accuracy in subjects with and without shoulder symptoms. BMC Musculoskelet Disord. 2007;8:64.

138. Slater H, Paananen M, Smith AJ, O'Sullivan P, Briggs AM, Hickey M, et al. Heightened cold pain and pressure pain sensitivity in young female adults with moderate-to-severe menstrual pain. Pain. 2015;156(2):2468-78.

SECCIÓN SEGUNDA

ESTUDIO 1

ESTUDIO 1

Characterization of postural control impairment in women with fibromyalgia

Abstract

The main goal of this cross-sectional study was to detect whether women with fibromyalgia syndrome (FMS) have altered postural control and to study the sensory contribution to postural control. We also explored the possibility that self-induced anxiety and lower limb strength may be related to postural control. For this purpose, 129 women within an age range of 40 to 70 years were enrolled. Eighty of the enrolled women had FMS. Postural control variables, such as *Ellipse*, Root mean square (*RMS*) and Sample entropy (*SampEn*), in both directions (*i.e.* mediolateral and anteroposterior), were calculated under five different conditions. A force plate was used to register the center of pressure shifts. Furthermore, isometric lower limb strength was recorded with a portable dynamometer and normalized by lean body mass. The results showed that women with FMS have impaired postural control compared with healthy people, as they presented a significant increase in *Ellipse* and *RMS* values ($p<0.05$) and a significant decrease in *SampEn* in both directions ($p<0.05$). Postural control also worsens with the gradual alteration of sensory inputs in this population ($p<0.05$). Performing a stressor dual task only impacts *Ellipse* in women with FMS ($p>0.05$). There were no significant correlations between postural control and lower limb strength ($p>0.05$). Therefore, women with FMS have impaired postural control that is worse when sensory inputs are altered but is not correlated with their lower limb strength.

1. INTRODUCTION

Fibromyalgia syndrome (FMS) is a rheumatologic disorder with clinical features such as widespread pain, fatigue, cognitive symptoms and mood disorders, such as depression and anxiety [1-4]. Moreover, previous studies have concluded that people with FMS may also have altered perception or interpretation of audiovestibular inputs due to neural disintegration at brainstem level [5] and some sensory or motor deficits and suboptimal muscle coordination [6] that may affect postural control. Indeed, the study conducted by Bennet *et al.* (2007) concluded that one of the ten most debilitating symptoms was altered balance, with a prevalence of 45 %[7].

So far, several studies have used objective devices to assess postural control in this population [8-11] using different tests that discriminated which of the different sensory inputs that are responsible for postural control (*i.e.* visual, proprioceptive and vestibular systems) were impaired. All of them explored the impact of FMS on postural control variables in the time-domain, showing a larger area and higher velocity of the center of pressure (COP) [11-12] or an altered postural stability rate in FMS patients [8-10-13] compared with healthy population. Nevertheless, although the postural control system is considered a non-linear system, where reactions are not proportional to the applied stimuli [14,15], none of the studies in this population have used non-linear variables to the assessment of the postural control. Conversely, this approach has been used in studies conducted on other populations. Indeed, people with vertigo show a posturographic signal with a small amount of complexity which makes the switch of behavioral modes more difficult and constrain the postural adaptation needed to select sensory information from the surrounding environment [16]. Non-linear variables have also demonstrated more rigid and less adaptable balance in people with Multiple Sclerosis [17] and hypermobility [18] and they have been used as a predictor of the risk of falls [19]. Therefore, this approach could provide complementary information about the ability to maintain the postural control in FMS population.

As described above, postural control is possible because of correct linkages between vestibular, visual and somatosensory information [20,21], therefore it is of particular interest to know the contribution of these sensory inputs to the postural control in FM population. Besides, there are other contributing factors that may influence postural control, as can be observed in studies focusing on mood conditions such as

anxiety, where high levels of anxiety have been associated with impaired balance control [22,23]. Other studies have focused on the motor effectors instead, suggesting that the ability of people with FMS to maintain balance may also be affected by the loss of strength that they suffer [24]. Similar findings have been shown in other studies on elderly people [25], patients with cystic fibrosis [26] and people with bone injuries [27,28].

Although both signs (*i.e.* anxiety and loss of strength) are common in people with FMS [2,29-32], so far no previous studies have analyzed the relationship between lower limb strength and the ability to maintain static balance in women with FMS or the impact of anxiety on their static postural control. Understanding this possible relationship could help therapists to design cause-based treatment plans to improve balance, including strength exercises or focusing on other aspects that are responsible for postural control (*i.e.* proprioception, visual disturbance, anxiety, etc.).

Our main objective was to determine whether women with FMS suffer impaired postural control in comparison with their healthy counterparts and to study the sensory contribution to postural control in this population. The impact of self-induced anxiety on postural control was also analyzed. In addition, we explored the relationship between postural control and lower limb strength.

2. MATERIALS AND METHODS

2.1. Participants

The study design was cross-sectional and purposive sampling (specifically, modal instance sampling) was used to select the study participants. The FMS group (FMG) was composed of 80 women between 43 and 70 years of age who had been diagnosed with FMS. They were recruited from several Fibromyalgia associations in Spain over a period of a year and a half. The control group (CG) was composed of 49 age-matched healthy women. The inclusion criterion for the FMG was diagnosis based on 2010 American College of Rheumatology criteria: widespread pain index (WPI) ≤ 7 and symptom severity (SS) scale ≤ 5 or WPI = 3-6 and SS scale score ≤ 9. Additionally, the symptoms had to have lasted for at least 3 months

[4]. For both groups, the exclusion criteria comprised an inflammatory rheumatic disease or an inner ear disorder, the use of antidepressant opioid or sedative drugs, current vertigo or dizziness, visual loss, neurological disorder, peripheral neuropathy and surgery within the past year that would cause balance deficits.

The Institutional Review Board (IRB) of the University of Valencia approved all the procedures that were performed in accordance with the principles of the World Medical Association's Declaration of Helsinki. Written informed consent was obtained from the participants before the tests started.

2.2. Procedures

Anthropometric and clinical measurements. Foot-to-foot bioelectrical impedance was measured with the Tanita bc-601 Body Fat Analyzer (Tanita Corp., Tokyo, Japan) [33,34]. Subjects stood on the metal sole plates of the device wearing only their underwear and all measure were made after a period of 10 min standing in order to minimize potential errors from acute shifts in fluid distribution. Body mass index was estimated for all participants using the standard prediction equations provided by the manufacturer. Furthermore, perceived pain intensity was measured on a 10-cm visual analog scale (VAS) consisting of a continuous line between two endpoints, with 0 being no pain and 10 being maximum tolerable pain [35].

Postural control. The postural control test was performed using the Wii Balance Board (WBB) (Nintendo, Kyoto, Japan) force platform. Previous studies have validated this device as a good means of analyzing postural control in the standing position [36,37]. The platform was placed on a stable surface on the floor to avoid signal distortion and noise. Subjects were asked to place their feet hip-width apart, toes pointing forward and a*rms* relaxed beside their side in all the tests. A reference point was situated 2 metres in front of the subject at eye level. All the subjects were briefed on the importance of maintaining this position and were asked to avoid any body movement. The subjects performed two consecutive 60-second repetitions [38] of five different tests in a random order. They rested for 30 seconds between tests and repetitions, unless they needed extra time. All the tests are described below.

Standing position with eyes open (*EO*): in the previously described position, and with their eyes open, they maintained the position for 60 seconds. In this test all sensory inputs (*i.e.* visual, proprioceptive and vestibular) were intact, so this was used as a control measurement.

Standing position while recalling a stressful day (Dual task [*DT*]): the participants had to maintain the bipedal standing position with their eyes open, recalling a stressful day in their life. They were instructed to think about a common stressful day for two minutes before the test started. They subsequently recounted the stressful events to the physiotherapist in the order in which they occurred. The purpose of this test was to explore the effect of self-induced anxiety on postural control.

Standing position with eyes closed (*EC*): the participants performed this test in the previously described position, but with their eyes closed. The purpose of the test was to analyze the extent to which proprioceptive and vestibular inputs can make up for a lack of visual information.

Standing position on a piece of foam with eyes open (*FEO*): the test was conducted according to the same procedure as EO, but with the participants standing on a piece of foam. The dimensions of the foam were 45 x 27 x 9 cm and the density was 56.7 kg/m^3. The purpose of this test was to study the contribution of visual and vestibular inputs to postural control when the proprioceptive system was altered intentionally.

Standing position on a piece of foam with eyes closed (*FEC*): the test used was the same as above, but the visual information was overridden. The aim of this test was to analyze the action of the vestibular system when visual information was not present and the proprioceptive input was altered intentionally. The vestibular organ is an inertial measuring system that allows us to sense self-motion with respect to the six degrees of freedom in space in the absence of external sensory cues. Since overriding the rest of the sensory information was not possible with this type of assessment, the main contribution of the vestibular system was assessed with this test, as described above [9,32].

Lower limb strength. Maximal isometric strength was assessed using a portable dynamometer NedDFM/IBV (Instituto de Biomecánica de Valencia, Valencia, Spain). Specifically, the isometric quadriceps and hamstring strength of both lower limbs were recorded. To measure this, the participants remained seated without any back support, with their upper limbs beside their body and hips and knees flexed at 90°. When quadriceps strength was assessed, the individuals had to try to extend their knee as hard as they could against the evaluator's resistance without moving their hip, trunk or upper limbs. When hamstring strength was assessed, the participants were required to flex their knee as hard as they could instead. In this case, they were not allowed to move their hip, trunk or upper limb from the original position either. For both measurements the dynamometer was place on the distal portion of the leg and the evaluator was fixed against a wall to resist the participant's strength and avoid any leg movement. Three repetitions of each measurement were performed consecutively with a 30-second rest between them, and the mean of the three repetitions was calculated. The two measurements (*i.e.* quadriceps and hamstring strength) were conducted in a counterbalanced order.

2.3. Reliability studies

Before the study began, we investigated the test-retest reliability of the strength assessment procedures described (isometric measurement of quadriceps and hamstring strength) and the BMI measurement that was recorded with the bioelectrical impedance device, since the reliability of these protocols had not been established previously. For this purpose, a convenience sample composed of 15 healthy women (not the individuals in the CG), with a mean (SD) age of 50.86 (4.63) years, came to our lab to be assessed in two different sessions (eight days apart) by two physiotherapists with extensive experience in biomechanical evaluation. In one of the sessions, the participants were assessed by both physiotherapists, whilst in the other, only one of them conducted the assessment.

2.4. Stabilometry data analysis

The ground reaction force was recorded with a Wii Balance Board (WBB) force plate with four uni-axial vertical force transducers at each corner (Nintendo, Kyoto, Japan). The raw data were acquired using WiiLab software (University of

Colorado Boulder, Colorado, USA) for Matlab R2007 (Mathworks Inc, Natick, USA).

Center of pressure (COP) displacement signals were filtered digitally by a Butterworth low-pass filter. We used a 10 Hz cut-off frequency to assure that 99 % of power spectral density was below this threshold [36]. The first 10 seconds of each test were excluded from the analysis to avoid any interference from delayed stabilization of the recording equipment after the person stepped onto the force plate [39]. Raw data were recorded at a frequency of 40 Hz. Once the previously described steps had been conducted, three posturographic variables were calculated for each of the five tests performed (each test is considered the mean of the two repetitions performed). An explanation and justification of the selected variables is given below.

Ellipse (*Ellipse*)**:** the 95 % confidence *ellipse* area is a measure of the area that COP traverses. It is determined by taking the radius of the major and minor axes and then fitting an *ellipse* that would include 95 % of the points [40]. This variable was used as the main measure of postural stability. The overall size of the *ellipse* summarizes the amount of overall motion in square millimeters, and the relative orientation of the *ellipse* is an indication of the degree to which hip and ankle motion are correlated [41].

Root mean square of the COP distance (*RMS*)**:** this variable measures the average absolute displacement around the mean COP and it is considered a measure of error in the balance control system [42]. It is sensitive to alterations in proprioception [43] and when somatosensory feedback for posture is delayed peripherally, the COP drifts, resulting in a larger than normal *RMS* [44].

Sample entropy (*SampEn*)**:** this variable indicates the regularity of a time series (*i.e.* COP path) by calculating the probability of it having repeated itself. The calculation of *SampEn* comprised the following steps [45]: (i) computation of the increase in the recorded COP time series according to the suggestions put forward by Govindan *et al.* [46]; (ii) computation of the *SampEn* values (using the PhysioToolkit-PhysioNet*SampEn* software) [47]; and (iii) calculation of the input parameters, m and r, using the empirical approach described by Ramdani *et al.*[45]. This last step was conducted with our own data and the results achieved the value m = 4 and r =

0.35, with N = 2000, where *N* is the number of input data points, *m* is the length of compared runs, and *r* is the tolerance. The information provided by *SampEn* in a specific population has always been related to their healthy counterparts. When comparing specific pathologic populations with healthy samples, lower *SampEn* values have been associated with higher regularity of the time series, which may be related to a poor capability of the neuromuscular system to adapt to perturbations. In contrast, higher values would be indicative of unstable systems that are too sensitive to perturbations [15].

RMS and *SampEn* were calculated for anteroposterior (AP) and mediolateral (ML) directions of COP displacement, which have been related to the contribution of ankle and hip movement to postural control, respectively [48]. In this respect, Winter *et al.* concluded that the complexity of these control mechanisms depends on the posture adopted, which may require combined strategies. However, for the healthy population, in a side-by-side stance, AP balance is more closely related to ankle control, whereas ML balance is related to hip control [48].

2.5. Statistics

Statistical analysis was performed using SPSS software Version 21 (SPSS Inc., Chicago, IL, USA). Standard statistical methods were used to obtain the mean as a measure of central tendency and the standard deviation (SD) as a measure of dispersion. For the inferential analysis, a mixed model MANOVA [group (FMG and CG) and condition (EO, DT, EC, FEO, FEC)] was performed to establish the effects of group and condition on the dependent balance variables (*i.e. Ellipse*, *RMS* and *SampEn*). When the univariate contrasts showed statistically significant main or interaction effects, pairwise comparisons were performed with the Bonferroni correction. Additionally, Spearman correlations between bilateral lower limb strength (average of dominant and non-dominant lower limb strength) and balance variables were performed for the FMG only. An independent Student's t-test was performed to verify whether the groups were similar in age, body mass index (BMI) and pain at baseline.

The reliability of quadriceps and hamstring strength recorded by the dynamometer and BMI recorded by the bioelectrical impedance assessment was determined

using a repeated measures analysis of variance (ANOVA) to calculate the (2,1) intra-class correlation coefficient (ICC) [49]. Within-day and inter-observer reliability were determined by comparing values obtained by two different observers in two repeated assessments several minutes apart.

Between-days and intra-observer reliability were determined by comparing the outcomes of two assessments repeated by the same observer, at least eight days apart. A p-value of 0.05 was accepted as the level of significance.

3. RESULTS

3.1. Participants

The FMG was composed of 80 women with a mean (SD) age of 53.95 (6.71) years and a BMI of 26.94 (5.85). The CG was composed of 49 women with a mean (SD) age of 54.47 (5.86) years and a BMI of 25.98 (4.88). There were no significant differences between groups in any of these variables ($p>0.05$). The FMG showed a mean (SD) pain score of 7.70 (2.04), whilst in CG this score was 1.82 (2.44), which means there were significant differences in pain between groups [$t(127) = 14.75$, $p<0.05$, $r = 0.79$].

3.2. Postural control between groups

The multivariate analysis showed that there was a significant interaction between 'group' and 'condition' [$F_{(20, 2028)} = 3.43$, $p<0.05$, $\eta2 = 0.22$] and a significant main effect of 'condition' [$F_{(20, 2028)} = 28.83$, $p<0.05$, $\eta2 = 0.22$] and 'group' [$F_{(5, 123)} = 4.23$, $p<0.05$, $\eta2 = 0.15$]. The univariate analysis showed that the groups presented unequal results of *RMS_AP* in the different test performed since a significant factor interaction was achieved [$F_{(1.87, 410.35)} = 5.10$, $p<0.05$, $\eta2 = 0.04$]. The postural control in both groups varied according to the test performed because a significant main effect of the 'condition' factor was obtained for *Ellipse* [$F_{(1.83, 231.80)} = 129.28$, $p<0.05$, $\eta2 = 0.50$], *RMS_AP* [$F_{(3.23, 410.35)} = 130.78$, $p<0.05$, $\eta2 = 0.51$], *RMS_ML* [$F_{(3.80, 377.96)} = 191.54$, $p<0.05$, $\eta2 = 0.60$], *SampEn_Ap* [$F_{(3.80, 482.44)} = 145.82$, $p<0.05$, $\eta2 = 0.53$] and *SampEn_ML* [$F_{(3.61, 458.13)} = 159.37$, $p<0.05$, $\eta2$

= 0.56]. Additionally, a significant main effect of the 'group' factor was obtained for *Ellipse* [$F_{(1, 127)}$ = 18.82, p<0.05, η2 = 0.13], *RMS_AP* [$F_{(1, 127)}$ = 18.97, p<0.05, η2 = 0.13], *RMS_ML* [$F_{(1, 127)}$ = 14.68, p<0.05, η2 = 0.10], *SampEn_Ap* [$F_{(1, 127)}$ = 16.46, p<0.05, η2 = 0.12] and *SampEn_ML* [$F_{(1, 127)}$ = 16.86, p<0.05, η2 = 0.12] which implies that the groups presented a different postural control regardless of the test performed.

The subsequent between-group analysis showed that there were significant differences in all variables in all the tests conducted, with the exception of *RMS_AP* and *SampEn_AP* for the EO test and *SampEn_ML* for the FEO test. The *Ellipse* and *RMS* values (in both directions) were significantly higher in the FMG than in the CG. Regarding variability, *SampEn* was lower in the FMG than in the CG, which implies a more repetitive movement pattern. Fig 1 shows the between-group results in each of the tests conducted.

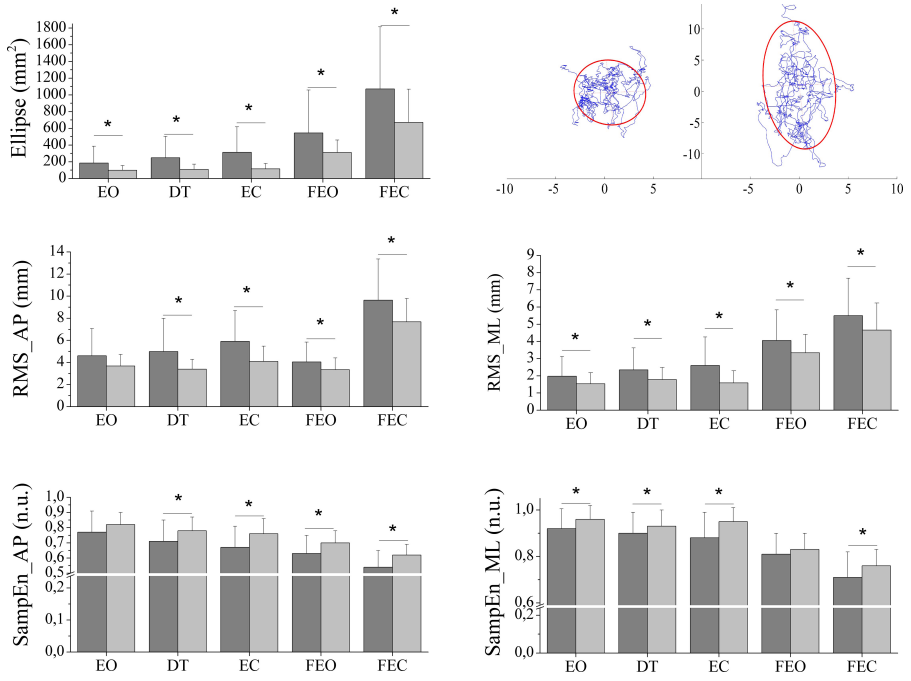

Fig 1. Differences between groups in postural control variables.

The bars represent the mean and the error bars, the standard deviation. Dark grey bar = fibromyalgia group; Light grey bar = control group; EO = eyes open test; DT = dual task test; EC = eyes closed test; FEO = foam eyes open test; FEC = foam eyes closed test; AP = anteroposterior; ML = mediolateral; *RMS* = root mean square of the center of pressure distance; *SampEn* = sample entropy. At the top right of the panel, the *Ellipse* of a representative case of the fibromyalgia group (right side) and one of control group (left side) is shown. * indicates significant differences between groups (p < 0.01).

3.3. Sensory input results

The posturographic variables were altered in both groups when the difficulty of the task was increased placing a foam on the force plate (*i.e.* FEO and FEC). This alteration is reflected as an increase in the values of *Ellipse* and *RMS* and a decrease in the values of *SampEn*, compared with the results obtained in those test in which the foam was not used.

Nevertheless, the postural control of the groups was different when the proprioceptive system was not disturbed (*i.e.* EO and EC). If we compare EC with EO, the CG did not show any significant differences in the postural control variables, except for *SampEn* in the AP direction.

However, the FMG showed a significant increase in *Ellipse* and *RMS* in both directions and a decrease in *SampEn* also in both directions. All the data are shown in Table 1.

3.4. Impact of self-induced anxiety on postural control

When DT and EO were performed, no significant differences were obtained for any of the posturographic variables in the CG ($p>0.05$). However, the FMG showed significantly higher *Ellipse* values (Table 1).

Table 1. Pairwise comparisons of the posturographic variables.

	Ellipse (mm²)		*RMS*_AP (mm)		*RMS*_ML (mm)		*SampEn*_AP (n.u.)		*SampEn*_ML(n.u.)	
	CG	FMG	CG	FMG	CG	FMG	CG	FMG	CG	FMG
EO	99.87 (56.23)	184.28 (202.90)	3.68 (1.05)	4.61 (2.46)	1.54 (0.64)	1.98 (1.14)	0.82 (0.08)	0.77 (0.14)	0.96 (0.06)	0.92 (0.09)
DT	109.17 (63.64)	248.16 (257.37)[1]	3.40 (0.88)	4.99 (3.00)	1.77 (0.71)	2.34 (1.28)	0.78 (0.09)	0.71 (0.11)	0.93 (0.07)	0.90 (0.09)
EC	116.08 (65.39)	313.07 (304.97)[1]	4.10 (1.38)	5.91 (2.79)[1]	1.59 (0.70)	2.60 (1.66)[12]	0.76 (0.10)[1]	0.67 (0.14)[1]	0.95 (0.06)	0.88 (0.11)[1]
FEO	311.22 (149.38)[123]	544.07 (515.15)[123]	5.05 (1.30)[123]	6.61 (3.11)[123]	3.33 (1.07)[123]	4.05 (1.79)[123]	0.70 (0.08)[123]	0.63 (0.12)[123]	0.83 (0.07)[123]	0.81 (0.09)[123]
FEC	670.95 (397.76)[1234]	1071.85 (741.42)[1234]	7.68 (2.12)[1234]	9.64 (3.73)[1234]	4.66 (1.58)[1234]	5.50 (2.17)[1234]	0.62 (0.07)[1234]	0.54 (0.11)[1234]	0.76 (0.07)[1234]	0.71 (0.11)[1234]

Data are expressed as mean (SD). EO: eyes open; DT: dual task; EC: eyes closed; FEO: foam eyes open; FEC: foam eyes closed; *RMS*: root mean square variable; *SampEn*: sample entropy; n.u.: no units. AP: anteroposterior direction; ML: mediolateral direction. Superscript 1, 2, 3 and 4: significant differences versus test 1, 2, 3 and 4, respectively.

3.5. Relationship between lower limb strength and postural control

There was no significant correlation between lower limb strength (*i.e.* quadriceps and hamstring) and posturographic variables ($p>0.05$).

3.6. Test-retest reliability of strength and BMI assessment procedures

The quadriceps and hamstring strength procedures showed good reliability (2,1 ICC)[49] for dominant lower limb strength, ranging from 0.78 to 0.86. The intra-observer and between-days ICC were 0.83 and 0.78 for quadriceps and hamstring strength, respectively. The inter-observer and within-day ICC were 0.86 and 0.83 for quadriceps and hamstring strength, respectively. Regarding the BMI measurement, the reliability was very good. The intra- observer and between-days ICC was 0.99. The inter-observer and within-day ICC was 1.00.

4. DISCUSSION

The results derived from this study show that women with FMS have impaired postural control compared with their healthy counterparts. These results are consistent with previous studies [9-11,13,24] but also yield some new findings about the postural control strategy. In general, there is a significant increase in the values of the linear variables (*i.e. Ellipse* and *RMS*) and a significant decrease in *SampEn* (a non-linear variable). Furthermore, when a sensory input is removed or disturbed, impairment of postural control increases.

Specifically, the *Ellipse* values were an average of 2.03 times higher in women with FMS than in healthy women. This result means that the COP trajectory covers a larger area in this population while standing and it is consistent with the results of a previous study conducted in women with fibromyalgia that reported a similar increase in the area in a bipedal test with eyes open [11]. It also coincides with the results of previous studies conducted in people with Multiple Sclerosis [17] or vestibular system problems [50]. In fact, a previous study concluded that there is a tendency for the linear values of COP, sway area, range of the COP and *RMS*

in both directions (AP and ML) to increase, irrespective of the disability studied [51]. In the case of the population with FMS, a chronic painful condition, it is possible that the motor pattern adapts to this condition and therefore modifies movement and stiffness to protect against further pain. Previous studies in which pain was experimentally induced have reported a larger area. This is attributed to the impact of pain on γ motor neuron activity [52], which could modulate the neuromuscular response. Regarding *RMS*, there is a significant increase in the FMG compared with the CG in both directions, ML and AP. This increase observed in women with FMS may be the result of slowed somatosensory feedback, which may reflect a deficit in the somatosensory feedback loop [43,44]. Nevertheless, a previous study pointed out that an increase in linear values does not always suggest a lack of balance, but may reflect a strategy of skillful individuals to explore their support base by being more flexible [51]. For this reason, in order to confirm the existence of a postural control deficit, *SampEn* was used as a non-linear variability variable. This variable reflects the automatism of postural control and net motor control signal output and comprises the whole body center of gravity and the muscles responsible for postural maintenance [53]. Our results showed that *SampEn* values were generally lower in women with FMS than in healthy women. This decrease in the intrinsic complexity of the steady-state dynamics is associated with a functional decline of the postural control system [54]. Indeed, it is known that a small amount of complexity makes it more difficult to switch behavioral modes, affecting the postural adaptation that is needed to select sensory information from the surrounding environment [55] and indicating that postural behavior is more rigid, which results in a loss of adaptability and local stability [56]. These results are in line with previous studies in which other pathologies were studied, all of which showed lower SampEn or Approximate Entropy compared with healthy people [16,17,51].

In order to further analyze sensory input alterations, as explained in the methods section, different tests were conducted (*i.e.* EO, EC, FEO and FEC) in which some of the sensory inputs were altered intentionally. The results showed that postural control was worse in both groups (*i.e. Ellipse* and *RMS* values increased and *SampEn* decreased) when the proprioceptive information was altered using a piece of foam (*i.e.* FEO and FEC). This is justified by the aforementioned linkage between the three sensory inputs. In this case, postural control needs to be maintained even

when the proprioceptive information is disturbed, making it more difficult to maintain stability. These results are also in line with those obtained in several previous studies in which increasingly complex tasks were assessed in different populations [16,17,57] and an increase in linear variables and decrease in COP variability were observed.

When EO and EC were compared, the postural control was different depending on which group they belonged to. There were no significant differences between EO and EC in the CG, except for *SampEn_AP*. This may be due to the fact that other sensory input information can make up for the lack of vision [51], although there was a reduction in the complexity of the COP trajectory in the AP direction. However, the FMG could not make up for that information properly and therefore experienced an increase in *Ellipse* and *RMS* and a decrease in variability. It has been suggested that visual input is the most reliable source of information needed for the central nervous system to send the motor response peripherally [58]. Under normal circumstances, when vision is not present (as is the case in EC), the somatosensory information needs to supply this lack of information, but as mentioned above, in women with FMS the somatosensory information seems to be slowed down, as shown in the results, where an increase in *RMS* values was obtained.

The use of a DT to assess the impact of self-induced anxiety on postural control was based on the previously described linkages between balance and anxiety [23]. The role of the para- brachial nucleus (PBN) in conditioning fear and anxiety responses has been demonstrated [59], as have the projections sent from the PBN to the vestibular nuclei [60]. Likewise, the locus coeruleus has been implicated both as an initiator of anxiety responses [59] and as a modulator of vestibular function [61]. Our results showed that the postural behavior in this DT compared with the EO test is different depending on which group the individual belongs to. The CG did not achieve significant differences in any of the posturographic variables, while the FMG presented an increase in *Ellipse* values in the DT compared with the EO test. These results suggest that the DT conducted increases their level of anxiety and vestibular activity is therefore modified and has an impact on postural control. Nevertheless, no significant differences were obtained for *RMS* or *SampEn*, which may be explained by two assumptions. First of all, the test conducted induces the anxiety response by recalling stressor events, but not using any other sensory

cues. The use of more information that elicits a greater anxiety response may alter not only the *Ellipse* values but also the complexity of the signal, since it has been demonstrated that some units in the caudal PBN also receive input from eye movement, for example. The other reason that could explain this result is that an increase in linear values does not always suggest a lack of balance, but a more flexible strategy [51]. However, both explanations need to be contrasted with more specific studies. These results therefore suggest that the alteration in postural control is partially modulated by remembrance-related anxiety.

Apart from studying sensory inputs, we explored the possible association between postural control and lower limb strength. Past studies have shown an association between altered postural control and a lack of strength in elderly people and in people with cystic fibrosis [25,26]. In fact, previous studies have suggested that people with FMS may be more prone to fall because they have similar lower body strength to older healthy women [62] and the rate of torque development for hip extension is considered a strong predictor of falls [29]. Nevertheless, the authors of these studies did not find a relationship between falls and peak torque. The results of our correlation analysis between lower limb strength and postural control variables are consistent with the aforementioned results, since we did not find a significant correlation between them either. These results, in conjunction with those previously reported, reinforce the hypothesis of a disrupted somatosensory system in this population as the main cause of their altered postural control. However, future studies should aim to provide further knowledge about proprioceptive information in these people using specific assessment tools. Furthermore, the results of this study should be taken cautiously because due to the fatigue, one of the most common symptoms of this population [4], we only conducted two trials of each condition in the postural control assessment. The number of trials should be expanded when the population assessed could perform the protocol without fatigue in order to improve the reliability of the tests.

5. CONCLUSIONS

The results obtained from this study demonstrate that women with FMS have impaired postural control compared with their healthy counterparts. Furthermore, their somatosensory system seems to be affected, as shown by the increase in *RMS* and *Ellipse* and reduction in *SampEn* values when visual information is missing. Postural control is partially influenced by self-induced anxiety and it is not related to lower limb strength.

6. ACKNOWLEDGMENTS

This research was supported by Conselleria d'Educació, Ciència i Esports [Valencian Regional Department of Education, Science and Sports], València, Spain [Grant GV2016/140].

7. REFERENCES

1. Talotta R, Bazzichi L, Di Franco M, Casale R, Batticciotto A, Gerardi MC, *et al.* One year in review 2017: fibromyalgia. Clin Exp Rheumatol. 2017;35 Suppl 105:6-12.

2. Thieme K, Turk DC, Flor H. Comorbid depression and anxiety in fibromyalgia syndrome: relationship to somatic and psychosocial variables. Psychosom Med. 2004; 66:837-44.

3. Cohen H, Buskila D, Neumann L, Ebstein RP. Confirmation of an association between fibromyalgia and serotonin transporter promoter region (5-HTTLPR) polymorphism, and relationship to anxiety-related personality traits. Arthritis Rheumatol. 2002;46:845-47.

4. Wolfe F, Clauw DJ, Fitzcharles M-A, Goldenberg DL, Katz RS, Mease P, *et al.* The American College of Rheumatology preliminary diagnostic criteria for fibromyalgia and measurement of symptom severity. Arthritis Care Res. 2010;62:600-10.

5. Bayazõt YA, GuÈrsoy S, OÈ zer E, Karakurum G, Madenci E. Neurotologic manifestations of the fibromyalgia syndrome. J Neurol Sci. 2002;196:77-80.

6. Jones KD, Horak FB, Winters KS, Morea JM, Bennett RM. Fibromyalgia is associated with impaired balance and falls. J Clin Rheumatol Pract Rep Rheum Musculoskelet Dis. 2009;15:16-21.

7. Bennett RM, Jones J, Turk DC, Russell IJ, Matallana L. An internet survey of 2,596 people with fibromyalgia. BMC Musculoskelet Disord. 2007;8:1.

8. Akkaya N, Akkaya S, Atalay NS, Acar M, Catalbas N, Sahin F. Assessment of the relationship between postural stability and sleep quality in patients with fibromyalgia. Clin Rheumatol. 2013;32:325-331.

9. Jones KD, King LA, Mist SD, Bennett RM, Horak FB. Postural control deficits in people with fibromyalgia: a pilot study. Arthritis Res Ther. 2011;13:R127.

10. Russek LN, Fulk GD. Pilot study assessing balance in women with fibromyalgia syndrome. Physiother Theory Pract. 2009;25:555-565.

11. Trevisan DC, Driusso P, Avila MA, Gramani-Say K, Moreira FMA, Parizotto NA. Static postural sway of women with and without fibromyalgia syndrome: A cross-sectional study. Clin Biomech. 2017.

12. Muto L, Mango P, Sauer J, Susan Y, Sousa A, Marques A. Postural control and balance self-efficacy in women with fibromyalgia. Are there differences? Eur J Phys Rehabil Med. 2014.

13. Ko Y-H, Rose DJ, others. A Comparison of Central Sensory Reception and Integration Abilities between Older Females with and without Fibromyalgia: A Pilot Study. Adv Aging Res. 2015;4:58.

14. Paillard T, Chaubet V, Maitre J, Dumitrescu M, Borel L. Disturbance of contralateral unipedal postural control after stimulated and voluntary contractions of the ipsilateral limb. Neurosci Res. 2010;68:301-06.

15. Stergiou N, Harbourne RT, Cavanaugh JT. Optimal movement variability: a new theoretical perspective for neurologic physical therapy. J Neurol Phys Ther. 2006;30:120-29.

16. Schniepp R, Wuehr M, Pradhan C, Novozhilov S, Krafczyk S, Brandt T, *et al.* Nonlinear variability of body sway in patients with phobic postural vertigo. Front Neurol. 2013;4:115.

17. Huisinga JM, Yentes JM, Filipi ML, Stergiou N. Postural control strategy during standing is altered in patients with multiple sclerosis. Neurosci Lett. 2012;524:124-28.

18. Rigoldi C, Cimolin V, Camerota F, Celletti C, Albertini G, Mainardi L, *et al.* Measuring regularity of human postural sway using approximate entropy and sample entropy in patients with Ehlers-Danlos syndrome hypermobility type. Res Dev Disabil. 2013;34:840-46.

19. Zhou J, Habtemariam D, Iloputaife I, Lipsitz LA, Manor B. The complexity of standing postural sway associates with future falls in community-dwelling older adults: the MOBILIZE Boston Study. Sci Rep. 2017;7:2924.

20. Mergner T, Rosemeier T. Interaction of vestibular, somatosensory and visual signals for postural control and motion perception under terrestrial and microgravity conditions - a conceptual model. Brain Res Rev. 1998;28:118-35.

21. Samuel AJ, Solomon J, Mohan D. A Critical Review on the Normal Postural Control. Physiother Occup Ther J. 2015;8:71.

22. Bolmont B, Gangloff P, Vouriot A, Perrin PP. Mood states and anxiety influence abilities to maintain balance control in healthy human subjects. Neurosci Lett. 2002;329:96-100.

23. Balaban CD. Neural substrates linking balance control and anxiety. Physiol Behav. 2002;77:469-75.

24. Muto LHA, Sauer JF, Yuan SLK, Marques AP. Assessment of postural control, strength of lower limbs and pain in individuals with and without fibromyalgia. Annals of the rheumatic diseases. BMJ Publishing Group British Med Assoc House, Tavistock Square, London, England; 2012. pp. 748-48.

25. King GW, Abreu EL, Cheng AL, Chertoff KK, Brotto L, Kelly PJ, *et al.* A multimodal assessment of balance in elderly and young adults. Oncotarget. 2016;7:13297-306.

26. Lima TRL, Guimaraes FS, Sá Ferreira A, Penafortes JTS, Almeida VP, Lopes AJ. Correlation between posture, balance control, and peripheral muscle function in adults with cystic fibrosis. Physiother Theory Pract. 2014;30:79-84.

27. Hirschmüller A, Konstantinidis L, Baur H, Müller S, Mehlhorn A, Kontermann J, *et al.* Do changes in dynamic plantar pressure distribution, strength capacity and postural control after intra-articular calcaneal fracture correlate with clinical and radiological outcome? Injury. 2011;42:1135-43.

28. Mehlhorn AT, Walther M, Yilmaz T, Gunst L, Hirschmüller A, Südkamp NP, *et al.* Dynamic plantar pressure distribution, strength capacity and postural control after Lisfranc fracturedislocation. Gait Posture. 2016.

29. Góes SM, Stefanello JM, Homann D, Lodovico A, Hubley-Kozey CL, Rodacki AL. Torque and muscle activation impairment along with insulin resistance are associated with falls in women with fibromyalgia. J Strength Cond Res Strength Cond Assoc. 2016.

30. Lund E, Kendall SA, Janerot-Sjöberg B, Bengtsson A. Muscle metabolism in fibromyalgia studied by P-31 magnetic resonance spectroscopy during aerobic and anaerobic exercise. Scand J Rheumatol. 2003;32:138-45.

31. Valkeinen H, Häkkinen A, Hannonen P, Häkkinen K, Alén M. Acute heavy-resistance exercise-induced pain and neuromuscular fatigue in elderly women with fibromyalgia and in healthy controls: Effects of strength training. Arthritis Rheum. 2006;54:1334-39.

32. Russell IJ. Fibromyalgia syndrome: approach to management. CNS Spectr. 2008; 13: 27-33.

33. Rasyada AR, Zulaika H, Akutagawa M, Emoto T, Kinouchi Y, Azhim A. The Impact of Visceral Fat and Blood Flow Velocity in Hypertensive Subjects Running Head: The Impact of Visceral Fat and Blood Flow Velocity. Health Sci J. 2016.

34. Azhim A, Ueno A, Tanaka M, Utsunomiya Y, Akutagawa M, Obara S, *et al.* Evaluation on Envelope Wavefo*rms* of Velocity in Common Carotid Artery: Age-, Gender-and Regular Exercise-related Effect. World Congress on Medical Physics and Biomedical Engineering, September 7-12, 2009, Munich, Germany. Springer; 2009. pp. 1075-1078.

35. Carlsson AM. Assessment of chronic pain. I. Aspects of the reliability and validity of the visual analogue scale. Pain. 1983;16:87-101.

36. Clark RA, Bryant AL, Pua Y, McCrory P, Bennell K, Hunt M. Validity and reliability of the Nintendo Wii Balance Board for assessment of standing balance. Gait Posture. 2010;31: 307-10.

37. Wikstrom EA. Validity and reliability of Nintendo Wii Fit balance scores. J Athl Train. 2012;47:306-13.

38. Carpenter MG, Frank JS, Winter DA, Peysar GW. Sampling duration effects on centre of pressure summary measures. Gait Posture. 2001;13:35-40.

39. Raymakers JA, Samson MM, Verhaar HJJ. The assessment of body sway and the choice of the stability parameter (s). Gait Posture. 2005;21:48-58.

40. Prieto TE, Myklebust JB, Hoffmann RG, Lovett EG, Myklebust BM. Measures of postural steadiness: differences between healthy young and elderly adults. Biomed Eng IEEE Trans On. 1996; 43: 956-66.

41. Speers RA, Kuo AD, Horak FB. Contributions of altered sensation and feedback responses to changes in coordination of postural control due to aging. Gait Posture. 2002;16:20-30.

42. Winter DA. Human balance and posture control during standing and walking. Gait Posture. 1995;3:193-214.

43. Niam S, Cheung W, Sullivan PE, Kent S, Gu X. Balance and physical impairments after stroke. Arch Phys Med Rehabil. 1999;80:1227-1233.

44. Rocchi L, Chiari L, Horak FB. Effects of deep brain stimulation and levodopa on postural sway in Parkinson's disease. J Neurol Neurosurg Psychiatry. 2002;73:267-74.

45. Ramdani S, Seigle B, Lagarde J, Bouchara F, Bernard PL. On the use of sample entropy to analyze human postural sway data. Med Eng Phys. 2009;31:1023-31.

46. Govindan RB, Wilson JD, Eswaran H, Lowery CL, Prei\s sl H. Revisiting sample entropy analysis. Phys Stat Mech Its Appl. 2007;376:158-64.

47. Goldberger AL, Amaral LA, Glass L, Hausdorff JM, Ivanov PC, Mark RG, *et al.* Physiobank, physiotoolkit, and physionet. Circulation. 2000;101:e215-e220.

48. Winter DA, Prince F, Frank JS, Powell C, Zabjek KF. Unified theory regarding A/P and M/L balance in quiet stance. J Neurophysiol. 1996;75:2334-43.

49. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychol Bull. 1979;86:420.

50. Teggi R, Colombo B, Bernasconi L, Bellini C, Comi G, Bussi M. Migrainous vertigo: results of caloric testing and stabilometric findings. Headache J Head Face Pain. 2009; 49:435-44.

51. da Costa CSN, Batistão MV, Rocha NACF. Quality and structure of variability in children during motor development: A systematic review. Res Dev Disabil. 2013;34:2810-30.

52. Birznieks I, Burton AR, Macefield VG. The effects of experimental muscle and skin pain on the static stretch sensitivity of human muscle spindles in relaxed leg muscles. J Physiol. 2008;586:2713-23.

53. Cavanaugh JT, Guskiewicz KM, Stergiou N. A nonlinear dynamic approach for evaluating postural control. Sports Med. 2005;35:935-50.

54. Vaillancourt DE, Newell KM. Changing complexity in human behavior and physiology through aging and disease. Neurobiol Aging. 2002;23:1-11.

55. Dusing SC, Harbourne RT. Variability in postural control during infancy: implications for development, assessment, and intervention. Phys Ther. 2010;90:1838.

56. Borg FG, Laxaback G. Entropy of balance some recent results. J Neuroengineering Rehabil. 2010;7:38-48.

57. Villarrasa-Sapiña I, García-Massó X, Serra-Añó P, Garcia-Lucerga C, Gonzalez L-M, Lurbe E. Differences in intermittent postural control between normal-weight and obese children. Gait Posture. 2016;49:1-6.

58. Salavati M, Akhbari B, Takamjani IE, Bagheri H, Ezzati K, Kahlaee AH. Effect of spinal stabilization exercise on dynamic postural control and visual dependency in subjects with chronic non-specific low back pain. J Bodyw Mov Ther. 2016;20:441-48.

59. Gorman JM, Kent JM, Sullivan GM, Coplan JD. Neuroanatomical hypothesis of panic disorder, revised. Am J Psychiatry. 2000;157:493-505.

60. Balaban CD. Organization of parabrachio-vestibular connections in rabbits and rats. Soc Neurosci Abstr. 2000. p. 1493.

61. Schuerger RJ, Balaban CD. Organization of the coeruleo-vestibular pathway in rats, rabbits, and monkeys. Brain Res Rev. 1999;30:189-217.

62. Panton LB, Kingsley JD, Toole T, Cress ME, Abboud G, Sirithienthad P, *et al.* A comparison of physical functional performance and strength in women with fibromyalgia, age and weight-matched controls, and older women who are healthy. Phys Ther. 2006;86:1479-88.

ESTUDIO 2

ESTUDIO 2

Impaired trunk posture in women with fibromyalgia

ABSTRACT

Study Design. A cross-sectional study.

Objectives. The main goal of the study was to analyze posture of Fibromyalgia syndrome (FMS) in women compared with healthy subjects to establish if posture assessment could be useful to characterize the syndrome. Secondarily, we explored the impact of sedentary behavior on trunk posture.

Summary of Background Data. Pain has been associated with poor static postures, however there is little information on the effect of FMS, which is characterized by widespread pain, on trunk posture.

Methods. One hundred eighteen women with FMS and 110 healthy counterparts participated in this study, in which trunk posture was assessed. The thoracic kyphosis, forward head position, and shoulder position (basal and maximum protraction) were measured. Further, maximum shoulder protraction and the ability to maintain the cervical and thoracic angle were assessed. To compare the differences in posture depending on the grouping, an independent Student t test was conducted. To analyze the differences between groups in the ability to maintain the position over a period of time and the differences in posture depending on more or less active lifestyles, two multivariate analysis of variance were performed.

Results. The results showed a significantly larger thoracic kyphosis, baseline shoulder protraction and lower craniovertebral angle and maximum protraction in FMG compared with CG ($P < 0.05$). FMG subjects exhibited an impaired ability to maintain the cervical and thoracic angles, as this varied throughout the test, unlike those of their counterparts. A sedentary lifestyle did not affect trunk posture in the FMS participants.

Conclusion. FMS female population present an altered trunk posture and an inability to maintain trunk position. Since this does not appear to be influenced by a more or less active lifestyle, specific treatment programs are needed to manage this clinical condition.

Key words: fibromyalgia, hyperkyphosis, muscle inability, posture, trunk.

Level of Evidence: 2

1. INTRODUCTION

Fibromyalgia syndrome (FMS) is a disease commonly characterized by persistent widespread musculoskeletal pain and other clinical conditions such as joint stiffness, chronic fatigue [1,2], and altered postural control [3]. All these symptoms, combined with a sedentary lifestyle in this population [4], may foster poor static postures. The relationship between pain and poor posture has been demonstrated in previous research in other populations, such as subjects with widespread musculoskeletal pain [5,6], rheumatoid arthritis [7], office employees [8].

Likewise, in 1998, Müller *et al.* [9] had forwarded the possibility of altered trunk posture being responsible for the onset of FMS. The authors demonstrated how individuals with FMS presented a higher percentage of spinal positional alterations compared with normal controls in te*rms* of hyperkyphosis and pitched-forward posture, but they did not report the specific posture in this population.

This syndrome is usually characterized using questionnaires or scales, given the multifactorial nature thereof. However, this condition has physical consequences, such as the associated trunk posture, that can be evaluated with objective tools and used as supplementary information. Müller *et al.* [9] concluded that postural assessment is highly important in their evaluative process in individuals diagnosed with FMS. Based on the above, it would be convenient to explore their trunk posture to tailor the most appropriate therapeutic approach [10]. Knowing their postural disorders and therefore treating them, could, in turn, break the vicious cycle that is produced when such disorders are maintained aggravating muscular and articular rigidity of the spine, causing greater pain, and hindering the affected subjects' daily and work activities, in turn causing increased stiffness and pain [11,12].

Therefore, the main goal of the study was to analyze posture in FMS women compared with healthy subjects to establish if posture assessment could be useful to characterize the syndrome. Secondarily, we explored the impact of sedentary behavior on trunk posture.

2. METHODS

2.1. Participants

This cross-sectional study used purposive modal instance sampling to select the participants. The FMS group (FMG) was composed of 118 women diagnosed with FMS who were recruited from several Fibromyalgia associations along a year and a half. The inclusion criteria for the FMG were women between 45 and 70 years of age diagnosed according to the 2010 American College of Rheumatology criteria. [13] The control group (CG) was composed of 110 age-matched women without symptoms.

Exclusion criteria for both groups were: history of fractures or surgery of the spine, inflammatory rheumatic disease, neurological disorder, peripheral neuropathy, or suffering any acute and terminal illness.

The Ethics Review Board of our institution approved all the procedures, performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from the participants before the tests started.

2.2. Measurements

Participants were clinically examined by a physiotherapist and classified as ''sedentary'' when they did not perform any type of physical activity. The order of evaluations of the posture of the trunk was randomized. All the procedures are explained later.

2.3. Thoracic kyphosis test

The test was conducted after the procedure of Lewis and Valentine [14]. The participants were asked to stand upright with the horizontal gaze maintained during the test. The spinous processes of Th1, Th2, Th12, and L1 vertebrae were located and adhesive markers were placed on them. After settling into a comfortable position, two Bubble inclinometers (Fabrication Enterprises, Inc, White Plains, NY) were placed at the markers. The mean of three repetitions was

used for the analysis. A good reliability of this procedure was established by Lewis and Valentine (intra-class correlation coefficient [ICC] = 0.97; standard error of measurement [SEM] = 1- 1.7°) [14].

2.4. Craniovertebral angle test

This angle was used as a measurement of a Forward Head Posture (FHP)[8] after the instructions of Falla *et al.* [15]. The subjects sat on a height-adjustable chair without backrest with their knees and hips flexed 90°, feet flat on the ground and head facing forward (Figure 1). Adhesive markers were positioned on the tragus of the ear (tragus) and the spinous process of the 7th cervical vertebra (C7). At that height, perpendicular to the sagittal plane and at 80 cm from the patient, a digital camera, Canon EOS 1200D (18 Mpx), was placed to take the picture of the participant. The photographic data were analyzed with the software *ImageJ* created by the National Institutes of Health [16]. To measure the craniovertebral angle, a line was drawn from the tragus to the spinous process of C7, the angle being at the intersection with the horizontal line.

2.5. Baseline and maximum shoulder protraction test

The *baseline shoulder protraction* was determined by measuring the pectoralis minor length according to the test described by Lewis and Valentine [17], based on the existing relationship between the position of the scapula and the length of the pectoralis minor [18]. The participants were placed in a relaxed supine position on a hard surface stretcher, with the hands resting on the abdomen. The distance from the posterior border of the acromion to the stretcher was measured in centimeters, using a standard plastic bevel, procedure proven reliable with ICC ranging from 0.88 to 0.93 [17]. The measurement was repeated three times and the average was used for the analysis [19].

The *maximum shoulder protraction* was measured in the same position and with the same procedure as above. The subjects were asked to raise the shoulder upwardly as much as they could in a transverse anatomical plane keeping the elbows in contact with the stretcher. The distance from that position to the stretcher was

measured three times. The average of the maximum shoulder protraction minus the average of the baseline shoulder protraction was used.

2.6. Test on the change in cervical and thoracic angle in sitting position

This test showed the participants' ability to maintain the trunk position for 5 minutes (*i.e.*, cervical and thoracic angle). The participants were sitting in the same position as described in the *Craniovertebral angle* test (Figure 1) but with a computer placed in front of them with the upper frame of the screen just below the height of the eyes 15 to assure the maintenance of the horizontal gaze. Adhesive markers were then positioned on the tragus, C7, and the spinous process of the 7th thoracic vertebra (T7). Once the initial sitting position was standardized, the women were asked to hold that position while they were distracted by reading a novel on the computer for 5 minutes. The dominant hand handled the mouse while the other rested motionless on the desk.

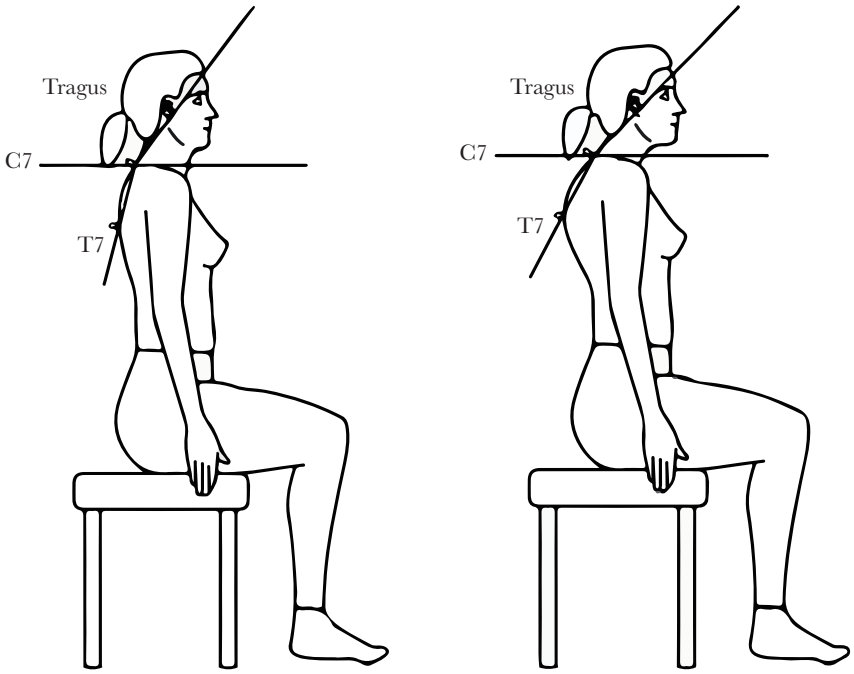

Figure 1. Trunk posture in sitting position. C7 indicates spinous process of the 7th cervical vertebra; T7, spinous process of the 7th thoracic vertebra.

To measure the changes in cervical and thoracic posture, a photograph was taken each minute (six photographs), using the same procedure as described in the Craniovertebral angle test. The photographs were also analyzed with ImageJ [16]. The *cervical angle* was formed at the intersection of the line drawn from the tragus to C7 with the horizontal line, while the *thoracic angle* was formed at the intersection of the line drawn from C7 to T7 with the horizontal line.

2.7. Reliability studies

The reliability of the two test procedures not previously validated was assessed before the study started. For the *Maximum shoulder protraction test*, a sample of convenience composed by 15 healthy women (other than CG subjects), with a mean (SD) age of 52.27 (6.62) years, was evaluated. For the *Test on the change in cervical and thoracic angle in sitting position*, the sample was composed of 15 other healthy women, with a mean (SD) age of 50.87 (4.63) years.

In both studies, the subjects attended our lab for assessment by two physiotherapists at two different sessions (8 days apart). Within-day and interobserver reliability was determined by comparing values obtained by the two different raters on the same day. Between-days and intraobserver reliability was determined by comparing the outcomes of two assessments repeated by the same rater, at least 8 days apart. Between-days and interobserver reliability were determined by comparing the results of two assessments conducted by the two different raters 8 days apart.

2.8. Sample size calculation

The sample size calculation was conducted with the software G-Power version 3.1 (University of Kiel, Germany) based on data of the variable "Thoracic kyphosis" analyzed in the study carried out by Greenfield *et al.* [20] in which a mean difference of 48 between groups was revealed. We set the type I error at 5 % and a statistical power of 80 %. Based on these assumptions, a sample of at least 92 individuals per group was required.

2.9. Stadistics

Statistical analysis was performed using SPSS software Version 22 (SPSS Inc. Chicago, IL). Since a paired Student t test revealed no differences between hemibodies ($P > 0.05$) its mean was calculated and included in the statistical analysis.

To compare the differences in posture depending on the grouping (*i.e.*, CG and FMG) an Independent Student *t* test was conducted and its size effect was computed with Pearson r. To analyze the differences between groups in the *Change in cervical and thoracic posture*, a Split-plot multivariate analysis of variance (MANOVA), with a between-subjects factor called "group" (FMG and CG) and a within-subject called "*time*" with six categories (T0, T1, T2, T3, T4, and T5), was conducted. Post-hoc comparisons were conducted with Sidak correction. To test the possible impact of sedentary behavior on the trunk posture a two-way MANOVA was conducted with two between-subjects factors, these being "*group*" (FMG and CG) and "*Behavior*," with two categories (sedentary *vs*. nonsedentary).

The reliability of tests on *Maximum shoulder protraction* and *Change in cervical and thoracic posture* was determined using an ANOVA to calculate the (2,1) ICC [21] and the SEM [22]. Type I error was established at < 5 %.

3. RESULTS

3.1. Participants

The mean (SD) age of the participants was 54.36 (6.82) years for the FMG and 54.76 (6.06) years for the CG. The body mass index was 27.31 (5.49) and 25.66 (4.49), respectively. There were no statistical differences for age between groups ($P > 0.05$). There was a statistical difference between groups in BMI [t (222.47) 2.56, $P < 0.05$, r 0.17], although the effect size was small and both groups were included in the overweight category, 27.31 points being the average for FMG and 25.66, for CG.

3.2. Participants posture variables

Descriptive results are shown in Table 1. The results showed a significantly larger *thoracic kyphosis* and a significantly lower *craniovertebral angle* in FMG compared with CG ($P < 0.05$). Regarding protraction, results showed a significantly higher *baseline shoulder protraction* and significantly lower *maximum shoulder protraction* in FMG than in CG ($P < 0.05$).

Table 1. Descriptive Results of the Posture Variables and Statistical Differences Between Groups.

	FMG	**CG**	**Size Effect (r)**
Thoracic kyphosis (°)	63 (11)	53 (13)*	0.42
Craniovertebral angle (°)	38 (7)	43 (5)*	0.36
Baseline protraction (cm)	8.6 (1.4)	8.1 (1.6)*	0.17
Maximum protraction (cm)	2.4 (1.1)	4.5 (1.5)*	0.69

Data are shown as mean (standard deviation).
**Statistical differences between groups (P < 0.05).*
FMG indicates fibromyalgia group; CG, control group; r, Pearson index for size effect.

Figure 2 presents the effect of FMS in a prolonged sitting posture. For both angles, the FMG showed significant differences every minute up to the last minute tested (*i.e.*, T4-T5), when the posture stabilizes. Conversely, the CG showed an initial significant difference (*i.e.*, T0-T1), but later both angles were sustained throughout the entire test.

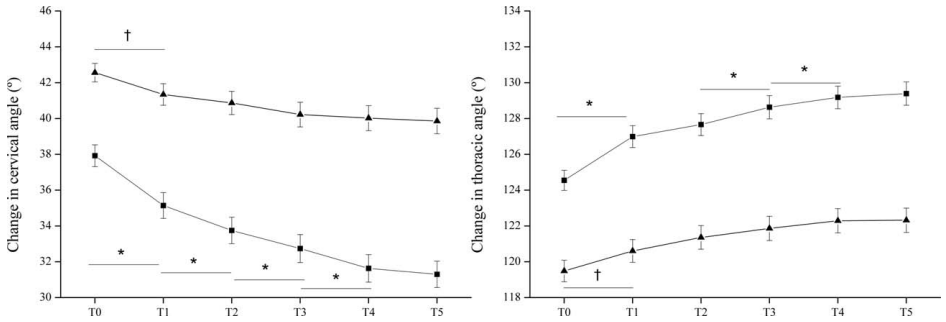

Figure 2. Group comparisons for change in cervical and thoracic posture. Data (mean) are expressed with squares (for the Fibromyalgia Group) and triangles (for the Control Group) and vertical lines represent the error bars. y indicates statistical differences for the Control Group ($P < 0.05$); *, statistical differences for the Fibromyalgia Group ($P < 0.05$).

3.3. Effect of sendetary behavior on trunk posture

As noted in Table 2, sedentary behavior had no effect on any of the trunk posture variables in the FMG ($P > 0.05$). The sedentary subgroup of the CG showed higher Thoracic kyphosis and lower Baseline shoulder protraction values compared with their nonsedentary counterparts ($P < 0.05$).

Table 2. Descriptive Results of the Posture Variables and Statistical Differences Between the Sedentary and Nonsedentary Groups.

		Sedentary	Nonsedentary
Thoracic kyphosis	**FMG**	66 (8)	62 (11)
	CG	59 (11)	52 (13)*
Craniovertebral angle	**FMG**	37 (7)	38 (7)
	CG	42 (6)	43 (5)
Baseline protraction	**FMG**	8.8 (2.6)	8.5 (1.4)
	CG	9.0 (2.0)	7.9 (1.5)*
Maximum protraction	**FMG**	2.1 (0.9)	2.5 (0.9)
	CG	4.6 (1.7)	4.5 (1.5)
Change in cervical angle	**FMG**	-4 (4)	-4 (5)
	CG	-2 (4)	-1 (3)
Change in thoracic angle	**FMG**	4 (4)	5 (5)
	CG	4 (3)	3 (3)

Data are shown as mean (standard deviation).
**Statistical differences between groups ($P < 0.05$).*
CG indicates control group; FMG, fibromyalgia group; r, Pearson index for size effect.

3.4. Reliability Studies

The results of the reliability studies conducted are displayed in Table 3 showing a good overall reliability.

Table 3. Analysis of the Reliability and Consistency of the Posture Procedures.

	1 Rater, 2 Days		**2 Raters, 1 Day**		**2 Raters, 2 Days**	
	ICC	SEM	ICC	SEM	ICC	SEM
Maximum protraction (cm)	0.98	0.36	0.94	0.61	0.96	0.50
Change in cervical posture (°)	0.86	1.60	0.75	1.20	0.80	1.43
Change in dorsal posture (°)	0.86	0.91	0.83	0.83	0.89	0.73

ICC indicates intraclass correlation coefficient (no units); SEM, standard error of measurement (units of the variable).

4. DISCUSSION

This study reveals differences in trunk posture in female subjects with FMS. In particular, alterations of the static posture are evidenced by hyperkyphosis, increased shoulder protraction and a reduced craniovertebral angle. Regarding thoracic kyphosis, the FMG showed an average increase of 10° compared with the CG. A previous study [9] also obtained a higher percentage of subjects with a pitched-forward position of the thoracic spine was obtained in the FMS group compared with the healthy group. Nevertheless, the absolute values of this position were not given in this population, thus, a comparison is not possible. Such hyperkyphosis may be associated with an impaired function of the upper trapezius that acts as stabilizer of the cervical spine and scapulae [23]. However, further studies should include the measurement of the lower lumbar and pelvic incidence to explore the contribution of possible restrictions of the lower body to the hyperkyphosis found.

The literature has established the impact of hyperkyphosis on mechanical restriction that can impair the physical function [24], reduce the upper limb range of motion [25], and decrease quality of life [24]. In addition, hyperkyphosis is one of the several conditions that can cause FHP [26], analyzed in this study with the measurement of the *Craniovertebral angle*, in turn, previously associated with neck pain [8]. Our results show that FMG subjects effectively positioned their heads abnormally forward, as they exhibited a reduction in the cervical angle that is associated with the flexion of the middle lower cervical segments and the extension of the suboccipital segments [26]. Given the importance of the deep neck muscles, such as the longus colli muscle, in postural function, this alteration may be associated with a functional impotence in supporting and straightening cervical lordosis [27]. Nevertheless, although the procedures conducted are reliable, more specific techniques (*e.g.*, radiography) could better determine the contribution of both mechanisms to FHP.

FHP may be associated with the scapular position, as the cervical posture is coupled to scapular posture [23]. For this reason, we also explored the amplitude of abduction movement of the scapula, which is the anterior movement in the transverse plane. The results demonstrate that, in a static position (*i.e., Baseline shoulder protraction*), the FMG had a higher value than the CG although the significant differences barely exceed the SEM established at 5 mm [17]. However, when the maximum movement was required (*i.e., Maximum shoulder protraction*), the CG showed a significantly

higher value than the FMG, doubling its magnitude. These results suggest that women with FMS, besides showing an increased shoulder protraction, because of the shortening of the pectoralis minor, could have a dysfunction in the pectoral muscles and anterior serratus [27] in addition to impairment of the torso muscles as already described (*i.e.*, trapezius, interscapulum muscles, *etc.*), which impedes the forced movement in the anterior direction in the transversal plane. In fact, previous studies confirmed that patients with chronic pain, as is the case of FMS population, show an increased muscle tension in the trapezius and infraspinatus and decreased isokinetic strength compared with pain-free controls [28]. The origin of pain in FMS is not well understood but it likely originates in the musculature, in which no clear alterations have been found. Our data speculatively support that a posture of alertness sustained by certain postural muscles when a subject persistently maintains such posture, may-at least in part-be responsible for the painful symptoms of FM.

Furthermore, we tested the capability of the trunk muscles to maintain a sitting position assessing the change in postural trunk angles over time. FMS participants revealed a progressive increase of the thoracic angle and a reduction of the cervical angle over the 5-minute period that they remained seated while performing a distracting task. This is consistent with a study in which subjects with cervical pain adopted a more forward head position when distracted [29]. These results support the hypothesis of an impaired endurance of the muscles responsible for the upright posture, in this case, not seemingly affected by a sedentary behavior as noted in Table 2. Therefore, this poor endurance may be associated with the pain experienced in this syndrome what would be in agreement with Falla *et al.* [15], who previously demonstrated an influence of neck pain in muscle endurance to maintain the cervical and thoracic position. Indeed, a peripheral stimulus in the form of muscle pain induces adaptations of the central nervous system, *i.e.*, altered muscle control strategies that manifest as a different motor unit recruitment pattern [30]. Conversely, CG showed a reduction in the cervical angle and an increase of the thoracic angle only during the first minute, as an initial adjustment, after which they maintained the position of both regions.

The results of the study could be further supported with the acquisition of electromyographic or tensiomyographic data that would be helpful to relate trunk

posture impairment with muscle activity and muscle properties, respectively. This would provide a better understanding of the alterations of the mechanisms responsible for trunk posture in women with FMS.

5. CONCLUSIONS

In conclusion, the results obtained from this study showed alterations in trunk posture in women with FMS. According to our results, hyperkyphosis, an anterior position of the shoulders and a forward position of the head are present in women with fibromyalgia. Moreover, the abduction movement of the shoulder and the ability to maintain an erect trunk position while sitting are impaired in this population. These results are not influenced by a sedentary lifestyle.

6. REFERENCES

1. Schweiger V, Del Balzo G, Raniero D, De Leo D, Martini A, Sarzi-Puttini P, et al. Current trendsmin disability claims due to fibromyalgia syndrome. Clin Exp Rheumatol. 2017;35(suppl 105):119-26.

2. Wolfe F. Criteria for fibromyalgia? What is fibromyalgia? Limitations to current concepts of fibromyalgia and fibromyalgia criteria. Clin Exp Rheumatol. 2017;35(suppl 105):3-5.

3. Rasouli O, Stensdotter A-K, Van der Meer ALH. TauG-guidance of dynamic balance control during gait initiation in patients with chronic fatigue syndrome and fibromyalgia. Clin Biomech (Bristol, Avon). 2016;37:147-52.

4. Segura-Jiménez, Álvarez-Gallardo IC, Estévez-López F, Soriano-Maldonado A, Delgado-Fernández M, Ortega FB, *et al.* Differences in sedentary time and physical activity between female patients with fibromyalgia and healthy controls: the al-Ándalus project. Arthritis Rheumatol. 2015;67:3047-57.

5. Rosario JL. Relief from back pain through postural adjustment: a controlled clinical trial of the immediate effects of muscular chains therapy (MCT). Int J Ther Massage Bodyw. 2014;7:2-6.

6. Zabaleta H, Rodriguez-de-Pablo C, Miljkovic N, Keller T, Garcia GA. sEMG-based detection of poor posture: A feasibility study. IEEE:1210-3.

7. Macovei LA, Rezus¸ E. Cervical spine lesions in rheumatoid arthritis patients. Rev Med Chir Soc Med Nat Iasi. 2016;120:70-6.

8. Nejati P, Lotfian S, Moezy A, Nejati M. The study of correlation between forward head posture and neck pain in Iranian office workers. Int J Occup Med Environ Health. 2015;28:295- 303.

9. Müller W, Kelemen J, Stratz T. Spinal factors in the generation of fibromyalgia syndrome. Z Rheumatol. 1998;57:36-42.

10. Talotta R, Bazzichi L, Di Franco M, Casale R, Batticciotto A, Gerardi MC, *et al.* One year in review 2017: fibromyalgia. Clin Exp Rheumatol. 2017;35(suppl 105):6-12.

11. Maddali Bongi S, Del Rosso A, Di Felice C, Calà M, Giambalvo Dal Ben G. Rességuier method and Qi Gong sequentially integrated in patients with fibromyalgia syndrome. Clin Exp Rheumatol. 2012;30:51-8.

12. Kim D, Cho M, Park Y, Yang Y. Effect of an exercise program for posture correction on musculoskeletal pain. J Phys Ther Sci. 2015;27:1791-4.

13. Wolfe F, Clauw DJ, Fitzcharles M-A, Goldenberg DL, Häuser W, Katz RS, *et al.* Fibromyalgia criteria and severity scales for clinical and epidemiological studies: a modification of the ACR Preliminary Diagnostic Criteria for Fibromyalgia. J Rheumatol. 2011;38:1113-22.

14. Lewis JS, Valentine RE. Clinical measurement of the thoracic kyphosis. A study of the intra-rater reliability in subjects with and without shoulder pain. BMC Musculoskelet Disord. 2010;11:39.

15. Falla D, Jull G, Russell T, Vicenzino B, Hodges P. Effect of neck exercise on sitting posture in patients with chronic neck pain. Phys Ther. 2007;87:408-17.

16. Schneider CA, Rasband WS, Eliceiri KW. NIH Image to ImageJ: 25 years of image analysis. Nat Methods. 2012;9:671-5.

17. Lewis JS, Valentine RE. The pectoralis minor length test: a study of the intra-rater reliability and diagnostic accuracy in subjects with and without shoulder symptoms. BMC Musculoskelet Disord. 2007;8:64.

18. Borstad JD. Resting position variables at the shoulder: evidence to support a posture-impairment association. Phys Ther. 2006;86:549-57.

19. Nijs J, Roussel N, Struyf F, Vicenzino B, Hodges P. Clinical assessment of scapular positioning in patients with shoulder pain: state of the art. J Manipulative Physiol Ther. 2007;30:69-75.

20. Greenfield B, Catlin PA, Coats PW, Green E, McDonald JJ, North C. Posture in patients with shoulder overuse injuries and healthy individuals. J Orthop Sports Phys Ther. 1995;21:287-95.

21. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychol Bull. 1979;86:420-8.

22. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. J Strength Cond Res. 2005;19:231-40.

23. Gaffney BM, Maluf KS, Curran-Everett D, Davidson BS. Associations between cervical and scapular posture and the spatial distribution of trapezius muscle activity. J Electromyogr Kinesiol. 2014;24:542-549.

24. Takahashi T, Ishida K, Hirose D, Nagano Y, Okumiya K, Nishinaga M, et al. Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people. Osteoporos Int. 2005;16:273-9.

25. Lee ST, Moon J, Lee SH, Cho KH, Im SH, Kim M, *et al.* Changes in activation of serratus anterior, trapezius and latissimus dorsi with slouched posture. Ann Rehabil Med. 2016;40:318- 25.

26. Khayatzadeh S, Kalmanson OA, Schuit D, Havey RM, Voronov LI, Ghanayem AJ, *et al.* Cervical spine muscle-tendon unit length differences between neutral and for- ward head postures: biomechanical study using human cadaveric specimens. Phys Ther. 2017;97:756-66.

27. Sahrmann S. Diagnosis and Treatment of Movement Impairment Syndromes. St Louis: Elsevier Health Sciences; 2002.

28. Elert J, Kendall SA, Larsson B, Maansson B, Gerdle B. Chronic pain and difficulty in relaxing postural muscles in patients with fibromyalgia and chronic whiplash associated disorders. J Rheumatol. 2001;28:1361-8.

29. Szeto GP, Straker LM, O'Sullivan PB. A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work-2: neck and shoulder kinematics. Man Ther. 2005;10:281-91.

30. Borchers AT, Gershwin ME. Fibromyalgia: a critical and comprehensive review. Clin Rev Allergy Immunol. 2015;49:100-51.

ESTUDIO 3

ESTUDIO 2

Physical condition factors that predict a better quality of life in women with fibromyalgia

ABSTRACT

What physical qualities can predict the quality of life (QoL) in women with fibromyalgia (FMS)? QoL is a very complex outcome affected by multiple comorbidities in people with fibromyalgia. This study aims to determine which physical qualities can predict the quality of life in women with FMS. Also, a comparison between the physical qualities of women with FM and healthy counterparts was conducted. In total, 223 women participated in this cross-sectional study, 123 with FMS, with ages ranging between 45 and 70 years. The study was conducted at several fibromyalgia associations and specialized medical units. QoL was measured as the main outcome. In addition, functional capacity, muscular strength, maintenance of thoracic posture, postural control, flexibility, pain threshold, and anxiety were measured. Prediction of the QoL was conducted with multiple linear regression analysis and comparison between groups, using the Mann-Whitney U test. There were significant differences between groups in all the variables measured ($p < 0.01$). The multiple linear regression model showed that factors influencing QoL in women with FMS for all the variables measured were functional capacity, handgrip strength and bicep strength, maintenance of thoracic posture, pain threshold, and anxiety ($R^2 = 0.53$, $p < 0.05$). To conclude, women with FMS show a significantly lower QoL than their healthy counterparts, and the factors that predict their perceived QoL are functional capacity, muscular strength, postural maintenance, pain threshold, and anxiety.

Keywords: quality of life; fibromyalgia; functional capacity; cardiorespiratory fitness; muscle strength; postural balance; pain threshold; anxiety.

1. INTRODUCTION

Fibromyalgia (FMS) is a common chronic pain condition that has a significant impact on quality of life (QoL) [1], possibly due to its interference with physical ability, function, work, and social activities [2]. Previous studies revealed that the global physical condition (PC) in FMS patients is impaired, since, compared to healthy counterparts, strength is reduced [3], postural control is altered [4,5], body posture is misaligned [6], or functional capacity is poor [1]. Furthermore, another important factor closely related to PC is flexibility, which is known to influence postural maintenance [7] and was independently associated with pain in this population [8], which was also associated with postural maintenance [6]. All these altered physical conditions could, in turn, possibly affect their perceived QoL.

The etiology and pathogenesis of FMS are still unknown, but the syndrome is claimed to be multifactorial [9] and, therefore, physiotherapeutic programs must contemplate different approaches in order to improve well-being and QoL in FMS patients.

Physical exercise was proposed as a suitable intervention for a variety of chronic pain populations, including FMS, with the purpose of reducing pain severity, improving PC, and enhancing QoL. Nevertheless, based on a recent review [10], the evidence on the effects of physical exercise is of low quality because of the small sample sizes, short length of the intervention programs, or the short follow-ups used in the studies. This, together with the lack of adherence [11] and the fatigue experienced with physical effort in this population, suggests the need for a thorough study of the correlations between QoL and PC to focus the interventions mainly on the development of the physical variables most related to QoL, avoiding fatigue as much as possible.

Physiotherapeutic interventions in people with FMS most usually focus on the improvement of PC [12-14] and some other variables related to PC, such as anxiety [15], commonly present in people with FMS, and those related to the perceived pain experience [16]. However, as mentioned above, it becomes necessary to establish which of the basic physical abilities or psychomotor qualities are more related to QoL and are likely to be addressed by physiotherapy. In this way, more personalized

physiotherapy treatments could be carried out, providing better care for patients with FMS.

This study was aimed at identifying predictors of QoL related to PC and anxiety. Additionally, it strove to determine the differences in PC of people with FMS compared to healthy counterparts.

2. METHODS

2.1. Participants

This cross-sectional study used purposive modal instance sampling to select the participants. The sample size calculation was conducted to ensure 80 % of power, setting the type I error at 5 %. A medium-size effect (d = 0.5) and seven independent variables were predicted. With these requirements, 103 people were required.

The FMS group (FMG) was composed of 123 women diagnosed with FM who were recruited from several fibromyalgia associations and specialized medical units over a year and a half. The inclusion criteria for the FMG were women between 45 and 70 years of age diagnosed according to the 2010 American College of Rheumatology criteria [17]. The control group (CG) was composed of 100 age-matched women without symptoms.

Exclusion criteria for both groups were as follows: history of fractures or surgery over the past six months, inflammatory rheumatic disease, neurological disorder, peripheral neuropathy, or suffering any acute and terminal illness.

2.2. Assessment procedures

Several features of the participants' PC were included as the dependent variables: functional capacity, muscular strength, maintenance of thoracic posture, postural control, and flexibility. Additionally, their pain threshold, QoL, and anxiety were measured.

2.2.1. Quality of life measures

QoL was assessed using the Spanish version of the Short Form-36 Health Survey (SF-36) [18] whose internal consistency and reliability was validated (Cronbach's α >0.70 and Intraclass correlation coefficient (ICC) >0.90, respectively) [19], and it is commonly used to measure physical, social, role, and emotional functioning. The score ranges from 0-100. Scores above or below 50 indicate better or worse health status, respectively, than the mean of the reference [20].

2.2.2. Functional capacity

The two-minute walk test (2MWT) was used to measure the functional capacity. This test consists of determining the maximum distance (in meters (m)) that can be walked in 2 min. This test shows a good correlation with the six-minute walk test (6MWT), which was extensively used as a reliable measure of functional capacity in individuals with a variety of characteristics [21,22], including individuals with fibromyalgia [8]. However, this test is less fatiguing and better tolerated [23]. It was carried out following the instructions of the study conducted by Johnston and colleagues [24].

2.2.3. Upper limb strength

Maximal isometric strength was assessed using two portable dynamometers, NedDFM/IBV (Instituto de Biomecánica de Valencia, Valencia, Spain), to assess the bicep strength, and NedVEP/IBV (Instituto de Biomecánica de Valencia, Valencia, Spain), to assess the handgrip strength. To conduct these two measures, the participants remained seated without any back support and with their feet on the floor. When bicep strength was assessed, the individuals had to attempt to flex their elbow with their palm upward as hard as they could against the evaluator's equal resistance without moving their trunk. The dynamometer was placed on the distal portion of the arm. When handgrip strength was assessed, the participants were required to tightly grasp the dynamometer as hard as they could. Three repetitions of each measurement were performed consecutively with a 30-s rest between them, and the mean of the three repetitions was calculated. The order of the two strength measurements was counterbalanced.

2.2.4. Maintenance of thoracic posture

To measure the participants' ability to maintain the thoracic position for 5 min, the change in thoracic angle in a sitting position was calculated. For this purpose, the participants sat with a computer placed in front of them with the upper frame of the screen just below the height of the eyes and handled the mouse with the dominant hand. Adhesive markers were then positioned on the tragus, C7, and the spinous process of the seventh thoracic vertebra (T7).

To measure changes in thoracic posture, a photograph was taken each minute, using the same procedure as described in a previous study of our group [6]. The photographs were also analyzed with the software ImageJ (National Institutes of Health, Bethesda, Maryland, USA) [25], and we computed the difference between the last and the first photograph. A higher angle of change denotes a poorer the ability to maintain the posture.

2.2.5. Postural control

The postural control test was performed using the Wii Balance Board (WBB) (Nintendo, Kyoto, Japan) force platform [26]. Subjects were asked to place their feet hip-width apart, toes pointing forward, and a*rms* relaxed at their sides in all the tests. A reference point was situated 2 m in front of the subject at eye level. All the subjects had to maintain the bipedal standing position with their eyes open during the test. The subjects performed two consecutive 60-s repetitions, and the mean was used for subsequent analyses. They rested for 30 s between repetitions, unless they needed extra time. The procedures were further explained in a previous study of our group [5].

Two variables derived from this test were measured: (i) *ellipse*: a measure of the area that the centre of pressure (COP) traverses, determined by taking the radius of the major and minor axes and then fitting an *ellipse* that would include 95 % of the points [27]; (ii) sample entropy (*SampEn*), indicating the regularity of a time series (*i.e.*, COP path) by calculating the probability of it having repeated itself. The calculation of *SampEn* was conducted following the description given by Randami *et al.* [28].

2.2.6. Flexibility

V-sit and reach (VSR) was used to measure the global flexibility of the participants [29]. The procedure requires that the individual be placed sitting on the floor in a V-sit position with their feet 30 cm apart. At the midpoint of that distance, the evaluator places a measuring tape starting from 23 cm. Two repetitions of each measurement were performed consecutively with a 30-s rest between them, and the mean of the repetitions was calculated.

2.2.7. Pain threshold

The pain threshold of the trapezius was measured with a Wagner FPK 20 algometer (Wagner Instruments, Greenwich, CT, USA) with a contact area of 1 cm^2 applied perpendicularly to the skin following the protocol of Slater and colleagues [30], locating the upper trapezius in the mid-point between the C7 spinous process and the acromion. Three repetitions of each measurement were performed consecutively with a 60-s rest between them, and the mean of the repetitions was calculated.

2.2.8. Anxiety

Anxiety was evaluated with the Hamilton anxiety rating scale (HARS), translated and validated in Spanish with good internal consistency [31]. Scores for the entire scale (emotional distress) ranged from 0-56, with higher scores indicating greater distress.

2.3. Data analysis

Data analysis was performed using SPSS (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL, USA) software, version 22. The Mann-Whitney U test was used to compare the previously described dependent variables between groups (*i.e.*, FMG and CG) since the normality was not satisfied (using Kolmogorov-Smirnov analysis). This test was also used to compare the age and body mass index (BMI) between groups. Furthermore, multiple linear regression analysis, with the backward method, was used to determine the influence on the QoL (measured with the SF-36) of the variables thought to be most influential. The following assumptions required for this analysis were checked: (i) independence of

observations with Durbin-Watson, (ii) linear relationship between the dependent variable and the independent variables using Spearman correlation analysis, and (iii) multicollinearity with variance inflation factor (VIF). A probability value of $p < 0.05$ was considered statistically significant.

2.4. Ethical approval

The project was approved by the Ethics Committee on Human Research of the University of Valencia (reference number: H1449048793044). All enrolled participants provided informed written consent prior to the study. The procedures were performed in accordance with the principles of the Declaration of Helsinki.

3. RESULTS

3.1. Participants

A total of 123 women with FMS were studied with a mean (SD) age of 54.40 (6.75) years. The CG was composed of 100 women with a mean (SD) age of 54.27 (6.08) years. Nevertheless, due to a technical failure in the postural control test, only 114 women with FMS completed all the measurements. Therefore, the statistical power was lower in the two variables derived from the postural control (Table 1), although 80 % of power was assured. There were no significant differences between groups in age ($p > 0.05$). The BMI was significantly higher in the FMG than in the CG (mean difference = 1.73 points; U = 7.31, Z = −2.41, $p = 0.02$), although both groups belonged to the "overweight" category.

3.2. Between-group comparisons

Table 1 shows that there were significant differences between groups in all the variables measured ($p < 0.01$). The QoL, functional capacity, isometric strength (both bicep strength and handgrip strength), *SampEn*, flexibility, and pain threshold were significantly lower, whilst the changes in maintenance of thoracic posture, the excursion of center of pressure (represented by the *ellipse*), and anxiety were significantly higher ($p < 0.01$).

Table 1. Results of the comparison between women with fibromyalgia and their healthy counterparts.

	FMG		**CG**		**Group Comparison**	
	Mean (SD)	**Median**	**Mean (SD)**	**Median**	**Z**	***p***
QoL	32.49 (15.10)	30.97	78.76 (12.81)	83.33	−12.29	<0.01
Functional capacity (m)	162.06 (27.8)	165.00	212.36 (25.54)	210.00	−10.72	<0.01
Bicep strength (kp)	52.49 (18.68)	47.33	95.92 (25.67)	95.94	−11.35	<0.01
Handgrip strength (kp)	82.13 (56.86)	71.83	155.24 (49.8)	156.80	−8.40	<0.01
Maintenance of thoracic posture (cm)	4.83 (4.66)	4.18	3.13 (3.03)	2.55	−2.92	<0.01
Ellipse **(mm^2)**	360.14 (495.2)	151.88	155.26 (171.88)	96.37	−4.20	<0.01
SampEn	0.69 (0.15)	0.69	0.77 (0.1)	0.78	−3.86	<0.01
Flexibility (cm)	−1.28 (12.65)	-2.00	9.82 (9.9)	11.00	−7.04	<0.01
Pain threshold (kg cm^{-2})	2.61 (0.65)	2.40	4.16 (1.2)	4.18	−10.18	<0.01
Anxiety	28.88 (9.52)	29.00	9.96 (6.82)	8.50	−11.72	<0.01

FMG-fibromyalgia group; CG-control group; QoL-quality of life; *SampEn*-sample entropy; Z- Mann whitney u test z value; p-significance value.

3.3. Quality of life prediction

Table 2 shows the results of the multiple regression model to estimate the factors that affect QoL in women with FMS. As noted, of all the variables measured, those able to predict QoL in women with FM were as follows: functional capacity, handgrip strength and bicep strength, maintenance of thoracic posture, pain threshold, and anxiety (R = 0.73, R^2 = 0.53, $p < 0.05$). The assumption of independence of observations was satisfied (Durbin-Watson = 1.89), as was the multicollinearity analysis (VIF ranged from 1.04-1.93). The linear relationships between the dependent and the included independent variables were significant ($p < 0.05$).

Table 2. Multiple regression model for quality of life in women with fibromyalgia.

Predictor for quality of life	Unstandardized coefficient beta	Standard error	Standardized coefficient beta	Confidence interval
Constant	22.53	8.85	-	4.99 to 40.07
Functional capacity	0.14	0.04	0.26	0.07 to 0.21
Bicep strength	0.06	1.72	0.07	−0.09 to 0.21
Handgrip strength	0.03	0.07	0.11	−0.02 to 0.08
Maintenance of thoracic posture	−0.22	0.02	−0.07	−0.65 to 0.22
Pain threshold	1.64	0.22	0.07	−1.77 to 5.05
Anxiety	−0.74	0.12	−0.48	−0.97 to −0.51

4. DISCUSSION

The current study shows that functional capacity, upper limb muscular strength, postural maintenance, pain threshold, and anxiety are important predictive factors of QoL in women with FMS. To the best of our knowledge, this is the first study that selected, from a variety of variables that can be treated by the physiotherapist, those that can predict changes in the QoL of women with fibromyalgia, in order to establish the appropriate therapeutic guidelines.

All the variables studied showed a significantly different score between women with FMS and their healthy counterparts, as disclosed in the results. Women with FMS were observed to have a poorer functional capacity, lower isometric strength, a poorer ability to maintain thoracic posture and to maintain postural control, as well as a lower pain threshold, reduced flexibility, and increased self-reported anxiety. Of these, however, postural control and flexibility did not show a significant contribution to QoL, as demonstrated by the regression analysis.

With regard to functional capacity, our findings are in accordance with previous studies showing that there are differences between women with FMS and healthy women [1,3,32-34]. According to our study, functional capacity rendered a lower value in women with FMS. This datum could be due, on the one hand, to lack of physical fitness, as these patients often adopt a more sedentary lifestyle [35], which might include frequently resting in bed when suffering from symptoms. On the other hand, this could be due to lower cardiorespiratory fitness in this population. In this regard, more accurate methods, such as the graded exercise test, to determine maximal oxygen uptake (VO2 max,) which is the gold standard for cardiorespiratory fitness (thus indicating the maximal aerobic power), would have been desirable. However, due to the particular characteristics of this population (*i.e.*, pain, fatigue), such exhausting measures are often difficult to implement. Thus, submaximal field exercise tests, such as the two-minute walking test, provide a feasible, safe, easy-to-administer, and inexpensive technique for the prediction of VO2 max [36], and may be considered as an indirect measure of maximal aerobic power or cardiorespiratory fitness in this population. Indeed, the two-minute walking test was shown to have a moderate-to-strong correlation with VO2 max consumption [37]. Our results are in agreement with previous studies showing that the cardiorespiratory fitness of women with FM was even lower than that of healthy sedentary women [38]. In addition, previous studies observed that these people reflect lower respiratory muscle resistance, lower strength in inspiratory muscles, and less chest mobility, which in turn could contribute to lower aerobic capacity [39].

Our results suggest that an increase in functional capacity implies an increase in the QoL score in this population. There is some controversy regarding the relationship between functional capacity and QoL. Two previous studies did not

show a clear relationship between QoL and functional capacity, although their sample was small [33,34]. However, Carbonell-Baeza *et al.*, with a sample size similar to ours, found a relationship between functional capacity and QoL in FMS [40]. Nevertheless, an adequate functional capacity is necessary to perform many daily life activities which imply a moderate level of physical activity. Diminished capacity could inevitably have an impact on the level of participation in this type of activity, which in turn would lead to a poorer QoL and even a dependence on other people [41].

With regard to muscle strength, previous studies found reduced muscle strength in women with FMS compared to healthy women, both in grip strength [3,32,42], linked to a state of sarcopenia [43], and in upper limb strength [3,32], linked to functional limb capacity [44]. The results of our study are consistent with those of the aforementioned studies, since, in our study, muscle strength was lower in people with FMS; specifically, isometric grip strength was 47 % lower than that of healthy subjects, and isometric strength of the upper limb was 45 % lower than the control group. This decrease in muscle strength could be due, as noted by previous studies, to physiological and neuromuscular factors typically found in FMS, such as alterations in blood circulation and changes in neuromuscular control mechanisms caused by pain [45].

Our study shows that an increase in isometric muscle strength, both in grip and the upper limb, can predict an improved QoL. In fact, a given study already established in this population a direct relationship between grip strength and upper limb strength with QoL in FMS patients [46]. This result implies that it would be useful for therapeutic intervention plans in this population to include strength training programs that could contribute to improve QoL. Furthermore, since FMS women are over the age of 50, the strength training may contribute, in turn, to preventing or postponing as much as possible the onset of sarcopenia and eventual frailty [47].

Parallel to the loss of strength, there is evidence in our study of an inability of the postural muscles to maintain posture, as reflected in the variable maintenance of thoracic posture. Our group previously confirmed a relationship between pain and poor sitting posture in FMS [6], as already established in populations with pain [48]. Postural disorders are observed in women with FMS, such as positioning the head abnormally forward; these are aggravated by the muscular and joint rigidity

of the spine present in this syndrome, thus increasing pain and preventing normal activities of daily and working life [49]. This difficulty in maintaining the upright posture of the trunk and neck may be due to altered muscle control strategies. This is because, by positioning the head abnormally forward, resistance of the muscles responsible for the upright posture deteriorates and peripheral muscle pain appears, inducing changes in the adaptation of the central nervous system and producing impaired control strategies [6]. Furthermore, some emotional states often present in women with FMS, such as depression and anxiety, necessarily influence QoL42 and may induce postural dealignment [50,51]. Indeed, depression significantly affects posture [52,53], as evidenced by an increased flexion thoracic kyphosis found in individuals with depression [53].

Our results show that a reduced ability to maintain trunk posture can predict a decline in QoL. The distribution of tonic muscle activity ("posture"] depends on the system of posture control [54]. In turn, postural control impairment can affect balance and the performance of daily living activities, and may eventually lead to falls [55], thus negatively affecting their quality of life, as reported in other populations [56,57]. In addition, stress and anxiety may affect postural control [5,58]. These findings are interesting for a better physiotherapeutic approach to patients with FM; neuromuscular control management through training with trunk and neck posture control exercises, as demonstrated in other pain populations, is an important point [48,59]. Furthermore, improving thoracic kyphosis and adopting an upright position was shown to reduce fatigue and stress [60,61], both key factors that should be improved in women with FM [2,62].

Other physical conditions that showed differences between women with FMS and healthy subjects are balance and flexibility. However, none of these showed any significant influence on QoL. Our results, regarding the postural control and flexibility variables, are consistent with Kibar's research [63], which conducted balance and flexibility training and found no improvement in QoL in women with FMS. Previous studies suggested that balance in people with FMS may be mediated by other factors such as anxiety, depression, and fatigue, and may, therefore, mask the relationship with QoL [55]. Future studies should analyze in greater depth the effect of balance alterations on QoL in this population to better understand the effect of possible confounding variables.

Parallel to the alteration of these physical properties, women with FMS suffer from generalized pain, which affects the day-to-day activities of women with FMS and their participation in society. Pain adversely affects their QoL and limits their daily life activities [64]. According to our results, a lower pain threshold implies a lower QoL score. These data are consistent with previous studies in FMS [16,65] and chronic pain populations [65]. Previous studies showed that pain in FMS patients can be reduced through physiotherapy intervention-based exercise programs with strength training or moderate aerobic exercise combined with health education, resulting in an improvement in QoL [15,66].

Thus, being aware of its impact on QoL, it is essential to address the subject not only using these approaches but also seeking for other specific intervention plans aimed at reducing pain, in order to improve as much as possible, the quality of life of women with FMS.

As discussed, chronic pain experience is linked to anxiety in these people [67,68]. Our study confi*rms* that women with FMS have significantly greater anxiety levels than their healthy counterparts. It was also noted from the regression analysis that anxiety predicts QoL, since an increase in anxiety results in a decrease in QoL. Although there are no previous studies that attempted to predict QoL in women with FMS using these types of variables, there were approximations that measured the correlation between the two variables. In this respect, the study by Ozcetin failed to show a correlation between the global score in the SF-36 with anxiety; however, they did find a negative relationship between anxiety and scores related to the physical and somatic function subscales of the SF-36 QoL questionnaire [68], demonstrating the link between physical state and the emotional component. It is useful for the physiotherapist to know how to objectively quantify the anxiety reported by patients with FMS, in order to improve their symptoms through regular physical training. Moderate aerobic training, as well as strength training in FM patients, was shown to be helpful in treatments to improve and reduce anxiety symptoms [15].

5. LIMITATIONS

Studies of this type involve some limitations worth considering. Firstly, this was a cross-sectional study and, although regression analyses were used to predict causal direction, the results should be taken cautiously. Nevertheless, it would still be useful to establish if differences in QoL between people with FMS and the control group could to some extent be related to the variables described. Secondly, this was a modal instance sample of patients, in an attempt to get a representative or typical expression of fibromyalgia phenomenology in only one region of the world. Broader, more representative samples of patients could have advantages. Finally, we controlled only for physical confounding variables; therefore, other confounding variables could be involved.

6. CONCLUSIONS

The results obtained from this study show that women with FM present differences in their overall physical condition compared to their healthy counterparts. The predictive factors of QoL in women with FM are functional capacity, muscle strength, postural maintenance, pain threshold, and anxiety.

7. REFERENCES

1. Costa ID, Gamundí A, Miranda JG, França LG, de Santana CN, Montoya P. Altered Functional Performance in Patients with Fibromyalgia. Front. Hum. Neurosci. 2017;1:,14.

2. Clauw DJ. Fibromyalgia a clinical review. JAMA. 2014;311,1547-55.

3. Larsson A, Palstam A, Bjersing J, Löfgren M, Ernberg M, Kosek E, *et al.* Controlled, cross-sectional, multi-center study of physical capacity and associated factors in women with fibromyalgia. BMC Musculoskelet. Disord. 2018;19:121.

4. Pérez-de-Heredia-Torres M, Huertas-Hoyas E, Martínez-Piédrola R, Palacios-Ceña D, Alegre-Ayala J, Santamaría-Vázquez M, *et al.* Balance deficiencies in women with fibromyalgia assessed using computerised dynamic posturography: A cross-sectional study in Spain. BMJ Open. 2017;7:e016239.

5. Sempere-Rubio N, López-Pascual J, Aguilar-Rodríguez M, Cortés-Amador S, Espí-López G, Villarrasa-Sapiña I, *et al.* Characterization of postural control impairment in women with fibromyalgia. PLoS ONE. 2018;13:e0196575.

6. Sempere-Rubio N, Aguilar-Rodríguez M, Espí-López G.V, Cortés-Amador S, Pascual E, Serra-Añó P. Impaired Trunk Posture in Women with Fibromyalgia. Spine. 2018;43:1536-42.

7. Muyor JM, López-Miñarro PA, Alacid F. The relationship between hamstring muscle extensibility and spinal postures varies with the degree of knee extension. J. Appl. Biomech. 2013;29:678-86.

8. Soriano-Maldonado A, Ruiz JR, Aparicio VA, Estévez-López F, Segura-Jiménez V, Álvarez-Gallardo IC, *et al.* Association of Physical Fitness with Pain in Women with Fibromyalgia: The al-Ándalus Project: Physical Fitness and Pain in Fibromyalgia. Arthritis Care Res. 2015;67:1561-70.

9. Higgs JB. Fibromyalgia in Primary Care. Prim. Care 2018;45:325-41.

10. Geneen LJ, Moore RA, Clarke C, Martin D, Colvin LA, Smith BH. Physical activity and exercise for chronic pain in adults: An overview of Cochrane Reviews. Cochrane Database Syst. Rev. 2017;1: CD011279.

11. Ang DC, Kaleth AS, Bigatti S, Mazzuca S, Saha C, Hilligoss J, *et al.* Research to Encourage Exercise for Fibromyalgia (REEF): Use of motivational interviewing design and method. Contemp. Clin. Trials. 2011;32:59-68.

12. Assumpcao A, Matsutani LA, Yuan SL, Santo AS, Sauer J, Mango P, *et al.* Muscle stretching exercises and resistance training in fibromyalgia: Which is better? A three-arm randomized controlled trial. Eur. J. Phys. Rehabil. Med. 2018;54:663-70.

13. De Lorena SB, de Lima MD, Ranzolin A, Duarte Â.L. Effects of muscle stretching exercises in the treatment of fibromyalgia: A systematic review. Rev. Bras. Reumatol. 2015;55:167-73.

14. Tits M. Fibromyalgia and physical therapy. Rev. Med. Brux. 2011;32:393-97.

15. McDowell CP, Cook DB, Herring MP. The Effects of Exercise Training on Anxiety in Fibromyalgia Patients: A Meta-analysis. Med. Sci. Sports Exerc. 2017;49:1868-76.

16. Go*rms*en L, Rosenberg R, Bach FW, Jensen TS. Depression, anxiety, health-related quality of life and pain in patients with chronic fibromyalgia and neuropathic pain. Eur. J. Pain 2010;14:127-128.

17. Wolfe F, Clauw DJ, Fitzcharles MA, Goldenberg DL, Katz RS, Mease P. The American College of Rheumatology preliminary diagnostic criteria for fibromyalgia and measurement of symptom severity. Arthritis Care Res. 2010;62:600-10.

18. Alonso J, Prieto L, Anto JM. The spanish version of the sf-36 health survey (the sf-36 health questionnaire): An instrument for measuring clinical results. Med. Clin. 1995;104:771-76.

19. Vilagut G, Ferrer M, Rajmil L, Rebollo P, Permanyer-Miralda G, Quintana JM, *et al.* The Spanish version of the Short Form 36 Health Survey: A decade of experience and new developments. Gac. Sanit. 2005;19:135-150.

20. Vilagut G, María Valderas J, Ferrer M, Garin O, López-García E, Alonso J. Interpretación de los cuestionarios de salud SF-36 y SF-12 en España: Componentes físico y mental. Med. Clin. 2008;130:726-35.

21. Çimen ÖB, Deviren SD, Yorgancıog˘ lu ZR. Pulmonary Function Tests, Aerobic Capacity, Respiratory Muscle Strength and Endurance of Patients with Rheumatoid Arthritis. Clin. Rheumatol. 2001;20:168-73.

22. Steffen T, Seney M. Test-Retest Reliability and Minimal Detectable Change on Balance and Ambulation Tests, the 36-Item Short-Form Health Survey, and the Unified Parkinson Disease Rating Scale in People with Parkinsonism. Phys. Ther. 2008;88:733-46.

23. Alfano LN, Lowes LP, Dvorchik I, Yin H, Maus EG, Flanigan K.M.; Mendell, J.R. The 2-min walk test is sufficient for evaluating walking abilities in sporadic inclusion body myositis. Neuromuscul. Disord. 2014;24:222-226.

24. Johnston K.N, Potter AJ, Phillips AC. Minimal important difference and responsiveness of 2-minute walk test performance in people with COPD undergoing pulmonary rehabilitation. Int. J. Chronic Obstr. Pulm. Dis. 2017;12:2849-57.

25. Schneider CA, Rasband WS, Eliceiri, K.W. NIH Image to ImageJ: 25 years of image analysis. Nat. Methods. 2012;9:671-75.

26. Wikstrom, E.A. Validity and reliability of Nintendo Wii Fit balance scores. J. Athl. Train. 2012;47:306-13.

27. Prieto TE, Myklebust JB, Hoffmann, RG, Lovett EG, Myklebust BM. Measures of postural steadiness: Differences between healthy young and elderly adults. IEEE Trans. Biomed. Eng. 1996;43:956-66.

28. Ramdani S, Seigle B, Lagarde J, Bouchara F, Bernard PL. On the use of sample entropy to analyze human postural sway data. Med. Eng. Phys. 2009;31:1023-31.

29. Plowman SA, Meredith M.D. (Eds.) The Prudential FITNESSGRAM Test Administration Manual; Cooper Institute for Aerobics Research: Dallas, TX, USA, 1992.

30. Slater H, Paananen M, Smith AJ, O'Sullivan P, Briggs AM, Hickey M, *et al.* Heightened cold pain and pressure pain sensitivity in young female adults with moderate-to-severe menstrual pain. Pain. 2015;156:2468-78.

31. Lobo A, Chamorro L, Luque A, Dal-Ré R, Badia X, Baró E. Grupo de Validación en Español de Escalas Psicométricas. Validación de las versiones en español de la Montgomery-Asberg Depression Rating Scale y la Hamilton Anxiety Rating Scale para la evaluación de la depresión y de la ansiedad. Med. Clín. 2002;118:493-99.

32. Álvarez-Gallardo IC, Carbonell-Baeza A, Segura-Jiménez V, Soriano-Maldonado A, Intemann T, Aparicio VA, *et al.* Physical fitness reference standards in fibromyalgia: The al-Andalus project. Scand. J. Med. Sci. Sports. 2017;27:1477-88.

33. Latorre-Román P, Santos-Campos M, Heredia-Jimenez J, Delgado-Fernández M, Soto-Hermoso V. Analysis of the performance of women with fibromyalgia in the six-minute walk test and its relation with health and quality of life. J. Sports Med. Phys. Fit. 2014;54:511-17.

34. Homann D, Stefanello JMF, Góes SM, Leite N. Impaired functional capacity and exacerbation of pain and exertion during the 6-minute walk test in women with fibromyalgia. Rev. Bras. Fisioter. 2011;15: 474-80.

35. McLoughlin MJ, Colbert LH, Stegner AJ, Cook DB. Are women with fibromyalgia less physically active than healthy women? Med. Sci. Sports Exerc. 2011;43:905-12.

36. American College of Sports Medicine. ACSM's Health-Related Physical Fitness Assessment Manual; Lippincott Williams and Wilkins: Philadelphia, PA, USA, 2013.

37. Bernstein ML, Despars JA, Singh NP, Avalos K, Stansbury DW, Light RW. Reanalysis of the 12-Minute Walk in Patients with Chronic Obstructive Pulmonary Disease. Chest. 1994;105:163-67.

38. Sañudo Corrales B, Galiano Orea D. Relationship between cardio-respiratory parameters and women with fibromyalgia. Reumatol. Clin. 2008;4:8-12.

39. Forti M, Zamunér RA, Andrade CP, Silva E. Lung Function, Respiratory Muscle Strength, and Thoracoabdominal Mobility in Women with Fibromyalgia Syndrome. Respir. Care 2016;61:1384-90.

40. Carbonell-Baeza A, Ruiz JR, Aparicio VA, Ortega FB, Delgado-Fernandez M. The 6-Minute Walk Test in Female Fibromyalgia Patients: Relationship with Tenderness, Symptomatology, Quality of Life, and Coping Strategies. Pain Manag. Nurs. 2013;14:193-99.

41. Galvez-Sánchez CM, Duschek S, Reyes Del Paso GA. Psychological impact of fibromyalgia: Current perspectives. Psychol. Res. Behav. Manag. 2019;12:117-27.

42. Sener U, Ucok K, Ulasli AM, Genc A, Karabacak H, Coban NF, *et al.* Evaluation of health-related physical fitness parameters and association analysis with depression, anxiety, and quality of life in patients with fibromyalgia. Int. J. Rheum. Dis. 2016;16:763-72.

43. Koca I, Savas E, Ozturk ZA, Boyaci A, Tutoglu A, Alkan S, *et al.* The evaluation in te*rms* of sarcopenia of patients with fibromyalgia syndrome. Wien. Klin. Wochenschr. 2016;128:816-21.

44. Jones J, Rutledge DN, Jones KD, Matallana L, Rooks DS. Self-assessed physical function levels of women with fibromyalgia: A national survey. Women's Health Issues 2008;18:406-12.

45. Gerdle B, Grönlund C, Karlsson SJ, Holtermann A, Roeleveld K. Altered neuromuscular control mechanisms of the trapezius muscle in fibromyalgia. BMC Musculoskelet. Disord. 2010:11:42.

46. Cardoso FdS, Curtolo M, Natour J, Lombardi Júnior I. Assessment of quality of life, muscle strength and functional capacity in women with fibromyalgia. Rev. Bras. Reumatol. 2011;51:338-43.

47. Nascimento CM, Ingles M, Salvador-Pascual A, Cominetti MR, Gomez-Cabrera MC. Sarcopenia, frailty and their prevention by exercise. Free Radic. Biol. Med. 2019;132:42-9.

48. Falla D, Jull G, Russell T, Vicenzino B, Hodges P. Effect of neck exercise on sitting posture in patients with chronic neck pain. Phys. Ther. 2007;87:408-17.

49. Kim D, Cho M, Park Y, Yang Y. Effect of an exercise program for posture correction on musculoskeletal pain. J. Phys. Ther. Sci. 2015;27:1791-4.

50. Grammer K, Fink B, Oberzaucher E, Atzmüller M, Blantar I, Mitteroecker P. The representation of self reported affect in body posture and body posture simulation. Coll. Antropol. 2004;28 (Suppl. 2):159-73.

51. Canales JZ, Fiquer JT, Campos RN, Soeiro-de-Souza MG, Moreno RA. Investigation of associations between recurrence of major depressive disorder and spinal posture alignment: A quantitative cross-sectional study. Gait Posture. 2017;52:258-64.

52. Rosario JL, Bezerra Diógenes MS, Mattei R, Leite JR. Differences and similarities in postural alterations caused by sadness and depression. J. Bodyw. Mov. Ther. 2014;18:540-4.

53. Canales JZ, Cordás TA, Fiquer JT, Cavalcante AF, Moreno RA. Posture and body image in individuals with major depressive disorder: A controlled study. Braz. J. Psychiatry. 2010;32:375-80.

54. Ivanenko Y, Gurfinkel V.S. Human Postural Control. Front. Neurosci. 2018;12:171.

55. Jones KD, Horak FB, Winters KS, Morea JM, Bennett RM. Fibromyalgia is associated with impaired balance and falls. J. Clin. Rheumatol. 2009;15:16-21.

56. Miyakoshi N, Kudo D, Hongo M, Kasukawa Y, Ishikawa Y, Shimada Y. Comparison of spinal alignment, muscular strength, and quality of life between women with postmenopausal osteoporosis and healthy volunteers. Osteoporos. Int. 2017;28:3153-60.

57. Pavão SL, Nunes GS, Santos AN, Rocha NACF. Relationship between static postural control and the level of functional abilities in children with cerebral palsy. Braz. J. Phys. Ther. 2014;18:300-7.

58. Doumas M, Morsanyi K, Young WR. Cognitively and socially induced stress affects postural control. Exp. Brain Res. 2018;236:305-14.

59. Jang HJ, Hughes LC, Oh DW, Kim SY. Effects of Corrective Exercise for Thoracic Hyperkyphosis on Posture, Balance, and Well-Being in Older Women: A Double-Blind, Group-Matched Design. J. Geriatr. Phys. Ther. 2017;42:E17-E27.

60. Wilkes C, Kydd R, Sagar M, Broadbent E. Upright posture improves affect and fatigue in people with depressive symptoms. J. Behav. Ther. Exp. Psychiatry. 2017;54:143-9.

61. Nair S, Sagar M, Sollers J, Consedine N, Broadbent E. Do slumped and upright postures affect stress responses? A randomized trial. Health Psychol. 2015;34:632-41.

62. Fischer S, Doerr JM, Strahler J, Mewes R, Thieme K, Nater UM. Stress exacerbates pain in the everyday lives of women with fibromyalgia syndrome-The role of cortisol and alpha-amylase. Psychoneuroendocrinology 2016;63:68-77.

63. Kibar S, Yıldız HE, Ay S, Evcik D, Ergin E.S. New Approach in Fibromyalgia Exercise Program: A Preliminary Study Regarding the Effectiveness of Balance Training. Arch. Phys. Med. Rehabil. 2014;96:1576-82.

64. Clauw DJ, Essex MN, Pitman V, Jones KD. Reframing chronic pain as a disease, not a symptom: Rationale and implications for pain management. Postgrad. Med. 2019;31;185-98.

65. Laursen BS, Bajaj P, Olesen AS, Delmar CH, Arendt-Nielsen L. Health related quality of life and quantitative pain measurement in females with chronic non-malignant pain. Eur. J. Pain. 2005;9:267-75.

66. Van Oosterwijck J, Meeus M, Paul L, De Schryver M, Pascal A, Lambrecht L, *et al.* Pain physiology education improves health status and endogenous pain inhibition in fibromyalgia: A double-blind randomized controlled trial. Clin. J. Pain. 2013;29:873-82.

67. Lee JW, Lee KE, Park DJ, Kim SH, Nah SS, Lee JH, *et al.* Determinants of quality of life in patients with fibromyalgia: A structural equation modeling approach. PLoS ONE. 2017;12:e0171186.

68. Ozcetin A, Ataoglu S, Kocer E, Yazycy S, Yildiz O, Ataoglu A, Ycmeli C. Effects of depression and anxiety on quality of life of patients with rheumatoid arthritis, knee osteoarthritis and fibromyalgia syndrome. West Indian Med. J. 2007;56:122-9.

SECCIÓN TERCERA

CONCLUSIONES GENERALES Y LÍNEAS FUTURAS

CONCLUSIÓN GENERAL

Con el presente trabajo de investigación se han ampliado los conocimientos sobre la capacidad funcional en las mujeres con FMS. Se ha determinado la alteración de diferentes componentes biomecánicos, además de la ansiedad autoinducida y el umbral de dolor, con el reto de determinar aquellas condiciones psicomotoras que influyen en la calidad de vida de estas personas. Todo esto con la finalidad de conseguir alcanzar un conocimiento adecuado sobre este síndrome, que sea susceptible de permitir un abordaje terapéutico más eficaz, para poder llevar a cabo tratamientos de fisioterapia con una mejor atención.

CONCLUSIONES ESPECÍFICAS

Estudio 1

1. Los resultados obtenidos en este estudio mostraron que las mujeres con fibromialgia tienen un control postural deteriorado.
2. Además, su sistema somatosensorial se ve afectado, como lo demostró el aumento de la *RMS* y la *Ellipse* así como la reducción de los valores de *SampEn* cuando faltaba información visual.
3. El control postural está parcialmente influenciado por la ansiedad autoinducida y no está relacionado con la fuerza de las extremidades inferiores.

Estudio 2

1. Se demostraron alteraciones en la postura del tronco en mujeres con el síndrome de fibromialgia. Concretamente, una mayor hipercifosis, una posición anterior de los hombros y una posición adelantada de la cabeza están presentes en mujeres con fibromialgia. Además, el movimiento de abducción del hombro y la capacidad de mantener una posición erguida del tronco mientras están en sedestación se ven afectados en esta población.
2. La alteración de la postura y de la capacidad para mantenerla, no están influenciados por un estilo de vida sedentario.

Estudio 3

1. Los factores predictivos de la calidad de vida en mujeres con FM son la capacidad funcional, la fuerza muscular, el mantenimiento postural, el umbral de dolor y la ansiedad.
2. Las mujeres con FM presentan diferencias en su condición física general en comparación con sus homólogas sanas de la misma edad.

LÍNEAS PRESENTES Y FUTURAS

A raíz de este proyecto, nuestro grupo de investigación ha seguido estudiando sobre este síndrome multifactorial. Nuestra aproximación actual se basa en averiguar más información sobre los mecanismos determinantes que afectan a la modulación del dolor percibido en mujeres con fibromialgia, mediante el análisis dinámico de redes neuronales.

Por otro lado, pretendemos conseguir caracterizar diversos grupos de mujeres con fibromialgia a través de otras señales fisiológicas como por ejemplo la frecuencia cardíaca.

Por último, se han establecido unos protocolos de intervención que puedan modular el dolor percibido desde distintos enfoques, con la finalidad de conseguir un efecto positivo en las mujeres con fibromialgia. Estos programas terapéuticos son el ejercicio físico, la terapia magnética transcraneal y la terapia hiperbárica. Dado que cada una de las intervenciones busca actuar sobre diferentes aspectos que influyen sobre el dolor, se podrá analizar la repercusión de cada una de ellas y evaluar cuáles son las vías que promueven la reducción del dolor en estas personas.

ANEXOS

ANEXO I: APROBACIÓN COMITÉ DE ÉTICA

VNIVERSITAT DE VALÈNCIA Vicerectorat d'Investigació i Política Científica

D. Francesc Francés Bozal, Profesor Contratado Doctor del Departamento de Medicina Preventiva y Salud Pública, Ciencias de la Alimentación, Toxicología y Medicina Legal, y Secretario del Comité Ético de Investigación en Humanos de la Comisión de Ética en Investigación Experimental de la Universitat de València,

CERTIFICA:

Que el Comité Ético de Investigación en Humanos, en la reunión celebrada el día 22 de diciembre de 2015, una vez estudiado el proyecto de investigación titulado:
"Desarrollo de una metodología de valoración del síndrome de fibromialgia (FIBROVAL)", número de procedimiento H1449048793044,
cuya responsable es Dña. Pilar Serra Añó,
ha acordado informar favorablemente el mismo dado que se respetan los principios fundamentales establecidos en la Declaración de Helsinki, en el Convenio del Consejo de Europa relativo a los derechos humanos y cumple los requisitos establecidos en la legislación española en el ámbito de la investigación biomédica, la protección de datos de carácter personal y la bioética.

Y para que conste, se firma el presente certificado en Valencia, a veintitrés de diciembre de dos mil quince.

ANEXO II: CARTA PARA EL RECLUTAMIENTO DE PARTICIPANTES

Buenos días,

me pongo en contacto con ustedes porque estamos realizando un proyecto de investigación sobre el análisis de la capacidad funcional en Fibromialgia.

Se trata de un proyecto de la Universidad de Valencia, del departamento de Fisioterapia y respaldado por la Generalitat Valenciana, Proyecto de I+D para grupos de investigación emergentes (GV/2016).

RESUMEN DEL PROYECTO

Averiguar la capacidad funcional de las mujeres con fibromialgia Su diagnóstico suscita mucha controversia en la comunidad científica. La falta de criterios estándares y objetivos dificulta, no sólo la valoración y clasificación de los pacientes con fibromialgia, sino también la prescripción de una pauta de intervención adecuada que mejore la calidad de vida de los mismos, pues el dolor generalizado que experimentan les impide realizar varias de sus actividades de la vida diaria. En este sentido es importante identificar qué factores físicos influyen en su calidad de vida y permitan determinar el tratamiento más personalizado y adecuado posible.

El presente proyecto pretende averiguar qué factores físicos contribuyen en la limitación de la calidad de vida en personas con fibromialgia.

Para ello participarán mujeres con fibromialgia y sanas, a las que se les medirán diferentes capacidades físicas. Concretamente se les evaluará la capacidad de desarrollar fuerza, medidas antropométricas, el control postural, el dolor, la movilidad y la postura, la capacidad funcional y la calidad de vida, esto último mediante test y cuestionarios. Finalmente se analizará la validez de estas pruebas con los criterios subjetivos desarrollados por la Sociedad Americana de Reumatología.

OBJETIVOS

La finalidad del proyecto era desarrollar un índice que contemplara diferentes pruebas de valoración objetivas asignando un peso específico a cada una de ellas, de forma que se facilitara la identificación de las personas que sufren el FMS. Más específicamente, los objetivos del proyecto fueron:

- Conocer la repercusión del síndrome sobre la capacidad para mantener el equilibrio, tanto en tareas simples como en tareas duales.
- Valorar la influencia del síndrome en la capacidad para desarrollar una acción isométrica de las extremidades.
- Averiguar la capacidad funcional general de las participantes y el impacto del síndrome en su calidad de vida.
- Saber la actitud postural en las personas con FM y su repercusión sobre la movilidad del raquis.
- Estudiar la fiabilidad y validez de las pruebas de valoración.

Para ello, se realizaría una valoración que consta de diferentes pruebas que se indican a continuación:

a. Valoración del equilibrio con una plataforma de fuerzas.
b. Análisis de la composición corporal mediante un impedanciómetro.
c. Comprobación del estado funcional y de la calidad de vida mediante cuestionarios.
d. Determinación del umbral de dolor con un algómetro.
e. Exploración de la postura corporal con inclinometría y otros test y pruebas delante de un ordenador.
f. Evaluación de la fuerza isométrica de miembros superiores e inferiores mediante dinamómetros.
g. Medición de la flexibilidad con test físico.

DURACIÓN

La duración de la valoración es de unas dos horas.

CRITERIOS INCLUSIÓN

Mujeres de 45 a 70 años.

Con Fibromialgia o sin ella.

CRITERIOS EXCLSUIÓN

Historial de fracturas o cirugía de la columna vertebral, enfermedad reumática inflamatoria, trastorno neurológico, neuropatía periférica, trastorno del oído interno, vértigo o mareos actuales, cirugía previa durante el año pasado que causaría déficit de equilibrio, no poder sentarse en el suelo, problemas cardiorrespiratorios graves o que padece alguna enfermedad aguda y terminal.

BENEFICIOS

Las personas que participen obtendrán un informe sobre su estado de salud y los resultados de los diferentes exámenes físicos y mediciones de su capacidad funcional.

Esperamos su colaboración.

Si desea participar en el estudio, póngase en contacto con:

Nuria Sempere, profesora asociada del Departamento de Fisioterapia de la Universitat de València.

Teléfono:

E-mail:

ANEXO III: TEXTO PARA EL RECLUTAMIENTO DE PARTICIPANTES VÍA WHATSAPP

Se necesita colaboración: mujeres entre 45 a 70 años.

Grupo de investigación FIBROVAL, de I+D grupos emergentes de la Generalitat Valenciana, formado por fisioterapeutas de la Universidad de Valencia, van a realizar una investigación sobre el desarrollo de una metodología para el análisis funcional en Fibromialgia.

Se trata de medir el equilibrio, el dolor con algometría, la fuerza de piernas y brazos, pruebas de postura, medidas antropométricas, batería de test y cuestionarios de calidad de vida, para poder objetivar y mejorar el diagnóstico en el Síndrome de la Fibromialgia.

Para ello se realizarán valoraciones individuales de dos horas de duración.

Se trata de conseguir entre todos que la ciencia avance en conocimientos sobre la Fibromialgia.

Obtendréis un informe sobre vuestro estado de salud.

Para la investigación, se necesitan mujeres entre 45-70 años, con diagnóstico de fibromialgia o mujeres sin fibromialgia, que no presenten problemas de movilidad o neurológicos importantes.

Poneos en contacto con la fisioterapeuta Nuria Sempere, tlf ---, para más información y detalles y pedir cita para la valoración, que se realizará en la Universidad de Valencia, Facultad de Fisioterapia o en polideportivos cerca de su casa.

El email para cualquier aclaración es ---.

¡Muchísimas gracias!

Os esperamos a todas en las mediciones.

ANEXO IV: BANDO EN VILLAR DEL ARZOBISPO

SE COMUNICA AL VECINDARIO QUE TODAS LAS MUJERES ENTRE 45 Y 70 AÑOS INTERESADAS EN PARTICIPAR EN UN ESTUDIO DE SALUD GRATUITO PASEN A APUNTARSE POR EL AYUNTAMIENTO.

A usted se le está invitando a participar en este estudio de investigación. Para llevarlo a cabo se realizarán:

1. Valoración del equilibrio.
2. Análisis de la composición corporal.
3. Comprobación del estado funcional y de la calidad de vida mediante cuestionarios.
4. Determinación del umbral de dolor con un algómetro.
5. Exploración de la postura corporal.
6. Evaluación de la fuerza isométrica de miembros superiores e inferiores.
7. Medición de la flexibilidad.

NO hay riesgos ni efectos secundarios en esta valoración

Cada una, OBTENDRÁ UN INFORME DE SU ESTADO DE SALUD Y CALIDAD DE VIDA CON LOS DIFERENTES ÍTEMS ANALIZADOS.

ANEXO V: CONSENTIMIENTO INFORMADO

Formulario de Consentimiento para el estudio:

"Caracterización de la capacidad funcional y de la calidad de vida en mujeres con fibromialgia".

Nombre del participante:

_____

A usted se le está invitando a participar en este estudio de investigación de la enfermedad de Fibromialgia. Antes de decidir si participa o no, debe conocer y comprender cada uno de los siguientes apartados. Una vez que haya comprendido el estudio de investigación, y si desea participar, entonces se le pedirá que firme usted esta forma de consentimiento, de forma libre y voluntaria.

1. Objetivos del estudio: Analizar la capacidad funcional de las personas con fibromialgia.
2. Duración: Aproximadamente máximo 2 valoraciones de una hora y media de duración cada una.
3. Procedimientos: La valoración consta de diferentes pruebas que se indican a continuación:

    a. Cuestionarios de calidad de vida, dolor y ansiedad
    b. Valoración del equilibrio con una plataforma de fuerzas
    c. Análisis de la composición corporal mediante un impedanciómetro
    d. Comprobación del estado funcional y de la calidad de vida mediante cuestionarios administrados por el valorador
    e. Determinación del umbral de dolor con un algómetro
    f. Exploración de la postura corporal con inclinometría, goniometría y pruebas posturales sentadas delante de un ordenador.

g. Evaluación de la fuerza isométrica de miembros superiores e inferiores mediante dinamómetros

h. Medición de la flexibilidad con test físico.

i. Saber su capacidad funcional con el test de 2 minutos marcha

4. Riesgos del estudio: No se han observado efectos secundarios o riesgos de estas mediciones. El paciente puede experimentar cansancio derivado de la valoración.

5. Beneficios: Con esta valoración, obtendrá un informe de su estado de salud y calidad de vida con los diferentes ítems analizados.

6. Aclaraciones:

- No está obligada a participar, su decisión es completamente voluntaria.
- No habrá ninguna consecuencia desfavorable para usted, en caso de no aceptar la invitación.
- Su identidad no será divulgada. Su participación en este estudio será tratada, en todo caso, respetándose en todo momento su anonimato y confidencialidad, regulada por la Ley de Protección de Datos Personales 15/99.
- Si decide participar en las mediciones, puede retirarse en el momento que lo desee, pudiendo informar o no, las razones de su decisión, la cual será respetada en su integridad.
- No tendrá que hacer gasto alguno durante el estudio.
- No recibirá remuneración económica por su participación.
- En el transcurso del estudio usted podrá solicitar información actualizada sobre el mismo al investigador responsable.
- Los resultados de esta investigación pueden ser publicados en revistas científicas y congresos de divulgación científica.

CARTA DE CONSENTIMIENTO INFORMADO:

Yo, _____

_____ .

He leído la hoja de información que se me ha entregado.

He comprendido la información anterior.

He podido hacer preguntas sobre el estudio.

He recibido respuestas satisfactorias sobre mis preguntas.

He sido informado y entiendo que los datos obtenidos en el estudio pueden ser publicados o difundidos con fines científicos.

Presto mi conformidad a participar en este estudio.

_____ _____

Fecha Firma del participante

ANEXO VI: AUTORIZACIÓN PARA EL USO DE LA IMAGEN

Dña. _____,

con D.N.I. _____

AUTORIZO a Núria Sempere con DNI XXX para que pueda emplear fotografías y/o registros audiovisuales para el desarrollo del estudio de investigación "Caracterización de la capacidad funcional y de la calidad de vida en mujeres con fibromialgia" de acuerdo con lo establecido en la ley orgánica 15/1999 de Protección de Datos de Carácter Personal, para la divulgación con fines científicos.

Valencia, a ___ de _____ 201__.

Firmado:

ANEXO VII: FORMULARIO DE CUMPLIMENTACIÓN DE LA HISTORIA CLÍNICA DEL PACIENTE

Proceda a valorar los criterios de inclusión y exclusión en el paciente. Por favor, marque con una cruz la opción que proceda.

CRITERIOS DE INCLUSIÓN:

Ser mujer entre 45 y 70 años de edad	SI	NO
Dar consentimiento informado	SI	NO
Si es del grupo de fibromialgia, que tenga un diagnóstico de Fibromialgia	SI	NO

CRITERIOS DE EXCLUSIÓN

Participar en otros programas de tratamiento similares a los que se van a evaluar en este ensayo	SI	NO
Menor de 45 años	SI	NO
Mayor de 70 años	SI	NO
Dificultades cognitivas o con insuficiente dominio de los dos idiomas oficiales de la Comunidad Valenciana que -a juicio del profesional sanitario que realice el reclutamiento- dificulte la comprensión de las cuestiones planteadas en las encuestas, escalas o instrumentos utilizados en el estudio siempre que no dispongan de un cuidador capaz de participar en el estudio	SI	NO

DATOS SOCIO-DEMOGRÁFICOS

- ¿Cuántos años tiene?
- Si padece fibromialgia, ¿cuantos años hace que se le ha diagnosticado?
- ¿Por quién fue diagnosticado?
- ¿Con qué criterios?
- ¿Cuánto mide, aproximadamente?
- ¿Dónde vive usted habitualmente?
  - □ Domicilio propio
  - □ Domicilio de un familiar
  - □ Residencia/Centro sociosanitario
  - □ Otros: _____
- ¿Cuál es su estado civil actual?
  - □ Casada
  - □ Soltera
  - □ Viuda
  - □ En pareja
  - □ Separada/divorciada
- ¿Cuál es su situación laboral actual?
  - □ Activa
  - □ En paro
  - □ Pensionista
  - □ Estudiante
  - □ Tareas domésticas
- ¿Qué nivel de estudios tiene?
  - □ No sabe leer/escribir
  - □ Primarios (EGB&)

- □ Secundarios
- □ Universitarios

- Profesión:
  - □ Ama de casa
  - □ Asistenta
  - □ Técnico
  - □ Universitaria

- ¿Número de hijos?
- ¿Ha habido alguna defunción en los últimos 5 años?
- En cuanto al consumo de tabaco: ¿Cuál es la opción que mejor se ajusta a su situación?
  - □ Sí fuma, diariamente.
  - □ Sí fuma, pero no diariamente.
  - □ No fuma actualmente, pero ha fumado antes.
  - □ No fuma, ni ha fumado nunca de manera habitual

- ¿Ha consumido algún tipo de bebida alcohólica (cerveza, vino, whisky…) en los últimos doce meses?
  - □ Todos los días.
  - □ Algún día a la semana.
  - □ Algún día al mes.
  - □ Alguna vez en el último año.
  - □ No he consumido bebidas alcohólicas en el último año.

- ¿Qué nivel de actividad física realiza en su tiempo libre?:
  - □ Completamente inactivo (leer, ver TV, ir al cine, &)
  - □ Realiza actividad física o deportiva ocasional o esporádica (caminar, pasear en bici, jardinería, gimnasia suave, actividades recreativas de ligero esfuerzo, &)

- □ Realiza actividad física regular varias veces al mes (tenis, gimnasia, correr, natación, ciclismo, etc.).

- ¿Cuántas horas de actividad física realiza a la semana? (Colocar número exacto de horas.)
  - □ Ninguna hora
  - □ Entre 1h y 2h a la semana
  - □ Entre 3h 5h a la semana
  - □ Entre 6h y 8h a la semana

ENFERMEDADES DIAGNOSTICADAS RELEVANTES

Problemas respiratorios: EPOC, asma, …

Problemas cardiocirculatorios: cardiopatía isquémica, hipertensión arterial, insuficiencia arterial, insuficiencia venolinfática, …

Problemas neurológicos: ACV, Parkinson, neuralgia, …

Problemas endocrinológicos: diabetes, tiroides, problemas de páncreas, hipófisis, …

Problemas musculoesqueléticos y/o articulares: artrosis, artritis, osteoporosis, hernia discal, …

Problemas visuales y/o auditivos:

Otros:

ANEXO VIII: COPIA ORIGINAL DEL ESTUDIO 1

Characterization of postural control impairment in women with fibromyalgia, en la revista *Plos One*

PLOS ONE

RESEARCH ARTICLE

Characterization of postural control impairment in women with fibromyalgia

Núria Sempere-Rubio[1], Juan López-Pascual[2], Marta Aguilar-Rodríguez[1], Sara Cortés-Amador[1], Gemma Espí-López[1], Israel Villarrasa-Sapiña[3], Pilar Serra-Añó[1]*

1 Department of Physiotherapy, University of Valencia, Valencia, Spain, **2** Biomechanics Institute of Valencia, Polytechnic University of Valencia, Valencia, Spain, **3** Department of Physical Education and Sports, University of Valencia, Valencia, Spain

* pilar.serra@uv.es

OPEN ACCESS

Citation: Sempere-Rubio N, López-Pascual J, Aguilar-Rodríguez M, Cortés-Amador S, Espí-López G, Villarrasa-Sapiña I, et al. (2018) Characterization of postural control impairment in women with fibromyalgia. PLoS ONE 13(5): e0196575. https://doi.org/10.1371/journal.pone.0196575

Editor: Yih-Kuen Jan, University of Illinois at Urbana-Champaign, UNITED STATES

Received: June 9, 2017

Accepted: April 16, 2018

Published: May 3, 2018

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Funding: This research was supported by Conselleria d'Educació, Ciència i Esports [Valencian Regional Department of Education, Science and Sports], València, Spain [Grant GV2016/140]. PSA, NSR, MAR, SCA, GEL, http://www.ceice.gva.es/va/inicio;jsessionid=CB78D8F7BA7A76F84A882D7307D23AC5. The funders had no role in study design,

Abstract

The main goal of this cross-sectional study was to detect whether women with fibromyalgia syndrome (FMS) have altered postural control and to study the sensory contribution to postural control. We also explored the possibility that self-induced anxiety and lower limb strength may be related to postural control. For this purpose, 129 women within an age range of 40 to 70 years were enrolled. Eighty of the enrolled women had FMS. Postural control variables, such as *Ellipse*, Root mean square (*RMS)* and Sample entropy (*SampEn*), in both directions (i.e. mediolateral and anteroposterior), were calculated under five different conditions. A force plate was used to register the center of pressure shifts. Furthermore, isometric lower limb strength was recorded with a portable dynamometer and normalized by lean body mass. The results showed that women with FMS have impaired postural control compared with healthy people, as they presented a significant increase in *Ellipse* and *RMS* values ($p<0.05$) and a significant decrease in *SampEn* in both directions ($p<0.05$). Postural control also worsens with the gradual alteration of sensory inputs in this population ($p<0.05$). Performing a stressor dual task only impacts *Ellipse* in women with FMS ($p>0.05$). There were no significant correlations between postural control and lower limb strength ($p>0.05$). Therefore, women with FMS have impaired postural control that is worse when sensory inputs are altered but is not correlated with their lower limb strength.

Introduction

Fibromyalgia syndrome (FMS) is a rheumatologic disorder with clinical features such as widespread pain, fatigue, cognitive symptoms and mood disorders, such as depression and anxiety [1–4]. Moreover, previous studies have concluded that people with FMS may also have altered perception or interpretation of audiovestibular inputs due to neural disintegration at brainstem level [5] and some sensory or motor deficits and suboptimal muscle coordination [6] that may affect postural control. Indeed, the study conducted by Bennet et al. (2007) concluded that one of the ten most debilitating symptoms was altered balance, with a prevalence of 45% [7].

data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

So far, several studies have used objective devices to assess postural control in this population [8–11] using different tests that discriminated which of the different sensory inputs that are responsible for postural control (i.e. visual, proprioceptive and vestibular systems) were impaired. All of them explored the impact of FMS on postural control variables in the time-domain, showing a larger area and higher velocity of the center of pressure (COP) [11,12] or an altered postural stability rate in FM patients [8–10,13] compared with healthy population. Nevertheless, although the postural control system is considered a non-linear system, where reactions are not proportional to the applied stimuli [14,15], none of the studies in this population have used non-linear variables to the assessment of the postural control. Conversely, this approach has been used in studies conducted on other populations. Indeed, people with vertigo show a posturographic signal with a small amount of complexity which makes the switch of behavioral modes more difficult and constrain the postural adaptation needed to select sensory information from the surrounding environment [16]. Non-linear variables have also demonstrated more rigid and less adaptable balance in people with Multiple Sclerosis [17] and hypermobility [18] and they have been used as a predictor of the risk of falls [19]. Therefore, this approach could provide complementary information about the ability to maintain the postural control in FM population.

As described above, postural control is possible because of correct linkages between vestibular, visual and somatosensory information [20,21], therefore it is of particular interest to know the contribution of these sensory inputs to the postural control in FM population. Besides, there are other contributing factors that may influence postural control, as can be observed in studies focusing on mood conditions such as anxiety, where high levels of anxiety have been associated with impaired balance control [22,23]. Other studies have focused on the motor effectors instead, suggesting that the ability of people with FMS to maintain balance may also be affected by the loss of strength that they suffer [24]. Similar findings have been shown in other studies on elderly people [25], patients with cystic fibrosis [26] and people with bone injuries [27,28].

Although both signs (i.e. anxiety and loss of strength) are common in people with FMS [2,29–32], so far no previous studies have analyzed the relationship between lower limb strength and the ability to maintain static balance in women with FMS or the impact of anxiety on their static postural control. Understanding this possible relationship could help therapists to design cause-based treatment plans to improve balance, including strength exercises or focusing on other aspects that are responsible for postural control (i.e. proprioception, visual disturbance, anxiety, etc.).

Our main objective was to determine whether women with FMS suffer impaired postural control in comparison with their healthy counterparts and to study the sensory contribution to postural control in this population. The impact of self-induced anxiety on postural control was also analyzed. In addition, we explored the relationship between postural control and lower limb strength.

Materials and methods

Participants

The study design was cross-sectional and purposive sampling (specifically, modal instance sampling) was used to select the study participants. The FMS group (FMG) was composed of 80 women between 43 and 70 years of age who had been diagnosed with FMS. They were recruited from several Fibromyalgia associations in Spain over a period of a year and a half. The control group (CG) was composed of 49 age-matched healthy women. The inclusion criterion for the FMG was diagnosis based on 2010 American College of Rheumatology criteria:

widespread pain index (WPI) ≥ 7 and symptom severity (SS) scale ≥ 5 or WPI = 3–6 and SS scale score ≥ 9. Additionally, the symptoms had to have lasted for at least 3 months [4]. For both groups, the exclusion criteria comprised an inflammatory rheumatic disease or an inner ear disorder, the use of antidepressant opioid or sedative drugs, current vertigo or dizziness, visual loss, neurological disorder, peripheral neuropathy and surgery within the past year that would cause balance deficits.

The Institutional Review Board (IRB) of the University of Valencia approved all the procedures that were performed in accordance with the principles of the World Medical Association's Declaration of Helsinki. Written informed consent was obtained from the participants before the tests started.

Procedures

Anthropometric and clinical measurements. Foot-to-foot bioelectrical impedance was measured with the Tanita bc-601 Body Fat Analyzer (Tanita Corp., Tokyo, Japan) [33,34]. Subjects stood on the metal sole plates of the device wearing only their underwear and all measurements were made after a period of 10 min standing in order to minimize potential errors from acute shifts in fluid distribution. Body mass index was estimated for all participants using the standard prediction equations provided by the manufacturer. Furthermore, perceived pain intensity was measured on a 10-cm visual analog scale (VAS) consisting of a continuous line between two endpoints, with 0 being no pain and 10 being maximum tolerable pain.[35].

Postural control. The postural control test was performed using the Wii Balance Board (WBB) (Nintendo, Kyoto, Japan) force platform. Previous studies have validated this device as a good means of analyzing postural control in the standing position [36,37]. The platform was placed on a stable surface on the floor to avoid signal distortion and noise. Subjects were asked to place their feet hip-width apart, toes pointing forward and arms relaxed beside their side in all the tests. A reference point was situated 2 metres in front of the subject at eye level. All the subjects were briefed on the importance of maintaining this position and were asked to avoid any body movement. The subjects performed two consecutive 60-second repetitions [38] of five different tests in a random order. They rested for 30 seconds between tests and repetitions, unless they needed extra time. All the tests are described below.

Standing position with eyes open (*EO*): in the previously described position, and with their eyes open, they maintained the position for 60 seconds. In this test all sensory inputs (i.e. visual, proprioceptive and vestibular) were intact, so this was used as a control measurement.

Standing position while recalling a stressful day (Dual task [*DT*]): the participants had to maintain the bipedal standing position with their eyes open, recalling a stressful day in their life. They were instructed to think about a common stressful day for two minutes before the test started. They subsequently recounted the stressful events to the physiotherapist in the order in which they occurred. The purpose of this test was to explore the effect of self-induced anxiety on postural control.

Standing position with eyes closed (*EC*): the participants performed this test in the previously described position, but with their eyes closed. The purpose of the test was to analyze the extent to which proprioceptive and vestibular inputs can make up for a lack of visual information.

Standing position on a piece of foam with eyes open (*FEO*): the test was conducted according to the same procedure as EO, but with the participants standing on a piece of foam. The dimensions of the foam were 45 x 27 x 9 cm and the density was 56.7 kg/m^3. The purpose of this test was to study the contribution of visual and vestibular inputs to postural control when the proprioceptive system was altered intentionally.

Standing position on a piece of foam with eyes closed (*FEC*): the test used was the same as above, but the visual information was overridden. The aim of this test was to analyze the action of the vestibular system when visual information was not present and the proprioceptive input was altered intentionally. The vestibular organ is an inertial measuring system that allows us to sense self-motion with respect to the six degrees of freedom in space in the absence of external sensory cues. Since overriding the rest of the sensory information was not possible with this type of assessment, the main contribution of the vestibular system was assessed with this test, as described above [9,32].

Lower limb strength. Maximal isometric strength was assessed using a portable dynamometer NedDFM/IBV (Instituto de Biomecánica de Valencia, Valencia, Spain). Specifically, the isometric quadriceps and hamstring strength of both lower limbs were recorded. To measure this, the participants remained seated without any back support, with their upper limbs beside their body and hips and knees flexed at 90˚. When quadriceps strength was assessed, the individuals had to try to extend their knee as hard as they could against the evaluator's resistance without moving their hip, trunk or upper limbs. When hamstring strength was assessed, the participants were required to flex their knee as hard as they could instead. In this case, they were not allowed to move their hip, trunk or upper limb from the original position either. For both measurements the dynamometer was place on the distal portion of the leg and the evaluator was fixed against a wall to resist the participant's strength and avoid any leg movement. Three repetitions of each measurement were performed consecutively with a 30-second rest between them, and the mean of the three repetitions was calculated. The two measurements (i.e. quadriceps and hamstring strength) were conducted in a counterbalanced order.

Reliability studies

Before the study began, we investigated the test-retest reliability of the strength assessment procedures described (isometric measurement of quadriceps and hamstring strength) and the BMI measurement that was recorded with the bioelectrical impedance device, since the reliability of these protocols had not been established previously. For this purpose, a convenience sample composed of 15 healthy women (not the individuals in the CG), with a mean (SD) age of 50.86 (4.63) years, came to our lab to be assessed in two different sessions (eight days apart) by two physiotherapists with extensive experience in biomechanical evaluation. In one of the sessions, the participants were assessed by both physiotherapists, whilst in the other, only one of them conducted the assessment.

Stabilometry data analysis

The ground reaction force was recorded with a Wii Balance Board (WBB) force plate with four uni-axial vertical force transducers at each corner (Nintendo, Kyoto, Japan). The raw data were acquired using WiiLab software (University of Colorado Boulder, Colorado, USA) for Matlab R2007 (Mathworks Inc, Natick, USA).

Center of pressure (COP) displacement signals were filtered digitally by a Butterworth low-pass filter. We used a 10 Hz cut-off frequency to assure that 99% of power spectral density was below this threshold [36]. The first 10 seconds of each test were excluded from the analysis to avoid any interference from delayed stabilization of the recording equipment after the person stepped onto the force plate [39]. Raw data were recorded at a frequency of 40 Hz. Once the previously described steps had been conducted, three posturographic variables were calculated for each of the five tests performed (each test is considered the mean of the two repetitions performed). An explanation and justification of the selected variables is given below.

Ellipse (*Ellipse*): the 95% confidence ellipse area is a measure of the area that COP traverses. It is determined by taking the radius of the major and minor axes and then fitting an ellipse that would include 95% of the points [40]. This variable was used as the main measure of postural stability. The overall size of the ellipse summarizes the amount of overall motion in square millimeters, and the relative orientation of the ellipse is an indication of the degree to which hip and ankle motion are correlated [41].

Root mean square of the COP distance *(RMS)*: this variable measures the average absolute displacement around the mean COP and it is considered a measure of error in the balance control system [42]. It is sensitive to alterations in proprioception [43] and when somatosensory feedback for posture is delayed peripherally, the COP drifts, resulting in a larger than normal RMS [44].

Sample entropy *(SampEn)*: this variable indicates the regularity of a time series (i.e. COP path) by calculating the probability of it having repeated itself. The calculation of *SampEn* comprised the following steps [45]: (i) computation of the increase in the recorded COP time series according to the suggestions put forward by Govindan et al. [46]; (ii) computation of the *SampEn* values (using the PhysioToolkit-PhysioNetSampEn software) [47]; and (iii) calculation of the input parameters, m and r, using the empirical approach described by Ramdani et al. [45]. This last step was conducted with our own data and the results achieved the value m = 4 and r = 0.35, with N = 2000, where *N* is the number of input data points, *m* is the length of compared runs, and *r* is the tolerance. The information provided by *SampEn* in a specific population has always been related to their healthy counterparts. When comparing specific pathologic populations with healthy samples, lower *SampEn* values have been associated with higher regularity of the time series, which may be related to a poor capability of the neuromuscular system to adapt to perturbations. In contrast, higher values would be indicative of unstable systems that are too sensitive to perturbations [15].

RMS and *SampEn* were calculated for anteroposterior (AP) and mediolateral (ML) directions of COP displacement, which have been related to the contribution of ankle and hip movement to postural control, respectively [48]. In this respect, Winter et al. concluded that the complexity of these control mechanisms depends on the posture adopted, which may require combined strategies. However, for the healthy population, in a side-by-side stance, AP balance is more closely related to ankle control, whereas ML balance is related to hip control [48].

Statistics

Statistical analysis was performed using SPSS software Version 21 (SPSS Inc., Chicago, IL, USA). Standard statistical methods were used to obtain the mean as a measure of central tendency and the standard deviation (SD) as a measure of dispersion. For the inferential analysis, a mixed model MANOVA [group (FMG and CG) and condition (EO, DT, EC, FEO, FEC)] was performed to establish the effects of group and condition on the dependent balance variables (i.e. *Ellipse*, *RMS* and *SampEn*). When the univariate contrasts showed statistically significant main or interaction effects, pairwise comparisons were performed with the Bonferroni correction. Additionally, Spearman correlations between bilateral lower limb strength (average of dominant and non-dominant lower limb strength) and balance variables were performed for the FMG only. An independent Student's t-test was performed to verify whether the groups were similar in age, body mass index (BMI) and pain at baseline.

The reliability of quadriceps and hamstring strength recorded by the dynamometer and BMI recorded by the bioelectrical impedance assessment was determined using a repeated measures analysis of variance (ANOVA) to calculate the (2,1) intra-class correlation coefficient

(ICC)[49]. Within-day and inter-observer reliability were determined by comparing values obtained by two different observers in two repeated assessments several minutes apart. Between-days and intra-observer reliability were determined by comparing the outcomes of two assessments repeated by the same observer, at least eight days apart. A p-value of 0.05 was accepted as the level of significance.

Results

Participants

The FMG was composed of 80 women with a mean (SD) age of 53.95 (6.71) years and a BMI of 26.94 (5.85). The CG was composed of 49 women with a mean (SD) age of 54.47 (5.86) years and a BMI of 25.98 (4.88). There were no significant differences between groups in any of these variables ($p>0.05$). The FMG showed a mean (SD) pain score of 7.70 (2.04), whilst in CG this score was 1.82 (2.44), which means there were significant differences in pain between groups [$t\ (127) = 14.75$, $p<0.05$, $r = 0.79$].

Postural control between groups

The multivariate analysis showed that there was a significant interaction between 'group' and 'condition' [$F_{(20,\ 2028)} = 3.43$, $p<0.05$, $\eta2 = 0.22$] and a significant main effect of 'condition' [$F_{(20,\ 2028)} = 28.83$, $p<0.05$, $\eta2 = 0.22$] and 'group' [$F_{(5,\ 123)} = 4.23$, $p<0.05$, $\eta2 = 0.15$]. The univariate analysis showed that the groups presented unequal results of *RMS_AP* in the different test performed since a significant factor interaction was achieved [$F_{(1.87,\ 410.35)} = 5.10$, $p<0.05$, $\eta2 = 0.04$]. The postural control in both groups varied according to the test performed because a significant main effect of the 'condition' factor was obtained for *Ellipse* [$F_{(1.83,\ 231.80)} = 129.28$, $p<0.05$, $\eta2 = 0.50$], *RMS_AP* [$F_{(3.23,\ 410.35)} = 130.78$, $p<0.05$, $\eta2 = 0.51$], *RMS_ML* [$F_{(3.80,\ 377.96)} = 191.54$, $p<0.05$, $\eta2 = 0.60$], *SampEn_Ap* [$F_{(3.80,\ 482.44)} = 145.82$, $p<0.05$, $\eta2 = 0.53$] and *SampEn_ML* [$F_{(3.61,\ 458.13)} = 159.37$, $p<0.05$, $\eta2 = 0.56$]. Additionally, a significant main effect of the 'group' factor was obtained for *Ellipse* [$F_{(1,\ 127)} = 18.82$, $p<0.05$, $\eta2 = 0.13$], *RMS_AP* [$F_{(1,\ 127)} = 18.97$, $p<0.05$, $\eta2 = 0.13$], *RMS_ML* [$F_{(1,\ 127)} = 14.68$, $p<0.05$, $\eta2 = 0.10$], *SampEn_Ap* [$F_{(1,\ 127)} = 16.46$, $p<0.05$, $\eta2 = 0.12$] and *SampEn_ML* [$F_{(1,\ 127)} = 16.86$, $p<0.05$, $\eta2 = 0.12$] which implies that the groups presented a different postural control regardless of the test performed.

The subsequent between-group analysis showed that there were significant differences in all variables in all the tests conducted, with the exception of *RMS_AP* and *SampEn_AP* for the EO test and *SampEn_ML* for the FEO test. The *Ellipse* and *RMS* values (in both directions) were significantly higher in the FMG than in the CG. Regarding variability, *SampEn* was lower in the FMG than in the CG, which implies a more repetitive movement pattern. Fig 1 shows the between-group results in each of the tests conducted.

Sensory input results

The posturographic variables were altered in both groups when the difficulty of the task was increased placing a foam on the force plate (i.e. FEO and FEC). This alteration is reflected as an increase in the values of *Ellipse* and *RMS* and a decrease in the values of *SampEn*, compared with the results obtained in those test in which the foam was not used.

Nevertheless, the postural control of the groups was different when the proprioceptive system was not disturbed (i.e. EO and EC). If we compare EC with EO, the CG did not show any significant differences in the postural control variables, except for *SampEn* in the AP direction.

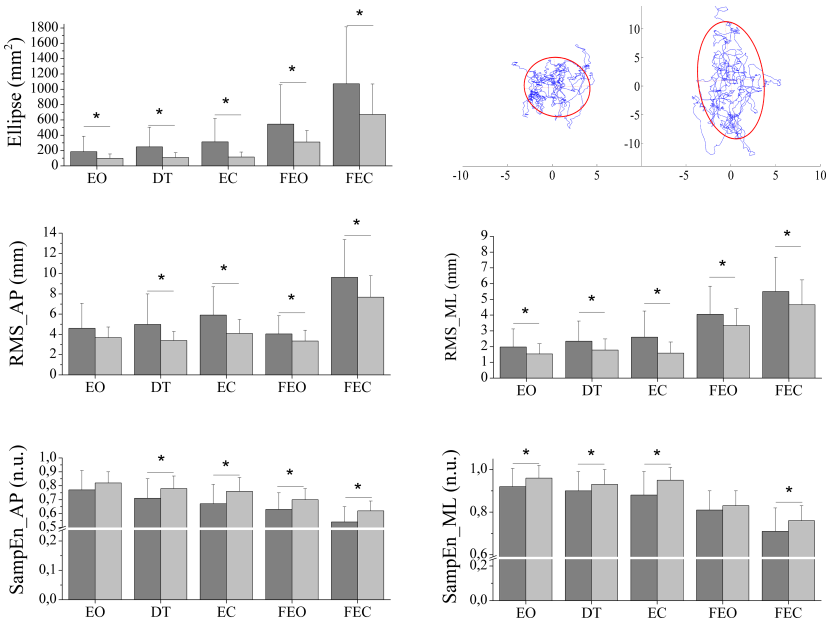

Fig 1. Differences between groups in postural control variables. The bars represent the mean and the error bars, the standard deviation. Dark grey bar = fibromyalgia group; Light grey bar = control group; EO = eyes open test; DT = dual task test; EC = eyes closed test; FEO = foam eyes open test; FEC = foam eyes closed test; AP = anteroposterior; ML = mediolateral; RMS = root mean square of the center of pressure distance; SampEn = sample entropy. At the top right of the panel, the Ellipse of a representative case of the fibromyalgia group (right side) and one of control group (left side) is shown. * indicates significant differences between groups ($p < 0.01$).

https://doi.org/10.1371/journal.pone.0196575.g001

However, the FMG showed a significant increase in *Ellipse* and *RMS* in both directions and a decrease in *SampEn* also in both directions. All the data are shown in Table 1.

Impact of self-induced anxiety on postural control

When DT and EO were performed, no significant differences were obtained for any of the posturographic variables in the CG ($p>0.05$). However, the FMG showed significantly higher *Ellipse* values (Table 1).

Relationship between lower limb strength and postural control

There was no significant correlation between lower limb strength (i.e. quadriceps and hamstring) and posturographic variables ($p>0.05$).

Table 1. Pairwise comparisons of the posturographic variables.

	Ellipse (mm^2)		RMS_AP (mm)		RMS_ML (mm)		SampEn_AP (n.u.)		SampEn_ML(n.u.)	
	CG	FMG	CG	FMG	CG	FMG	CG	FMG	CG	FMG
EO	99.87 (56.23)	184.28 (202.90)	3.68 (1.05)	4.61 (2.46)	1.54 (0.64)	1.98 (1.14)	0.82 (0.08)	0.77 (0.14)	0.96 (0.06)	0.92 (0.09)
DT	109.17 (63.64)	248.16 (257.37)[1]	3.40 (0.88)	4.99 (3.00)	1.77 (0.71)	2.34 (1.28)	0.78 (0.09)	0.71 (0.11)	0.93 (0.07)	0.90 (0.09)
EC	116.08 (65.39)	313.07 (304.97)[1]	4.10 (1.38)	5.91 (2.79)[1]	1.59 (0.70)	2.60 (1.66)[12]	0.76 (0.10)[1]	0.67 (0.14)[1]	0.95 (0.06)	0.88 (0.11)[1]
FEO	311.22 (149.38)[123]	544.07 (515.15)[123]	5.05 (1.30)[123]	6.61 (3.11)[123]	3.33 (1.07)[123]	4.05 (1.79)[123]	0.70 (0.08)[123]	0.63 (0.12)[123]	0.83 (0.07)[123]	0.81 (0.09)[123]
FEC	670.95 (397.76)[1234]	1071.85 (741.42)[1234]	7.68 (2.12)[1234]	9.64 (3.73)[1234]	4.66 (1.58)[1234]	5.50 (2.17)[1234]	0.62 (0.07)[1234]	0.54 (0.11)[1234]	0.76 (0.07)[1234]	0.71 (0.11)[1234]

Data are expressed as mean (SD). EO: eyes open; DT: dual task; EC: eyes closed; FEO: foam eyes open; FEC: foam eyes closed; RMS: root mean square variable; SampEn: sample entropy; n.u.: no units. AP: anteroposterior direction; ML: mediolateral direction. Superscript 1, 2, 3 and 4: significant differences versus test 1, 2, 3 and 4, respectively.

https://doi.org/10.1371/journal.pone.0196575.t001

Test-retest reliability of strength and BMI assessment procedures

The quadriceps and hamstring strength procedures showed good reliability (2,1 ICC) [49] for dominant lower limb strength, ranging from 0.78 to 0.86. The intra-observer and between-days ICC were 0.83 and 0.78 for quadriceps and hamstring strength, respectively. The inter-observer and within-day ICC were 0.86 and 0.83 for quadriceps and hamstring strength, respectively. Regarding the BMI measurement, the reliability was very good. The intra-observer and between-days ICC was 0.99. The inter-observer and within-day ICC was 1.00.

Discussion

The results derived from this study show that women with FMS have impaired postural control compared with their healthy counterparts. These results are consistent with previous studies [9–11,13,24] but also yield some new findings about the postural control strategy. In general, there is a significant increase in the values of the linear variables (i.e. *Ellipse* and *RMS*) and a significant decrease in *SampEn* (a non-linear variable). Furthermore, when a sensory input is removed or disturbed, impairment of postural control increases.

Specifically, the *Ellipse* values were an average of 2.03 times higher in women with FMS than in healthy women. This result means that the COP trajectory covers a larger area in this population while standing and it is consistent with the results of a previous study conducted in women with fibromyalgia that reported a similar increase in the area in a bipedal test with eyes open [11]. It also coincides with the results of previous studies conducted in people with Multiple Sclerosis [17] or vestibular system problems [50]. In fact, a previous study concluded that there is a tendency for the linear values of COP, sway area, range of the COP and RMS in both directions (AP and ML) to increase, irrespective of the disability studied [51]. In the case of the population with FMS, a chronic painful condition, it is possible that the motor pattern adapts to this condition and therefore modifies movement and stiffness to protect against further pain. Previous studies in which pain was experimentally induced have reported a larger area. This is attributed to the impact of pain on γ motor neuron activity [52], which could modulate the neuromuscular response. Regarding *RMS*, there is a significant increase in the FMG compared with the CG in both directions, ML and AP. This increase observed in women with FMS may be the result of slowed somatosensory feedback, which may reflect a deficit in the somatosensory feedback loop [43,44]. Nevertheless, a previous study pointed out that an increase in linear values does not always suggest a lack of balance, but may reflect a strategy of skillful individuals to explore their support base by being more flexible [51]. For this reason, in order to

confirm the existence of a postural control deficit, *SampEn* was used as a non-linear variability variable. This variable reflects the automatism of postural control and net motor control signal output and comprises the whole body center of gravity and the muscles responsible for postural maintenance [53]. Our results showed that *SampEn* values were generally lower in women with FMS than in healthy women. This decrease in the intrinsic complexity of the steady-state dynamics is associated with a functional decline of the postural control system [54]. Indeed, it is known that a small amount of complexity makes it more difficult to switch behavioral modes, affecting the postural adaptation that is needed to select sensory information from the surrounding environment [55] and indicating that postural behavior is more rigid, which results in a loss of adaptability and local stability [56]. These results are in line with previous studies in which other pathologies were studied, all of which showed lower SampEn or Approximate Entropy compared with healthy people [16,17,51].

In order to further analyze sensory input alterations, as explained in the methods section, different tests were conducted (i.e. EO, EC, FEO and FEC) in which some of the sensory inputs were altered intentionally. The results showed that postural control was worse in both groups (i.e. *Ellipse* and *RMS* values increased and *SampEn* decreased) when the proprioceptive information was altered using a piece of foam (i.e. FEO and FEC). This is justified by the aforementioned linkage between the three sensory inputs. In this case, postural control needs to be maintained even when the proprioceptive information is disturbed, making it more difficult to maintain stability. These results are also in line with those obtained in several previous studies in which increasingly complex tasks were assessed in different populations [16,17,57] and an increase in linear variables and decrease in COP variability were observed.

When EO and EC were compared, the postural control was different depending on which group they belonged to. There were no significant differences between EO and EC in the CG, except for *SampEn_AP*. This may be due to the fact that other sensory input information can make up for the lack of vision [51], although there was a reduction in the complexity of the COP trajectory in the AP direction. However, the FMG could not make up for that information properly and therefore experienced an increase in *Ellipse* and *RMS* and a decrease in variability. It has been suggested that visual input is the most reliable source of information needed for the central nervous system to send the motor response peripherally [58]. Under normal circumstances, when vision is not present (as is the case in EC), the somatosensory information needs to supply this lack of information, but as mentioned above, in women with FMS the somatosensory information seems to be slowed down, as shown in the results, where an increase in *RMS* values was obtained.

The use of a DT to assess the impact of self-induced anxiety on postural control was based on the previously described linkages between balance and anxiety [23]. The role of the parabrachial nucleus (PBN) in conditioning fear and anxiety responses has been demonstrated [59], as have the projections sent from the PBN to the vestibular nuclei [60]. Likewise, the locus coeruleus has been implicated both as an initiator of anxiety responses [59] and as a modulator of vestibular function [61]. Our results showed that the postural behavior in this DT compared with the EO test is different depending on which group the individual belongs to. The CG did not achieve significant differences in any of the posturographic variables, while the FMG presented an increase in *Ellipse* values in the DT compared with the EO test. These results suggest that the DT conducted increases their level of anxiety and vestibular activity is therefore modified and has an impact on postural control. Nevertheless, no significant differences were obtained for *RMS* or *SampEn*, which may be explained by two assumptions. First of all, the test conducted induces the anxiety response by recalling stressor events, but not using any other sensory cues. The use of more information that elicits a greater anxiety response may alter not only the *Ellipse* values but also the complexity of the signal, since it has been

demonstrated that some units in the caudal PBN also receive input from eye movement, for example. The other reason that could explain this result is that an increase in linear values does not always suggest a lack of balance, but a more flexible strategy [51]. However, both explanations need to be contrasted with more specific studies. These results therefore suggest that the alteration in postural control is partially modulated by remembrance-related anxiety.

Apart from studying sensory inputs, we explored the possible association between postural control and lower limb strength. Past studies have shown an association between altered postural control and a lack of strength in elderly people and in people with cystic fibrosis [25,26]. In fact, previous studies have suggested that people with FMS may be more prone to fall because they have similar lower body strength to older healthy women [62] and the rate of torque development for hip extension is considered a strong predictor of falls [29]. Nevertheless, the authors of these studies did not find a relationship between falls and peak torque. The results of our correlation analysis between lower limb strength and postural control variables are consistent with the aforementioned results, since we did not find a significant correlation between them either. These results, in conjunction with those previously reported, reinforce the hypothesis of a disrupted somatosensory system in this population as the main cause of their altered postural control. However, future studies should aim to provide further knowledge about proprioceptive information in these people using specific assessment tools. Furthermore, the results of this study should be taken cautiously because due to the fatigue, one of the most common symptoms of this population [4], we only conducted two trials of each condition in the postural control assessment. The number of trials should be expanded when the population assessed could perform the protocol without fatigue in order to improve the reliability of the tests.

Conclusions

The results obtained from this study demonstrate that women with FMS have impaired postural control compared with their healthy counterparts. Furthermore, their somatosensory system seems to be affected, as shown by the increase in *RMS* and *Ellipse* and reduction in *SampEn* values when visual information is missing. Postural control is partially influenced by self-induced anxiety and it is not related to lower limb strength.

Supporting information

S1 Dataset. Study database.
(XLSX)

S2 Dataset. Reliability database.
(XLSX)

Acknowledgments

This research was supported by Conselleria d'Educació, Ciència i Esports [Valencian Regional Department of Education, Science and Sports], València, Spain [Grant GV2016/140].

Author Contributions

Conceptualization: Núria Sempere-Rubio, Juan López-Pascual, Gemma Espí-López, Pilar Serra-Añó.

Data curation: Núria Sempere-Rubio, Juan López-Pascual, Marta Aguilar-Rodríguez, Sara Cortés-Amador, Israel Villarrasa-Sapiña, Pilar Serra-Añó.

Formal analysis: Juan López-Pascual, Israel Villarrasa-Sapiña, Pilar Serra-Añó.

Funding acquisition: Pilar Serra-Añó.

Investigation: Núria Sempere-Rubio, Marta Aguilar-Rodríguez, Sara Cortés-Amador, Gemma Espí-López, Pilar Serra-Añó.

Methodology: Núria Sempere-Rubio, Marta Aguilar-Rodríguez, Sara Cortés-Amador, Pilar Serra-Añó.

Project administration: Pilar Serra-Añó.

Resources: Marta Aguilar-Rodríguez, Sara Cortés-Amador, Gemma Espí-López, Israel Villarrasa-Sapiña, Pilar Serra-Añó.

Software: Juan López-Pascual, Israel Villarrasa-Sapiña.

Validation: Marta Aguilar-Rodríguez, Sara Cortés-Amador, Gemma Espí-López.

Writing – original draft: Núria Sempere-Rubio, Juan López-Pascual, Pilar Serra-Añó.

Writing – review & editing: Gemma Espí-López, Pilar Serra-Añó.

References

1. Talotta R, Bazzichi L, Di Franco M, Casale R, Batticciotto A, Gerardi MC, et al. One year in review 2017: fibromyalgia. Clin Exp Rheumatol. 2017; 35 Suppl 105: 6–12.
2. Thieme K, Turk DC, Flor H. Comorbid depression and anxiety in fibromyalgia syndrome: relationship to somatic and psychosocial variables. Psychosom Med. 2004; 66: 837–844. https://doi.org/10.1097/01.psy.0000146329.63158.40 PMID: 15564347
3. Cohen H, Buskila D, Neumann L, Ebstein RP. Confirmation of an association between fibromyalgia and serotonin transporter promoter region (5-HTTLPR) polymorphism, and relationship to anxiety-related personality traits. Arthritis Rheumatol. 2002; 46: 845–847.
4. Wolfe F, Clauw DJ, Fitzcharles M-A, Goldenberg DL, Katz RS, Mease P, et al. The American College of Rheumatology preliminary diagnostic criteria for fibromyalgia and measurement of symptom severity. Arthritis Care Res. 2010; 62: 600–610.
5. Bayazıt YA, Gürsoy S, Özer E, Karakurum G, Madenci E. Neurotologic manifestations of the fibromyalgia syndrome. J Neurol Sci. 2002; 196: 77–80. PMID: 11959160
6. Jones KD, Horak FB, Winters KS, Morea JM, Bennett RM. Fibromyalgia is associated with impaired balance and falls. J Clin Rheumatol Pract Rep Rheum Musculoskelet Dis. 2009; 15: 16–21.
7. Bennett RM, Jones J, Turk DC, Russell IJ, Matallana L. An internet survey of 2,596 people with fibromyalgia. BMC Musculoskelet Disord. 2007; 8: 1. https://doi.org/10.1186/1471-2474-8-1
8. Akkaya N, Akkaya S, Atalay NS, Acar M, Catalbas N, Sahin F. Assessment of the relationship between postural stability and sleep quality in patients with fibromyalgia. Clin Rheumatol. 2013; 32: 325–331. https://doi.org/10.1007/s10067-012-2117-y PMID: 23179001
9. Jones KD, King LA, Mist SD, Bennett RM, Horak FB. Postural control deficits in people with fibromyalgia: a pilot study. Arthritis Res Ther. 2011; 13: R127. https://doi.org/10.1186/ar3432 PMID: 21810264
10. Russek LN, Fulk GD. Pilot study assessing balance in women with fibromyalgia syndrome. Physiother Theory Pract. 2009; 25: 555–565. https://doi.org/10.3109/09593980802668050 PMID: 19925263
11. Trevisan DC, Driusso P, Avila MA, Gramani-Say K, Moreira FMA, Parizotto NA. Static postural sway of women with and without fibromyalgia syndrome: A cross-sectional study. Clin Biomech. 2017.
12. Muto L, Mango P, Sauer J, Susan Y, Sousa A, Marques A. Postural control and balance self-efficacy in women with fibromyalgia. Are there differences? Eur J Phys Rehabil Med. 2014.
13. Ko Y-H, Rose DJ, others. A Comparison of Central Sensory Reception and Integration Abilities between Older Females with and without Fibromyalgia: A Pilot Study. Adv Aging Res. 2015; 4: 58.
14. Paillard T, Chaubet V, Maitre J, Dumitrescu M, Borel L. Disturbance of contralateral unipedal postural control after stimulated and voluntary contractions of the ipsilateral limb. Neurosci Res. 2010; 68: 301–306. https://doi.org/10.1016/j.neures.2010.08.004 PMID: 20723569
15. Stergiou N, Harbourne RT, Cavanaugh JT. Optimal movement variability: a new theoretical perspective for neurologic physical therapy. J Neurol Phys Ther. 2006; 30: 120–129. PMID: 17029655

16. Schniepp R, Wuehr M, Pradhan C, Novozhilov S, Krafczyk S, Brandt T, et al. Nonlinear variability of body sway in patients with phobic postural vertigo. Front Neurol. 2013; 4: 115. https://doi.org/10.3389/fneur.2013.00115 PMID: 23966974

17. Huisinga JM, Yentes JM, Filipi ML, Stergiou N. Postural control strategy during standing is altered in patients with multiple sclerosis. Neurosci Lett. 2012; 524: 124–128. https://doi.org/10.1016/j.neulet.2012.07.020 PMID: 22824302

18. Rigoldi C, Cimolin V, Camerota F, Celletti C, Albertini G, Mainardi L, et al. Measuring regularity of human postural sway using approximate entropy and sample entropy in patients with Ehlers–Danlos syndrome hypermobility type. Res Dev Disabil. 2013; 34: 840–846. https://doi.org/10.1016/j.ridd.2012.11.007 PMID: 23246558

19. Zhou J, Habtemariam D, Iloputaife I, Lipsitz LA, Manor B. The complexity of standing postural sway associates with future falls in community-dwelling older adults: the MOBILIZE Boston Study. Sci Rep. 2017; 7: 2924. https://doi.org/10.1038/s41598-017-03422-4 PMID: 28592844

20. Mergner T, Rosemeier T. Interaction of vestibular, somatosensory and visual signals for postural control and motion perception under terrestrial and microgravity conditions—a conceptual model. Brain Res Rev. 1998; 28: 118–135. PMID: 9795180

21. Samuel AJ, Solomon J, Mohan D. A Critical Review on the Normal Postural Control. Physiother Occup Ther J. 2015; 8: 71.

22. Bolmont B, Gangloff P, Vouriot A, Perrin PP. Mood states and anxiety influence abilities to maintain balance control in healthy human subjects. Neurosci Lett. 2002; 329: 96–100. PMID: 12161271

23. Balaban CD. Neural substrates linking balance control and anxiety. Physiol Behav. 2002; 77: 469–475. PMID: 12526985

24. Muto LHA, Sauer JF, Yuan SLK, Marques AP. Assessment of postural control, strength of lower limbs and pain in individuals with and without fibromyalgia. Annals of the rheumatic diseases. BMJ Publishing Group British Med Assoc House, Tavistock Square, London, England; 2012. pp. 748–748. https://doi.org/10.1136/annrheumdis-2012-201745

25. King GW, Abreu EL, Cheng A-L, Chertoff KK, Brotto L, Kelly PJ, et al. A multimodal assessment of balance in elderly and young adults. Oncotarget. 2016; 7: 13297–13306. https://doi.org/10.18632/oncotarget.7758 PMID: 26934319

26. Lima TRL, Guimaraes FS, Sá Ferreira A, Penafortes JTS, Almeida VP, Lopes AJ. Correlation between posture, balance control, and peripheral muscle function in adults with cystic fibrosis. Physiother Theory Pract. 2014; 30: 79–84. https://doi.org/10.3109/09593985.2013.820246 PMID: 24405398

27. Hirschmüller A, Konstantinidis L, Baur H, Müller S, Mehlhorn A, Kontermann J, et al. Do changes in dynamic plantar pressure distribution, strength capacity and postural control after intra-articular calcaneal fracture correlate with clinical and radiological outcome? Injury. 2011; 42: 1135–1143. https://doi.org/10.1016/j.injury.2010.09.040 PMID: 21075372

28. Mehlhorn AT, Walther M, Yilmaz T, Gunst L, Hirschmüller A, Südkamp NP, et al. Dynamic plantar pressure distribution, strength capacity and postural control after Lisfranc fracture-dislocation. Gait Posture. 2016.

29. Góes SM, Stefanello JM, Homann D, Lodovico A, Hubley-Kozey CL, Rodacki AL. Torque and muscle activation impairment along with insulin resistance are associated with falls in women with fibromyalgia. J Strength Cond Res Strength Cond Assoc. 2016.

30. Lund E, Kendall SA, Janerot-Sjöberg B, Bengtsson A. Muscle metabolism in fibromyalgia studied by P-31 magnetic resonance spectroscopy during aerobic and anaerobic exercise. Scand J Rheumatol. 2003; 32: 138–145. PMID: 12892249

31. Valkeinen H, Häkkinen A, Hannonen P, Häkkinen K, Alén M. Acute heavy-resistance exercise–induced pain and neuromuscular fatigue in elderly women with fibromyalgia and in healthy controls: Effects of strength training. Arthritis Rheum. 2006; 54: 1334–1339. https://doi.org/10.1002/art.21751 PMID: 16575859

32. Russell IJ. Fibromyalgia syndrome: approach to management. CNS Spectr. 2008; 13: 27–33.

33. Rasyada AR, Zulaika H, Akutagawa M, Emoto T, Kinouchi Y, Azhim A. The Impact of Visceral Fat and Blood Flow Velocity in Hypertensive Subjects Running Head: The Impact of Visceral Fat and Blood Flow Velocity. Health Sci J. 2016.

34. Azhim A, Ueno A, Tanaka M, Utsunomiya Y, Akutagawa M, Obara S, et al. Evaluation on Envelope Waveforms of Velocity in Common Carotid Artery: Age-, Gender-and Regular Exercise-related Effect. World Congress on Medical Physics and Biomedical Engineering, September 7–12, 2009, Munich, Germany. Springer; 2009. pp. 1075–1078.

35. Carlsson AM. Assessment of chronic pain. I. Aspects of the reliability and validity of the visual analogue scale. Pain. 1983; 16: 87–101. PMID: 6602967

36. Clark RA, Bryant AL, Pua Y, McCrory P, Bennell K, Hunt M. Validity and reliability of the Nintendo Wii Balance Board for assessment of standing balance. Gait Posture. 2010; 31: 307–310. https://doi.org/10.1016/j.gaitpost.2009.11.012 PMID: 20005112

37. Wikstrom EA. Validity and reliability of Nintendo Wii Fit balance scores. J Athl Train. 2012; 47: 306–313. https://doi.org/10.4085/1062-6050-47.3.16 PMID: 22892412

38. Carpenter MG, Frank JS, Winter DA, Peysar GW. Sampling duration effects on centre of pressure summary measures. Gait Posture. 2001; 13: 35–40. PMID: 11166552

39. Raymakers JA, Samson MM, Verhaar HJJ. The assessment of body sway and the choice of the stability parameter (s). Gait Posture. 2005; 21: 48–58. https://doi.org/10.1016/j.gaitpost.2003.11.006 PMID: 15536033

40. Prieto TE, Myklebust JB, Hoffmann RG, Lovett EG, Myklebust BM. Measures of postural steadiness: differences between healthy young and elderly adults. Biomed Eng IEEE Trans On. 1996; 43: 956–966.

41. Speers RA, Kuo AD, Horak FB. Contributions of altered sensation and feedback responses to changes in coordination of postural control due to aging. Gait Posture. 2002; 16: 20–30. PMID: 12127183

42. Winter DA. Human balance and posture control during standing and walking. Gait Posture. 1995; 3: 193–214.

43. Niam S, Cheung W, Sullivan PE, Kent S, Gu X. Balance and physical impairments after stroke. Arch Phys Med Rehabil. 1999; 80: 1227–1233. PMID: 10527078

44. Rocchi L, Chiari L, Horak FB. Effects of deep brain stimulation and levodopa on postural sway in Parkinson's disease. J Neurol Neurosurg Psychiatry. 2002; 73: 267–274. https://doi.org/10.1136/jnnp.73.3.267 PMID: 12185157

45. Ramdani S, Seigle B, Lagarde J, Bouchara F, Bernard PL. On the use of sample entropy to analyze human postural sway data. Med Eng Phys. 2009; 31: 1023–1031. https://doi.org/10.1016/j.medengphy.2009.06.004 PMID: 19608447

46. Govindan RB, Wilson JD, Eswaran H, Lowery CL, Preîs sl H. Revisiting sample entropy analysis. Phys Stat Mech Its Appl. 2007; 376: 158–164.

47. Goldberger AL, Amaral LA, Glass L, Hausdorff JM, Ivanov PC, Mark RG, et al. Physiobank, physiotoolkit, and physionet. Circulation. 2000; 101: e215–e220. PMID: 10851218

48. Winter DA, Prince F, Frank JS, Powell C, Zabjek KF. Unified theory regarding A/P and M/L balance in quiet stance. J Neurophysiol. 1996; 75: 2334–2343. https://doi.org/10.1152/jn.1996.75.6.2334 PMID: 8793746

49. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychol Bull. 1979; 86: 420. PMID: 18839484

50. Teggi R, Colombo B, Bernasconi L, Bellini C, Comi G, Bussi M. Migrainous vertigo: results of caloric testing and stabilometric findings. Headache J Head Face Pain. 2009; 49: 435–444.

51. da Costa CSN, Batistão MV, Rocha NACF. Quality and structure of variability in children during motor development: A systematic review. Res Dev Disabil. 2013; 34: 2810–2830. https://doi.org/10.1016/j.ridd.2013.05.031 PMID: 23792377

52. Birznieks I, Burton AR, Macefield VG. The effects of experimental muscle and skin pain on the static stretch sensitivity of human muscle spindles in relaxed leg muscles. J Physiol. 2008; 586: 2713–2723. https://doi.org/10.1113/jphysiol.2008.151746 PMID: 18403422

53. Cavanaugh JT, Guskiewicz KM, Stergiou N. A nonlinear dynamic approach for evaluating postural control. Sports Med. 2005; 35: 935–950. PMID: 16271008

54. Vaillancourt DE, Newell KM. Changing complexity in human behavior and physiology through aging and disease. Neurobiol Aging. 2002; 23: 1–11. PMID: 11755010

55. Dusing SC, Harbourne RT. Variability in postural control during infancy: implications for development, assessment, and intervention. Phys Ther. 2010; 90: 1838. https://doi.org/10.2522/ptj.2010033 PMID: 20966208

56. Borg FG, Laxaback G. Entropy of balance-some recent results. J Neuroengineering Rehabil. 2010; 7: 38–48.

57. Villarrasa-Sapiña I, García-Massó X, Serra-Añó P, Garcia-Lucerga C, Gonzalez L-M, Lurbe E. Differences in intermittent postural control between normal-weight and obese children. Gait Posture. 2016; 49: 1–6. https://doi.org/10.1016/j.gaitpost.2016.06.012 PMID: 27344447

58. Salavati M, Akhbari B, Takamjani IE, Bagheri H, Ezzati K, Kahlaee AH. Effect of spinal stabilization exercise on dynamic postural control and visual dependency in subjects with chronic non-specific low back pain. J Bodyw Mov Ther. 2016; 20: 441–448. https://doi.org/10.1016/j.jbmt.2015.10.003 PMID: 27210863

59. Gorman JM, Kent JM, Sullivan GM, Coplan JD. Neuroanatomical hypothesis of panic disorder, revised. Am J Psychiatry. 2000; 157: 493–505. https://doi.org/10.1176/appi.ajp.157.4.493 PMID: 10739407

60. Balaban CD. Organization of parabrachio-vestibular connections in rabbits and rats. Soc Neurosci Abstr. 2000. p. 1493.

61. Schuerger RJ, Balaban CD. Organization of the coeruleo-vestibular pathway in rats, rabbits, and monkeys. Brain Res Rev. 1999; 30: 189–217. PMID: 10525175

62. Panton LB, Kingsley JD, Toole T, Cress ME, Abboud G, Sirithienthad P, et al. A comparison of physical functional performance and strength in women with fibromyalgia, age-and weight-matched controls, and older women who are healthy. Phys Ther. 2006; 86: 1479–1488. https://doi.org/10.2522/ptj.20050320 PMID: 17079747

ANEXO IX: COPIA ORIGINAL DEL ESTUDIO 2

Impaired trunk posture in women with fibromyalgia, en la revista *Spine*

Spine

SPINE Volume 43, Number 22, pp 1536–1542

BIOMECHANICS

Impaired Trunk Posture in Women With Fibromyalgia

Núria Sempere-Rubio, MSc,* Marta Aguilar-Rodríguez, PhD,* Gemma V Espí-López, PhD,* Sara Cortés-Amador, PhD,* Eliseo Pascual, PhD,† and Pilar Serra-Añó, PhD*

Study Design. A cross-sectional study.
Objectives. The main goal of the study was to analyze posture of Fibromyalgia syndrome (FMS) in women compared with healthy subjects to establish if posture assessment could be useful to characterize the syndrome. Secondarily, we explored the impact of sedentary behavior on trunk posture.
Summary of Background Data. Pain has been associated with poor static postures, however there is little information on the effect of FMS, which is characterized by widespread pain, on trunk posture.
Methods. One hundred eighteen women with FMS and 110 healthy counterparts participated in this study, in which trunk posture was assessed. The thoracic kyphosis, forward head position, and shoulder position (basal and maximum protraction) were measured. Further, maximum shoulder protraction and the ability to maintain the cervical and thoracic angle were assessed. To compare the differences in posture depending on the grouping, an independent Student *t* test was conducted. To analyze the differences between groups in the ability to maintain the position over a period of time and the differences in posture depending on more or less active lifestyles, two multivariate analysis of variance were performed.
Results. The results showed a significantly larger thoracic kyphosis, baseline shoulder protraction and lower craniovertebral angle and maximum protraction in FMG compared with CG ($P < 0.05$). FMG subjects exhibited an impaired ability to maintain the cervical and thoracic angles, as this varied throughout the test, unlike those of their counterparts. A sedentary lifestyle did not affect trunk posture in the FMS participants.
Conclusion. FMS female population present an altered trunk posture and an inability to maintain trunk position. Since this does not appear to be influenced by a more or less active lifestyle, specific treatment programs are needed to manage this clinical condition.
Key words: fibromyalgia, hyperkyphosis, muscle inability, posture, trunk.
Level of Evidence: 2
Spine 2018;43:1536–1542

From the *Physical Therapy Department, University of Valencia, Valencia, Spain; and †Clinical Medicine Department, Miguel Hernández University, Sant Joan d'Alacant, Spain.

Acknowledgment date: February 12, 2018. First revision date: March 12, 2018. Acceptance date: March 26, 2018.

NS-R and MA-R contributed equally.

The manuscript submitted does not contain information about medical device(s)/drug(s).

Conselleria d'Educació, Ciència i Esports [Valencian Regional Department of Education, Science and Sports], València, Spain [Grant GV2016/140] funds were received in support of this work.

No relevant financial activities outside the submitted work.

Address correspondence and reprint requests to Pilar Serra-Añó, PhD, Gascó Oliag, 5, Valencia 46010, Spain; E-mail: pilar.serra@uv.es

DOI: 10.1097/BRS.0000000000002681

Fibromyalgia syndrome (FMS) is a disease commonly characterized by persistent widespread musculoskeletal pain and other clinical conditions such as joint stiffness, chronic fatigue,[1,2] and altered postural control.[3] All these symptoms, combined with a sedentary lifestyle in this population,[4] may foster poor static postures. The relationship between pain and poor posture has been demonstrated in previous research in other populations, such as subjects with widespread musculoskeletal pain,[5,6] rheumatoid arthritis,[7] office employees.[8]

Likewise, in 1998, Müller *et al*[9] had forwarded the possibility of altered trunk posture being responsible for the onset of FMS. The authors demonstrated how individuals with FMS presented a higher percentage of spinal positional alterations compared with normal controls in terms of hyperkyphosis and pitched-forward posture, but they did not report the specific posture in this population.

This syndrome is usually characterized using questionnaires or scales, given the multifactorial nature thereof. However, this condition has physical consequences, such as the associated trunk posture, that can be evaluated with objective tools and used as supplementary information. Müller *et al*[9] concluded that postural assessment is highly important in their evaluative process in individuals diagnosed with FMS. Based on the above, it would be convenient to explore their trunk posture to tailor the most appropriate therapeutic approach.[10] Knowing their postural disorders and therefore treating them, could, in turn, break the vicious

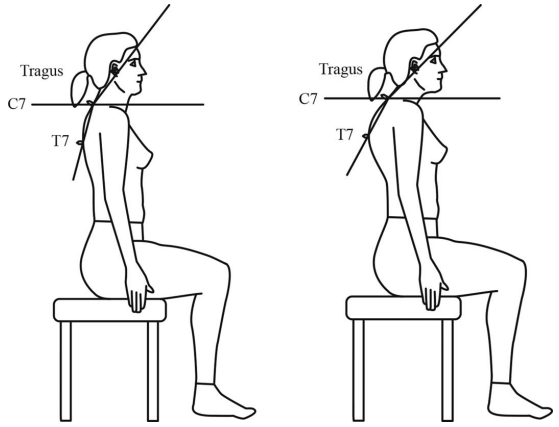

Figure 1. Trunk posture in sitting position. C7 indicates spinous process of the 7th cervical vertebra; T7, spinous process of the 7th thoracic vertebra.

cycle that is produced when such disorders are maintained aggravating muscular and articular rigidity of the spine, causing greater pain, and hindering the affected subjects' daily and work activities, in turn causing increased stiffness and pain.[11,12]

Therefore, the main goal of the study was to analyze posture in FMS women compared with healthy subjects to establish if posture assessment could be useful to characterize the syndrome. Secondarily, we explored the impact of sedentary behavior on trunk posture.

MATERIALS AND METHODS

Participants

This cross-sectional study used purposive modal instance sampling to select the participants. The FMS group (FMG) was composed of 118 women diagnosed with FMS who were recruited from several Fibromyalgia associations along a year and a half. The inclusion criteria for the FMG were women between 45 and 70 years of age diagnosed according to the 2010 American College of Rheumatology criteria.[13] The control group (CG) was composed of 110 age-matched women without symptoms.

Exclusion criteria for both groups were: history of fractures or surgery of the spine, inflammatory rheumatic disease, neurological disorder, peripheral neuropathy, or suffering any acute and terminal illness.

The Ethics Review Board of our institution approved all the procedures, performed in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from the participants before the tests started.

Measurements

Participants were clinically examined by a physiotherapist and classified as "sedentary" when they did not perform any type of physical activity. The order of evaluations of the posture of the trunk was randomized. All the procedures are explained later.

Thoracic Kyphosis Test

The test was conducted after the procedure of Lewis and Valentine.[14] The participants were asked to stand upright with the horizontal gaze maintained during the test. The spinous processes of Th1, Th2, Th12, and L1 vertebrae were located and adhesive markers were placed on them. After settling into a comfortable position, two Bubble inclinometers (Fabrication Enterprises, Inc, White Plains, NY) were placed at the markers. The mean of three repetitions was used for the analysis. A good reliability of this procedure was established by Lewis and Valentine (intra-class correlation coefficient [ICC] = 0.97; standard error of measurement [SEM] = 1–1.7°).[14]

Craniovertebral Angle Test

This angle was used as a measurement of a Forward Head Posture (FHP) [8] after the instructions of Falla *et al*.[15] The subjects sat on a height-adjustable chair without backrest with their knees and hips flexed 90°, feet flat on the ground and head facing forward (Figure 1). Adhesive markers were

positioned on the tragus of the ear (tragus) and the spinous process of the 7th cervical vertebra (C7). At that height, perpendicular to the sagittal plane and at 80 cm from the patient, a digital camera, Canon EOS 1200D (18 Mpx), was placed to take the picture of the participant. The photographic data were analyzed with the software *ImageJ* created by the National Institutes of Health.[16] To measure the craniovertebral angle, a line was drawn from the tragus to the spinous process of C7, the angle being at the intersection with the horizontal line.

Baseline and Maximum Shoulder Protraction Test

The *baseline shoulder protraction* was determined by measuring the pectoralis minor length according to the test described by Lewis and Valentine,[17] based on the existing relationship between the position of the scapula and the length of the pectoralis minor.[18] The participants were placed in a relaxed supine position on a hard surface stretcher, with the hands resting on the abdomen. The distance from the posterior border of the acromion to the stretcher was measured in centimeters, using a standard plastic bevel, procedure proven reliable with ICC ranging from 0.88 to 0.93.[17] The measurement was repeated three times and the average was used for the analysis.[19]

The *maximum shoulder protraction* was measured in the same position and with the same procedure as above. The subjects were asked to raise the shoulder upwardly as much as they could in a transverse anatomical plane keeping the elbows in contact with the stretcher. The distance from that position to the stretcher was measured three times. The average of the maximum shoulder protraction minus the average of the baseline shoulder protraction was used.

Test on the Change in Cervical and Thoracic Angle in Sitting Position

This test showed the participants' ability to maintain the trunk position for 5 minutes (*i.e.*, cervical and thoracic angle). The participants were sitting in the same position as described in the *Craniovertebral angle* test (Figure 1) but with a computer placed in front of them with the upper frame of the screen just below the height of the eyes [15] to assure the maintenance of the horizontal gaze. Adhesive markers were then positioned on the tragus, C7, and the spinous process of the 7th thoracic vertebra (T7). Once the initial sitting position was standardized, the women were asked to hold that position while they were distracted by reading a novel on the computer for 5 minutes. The dominant hand handled the mouse while the other rested motionless on the desk.

To measure the changes in cervical and thoracic posture, a photograph was taken each minute (six photographs), using the same procedure as described in the Craniovertebral angle test. The photographs were also analyzed with ImageJ.[16] The *cervical angle* was formed at the intersection of the line drawn from the tragus to C7 with the horizontal line, while the *thoracic angle* was formed at the intersection of the line drawn from C7 to T7 with the horizontal line.

Reliability Studies

The reliability of the two test procedures not previously validated was assessed before the study started. For the *Maximum shoulder protraction test*, a sample of convenience composed by 15 healthy women (other than CG subjects), with a mean (SD) age of 52.27 (6.62) years, was evaluated. For the *Test on the change in cervical and thoracic angle in sitting position*, the sample was composed of 15 other healthy women, with a mean (SD) age of 50.87 (4.63) years.

In both studies, the subjects attended our lab for assessment by two physiotherapists at two different sessions (8 days apart). Within-day and inter-observer reliability was determined by comparing values obtained by the two different raters on the same day. Between-days and intraobserver reliability was determined by comparing the outcomes of two assessments repeated by the same rater, at least 8 days apart. Between-days and interobserver reliability were determined by comparing the results of two assessments conducted by the two different raters 8 days apart.

Sample Size Calculation

The sample size calculation was conducted with the software G-Power version 3.1 (University of Kiel, Germany) based on data of the variable "Thoracic kyphosis" analyzed in the study carried out by Greenfield *et al*[20] in which a mean difference of 4° between groups was revealed. We set the type I error at 5% and a statistical power of 80%. Based on these assumptions, a sample of at least 92 individuals per group was required.

Statistics

Statistical analysis was performed using SPSS software Version 22 (SPSS Inc. Chicago, IL). Since a paired Student *t* test revealed no differences between hemibodies ($P > 0.05$) its mean was calculated and included in the statistical analysis.

To compare the differences in posture depending on the grouping (*i.e.*, CG and FMG) an Independent Student *t* test was conducted and its size effect was computed with Pearson r. To analyze the differences between groups in the *Change in cervical and thoracic posture*, a Split-plot multivariate analysis of variance (MANOVA), with a between-subjects factor called "group" (FMG and CG) and a within-subject called "time" with six categories (T0, T1, T2, T3, T4, and T5), was conducted. Post-hoc comparisons were conducted with Sidak correction. To test the possible impact of sedentary behavior on the trunk posture a two-way MANOVA was conducted with two between-subjects factors, these being "group" (FMG and CG) and "Behavior," with two categories (sedentary *vs.* nonsedentary).

The reliability of tests on *Maximum shoulder protraction* and *Change in cervical and thoracic posture* was determined using an ANOVA to calculate the (2,1) ICC [21] and the SEM.[22] Type I error was established at $< 5\%$.

TABLE 1. Descriptive Results of the Posture Variables and Statistical Differences Between Groups

	FMG	CG	Size Effect (r)
Thoracic kyphosis (°)	63 (11)	53 (13)*	0.42
Craniovertebral angle (°)	38 (7)	43 (5)*	0.36
Baseline protraction (cm)	8.6 (1.4)	8.1 (1.6)*	0.17
Maximum protraction (cm)	2.4 (1.1)	4.5 (1.5)*	0.69

Data are shown as mean (standard deviation).
**Statistical differences between groups ($P < 0.05$).*
FMG indicates fibromyalgia group; CG, control group; r, Pearson index for size effect.

RESULTS

Participants

The mean (SD) age of the participants was 54.36 (6.82) years for the FMG and 54.76 (6.06) years for the CG. The body mass index was 27.31 (5.49) and 25.66 (4.49), respectively. There were no statistical differences for age between groups ($P > 0.05$). There was a statistical difference between groups in BMI [t (222.47) = 2.56, $P < 0.05$, r = 0.17], although the effect size was small and both groups were included in the overweight category, 27.31 points being the average for FMG and 25.66, for CG.

Posture Variables

Descriptive results are shown in Table 1. The results showed a significantly larger *thoracic kyphosis* and a significantly lower *craniovertebral angle* in FMG compared with CG ($P < 0.05$). Regarding protraction, results showed a significantly higher *baseline shoulder protraction* and significantly lower *maximum shoulder protraction* in FMG than in CG ($P < 0.05$).

Figure 2 presents the effect of FMS in a prolonged sitting posture. For both angles, the FMG showed significant differences every minute up to the last minute tested (*i.e.*, T4-T5), when the posture stabilizes. Conversely, the CG showed an initial significant difference (*i.e.*, T0-T1), but later both angles were sustained throughout the entire test.

Effect of Sendetary Behavior on Trunk Posture

As noted in Table 2, sedentary behavior had no effect on any of the trunk posture variables in the FMG ($P > 0.05$). The sedentary subgroup of the CG showed higher *Thoracic kyphosis* and lower *Baseline shoulder protraction* values compared with their nonsedentary counterparts ($P < 0.05$).

Reliability Studies

The results of the reliability studies conducted are displayed in Table 3 showing a good overall reliability.

DISCUSSION

This study reveals differences in trunk posture in female subjects with FMS. In particular, alterations of the static posture are evidenced by hyperkyphosis, increased shoulder protraction and a reduced craniovertebral angle. Regarding thoracic kyphosis, the FMG showed an average increase of 10° compared with the CG. A previous study[9] also obtained a higher percentage of subjects with a pitched-forward position of the thoracic spine was obtained in the FMS group compared with the healthy group. Nevertheless, the absolute values of this position were not given in this population, thus, a comparison is not possible. Such hyperkyphosis may be associated with an impaired function of the upper trapezius that acts as stabilizer of the cervical spine and scapulae.[23] However, further studies should include the measurement of the lower lumbar and pelvic incidence to

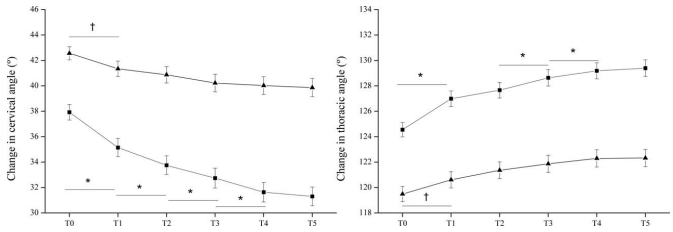

Figure 2. Group comparisons for change in cervical and thoracic posture. Data (mean) are expressed with squares (for the Fibromyalgia Group) and triangles (for the Control Group) and vertical lines represent the error bars. † indicates statistical differences for the Control Group ($P < 0.05$); ∗, statistical differences for the Fibromyalgia Group ($P < 0.05$).

TABLE 2. Descriptive Results of the Posture Variables and Statistical Differences Between the Sedentary and Nonsedentary Groups

		Sedentary	Nonsedentary
Thoracic kyphosis	FMG	66 (8)	62 (11)
	CG	59 (11)	52 (13)*
Craniovertebral angle	FMG	37 (7)	38 (7)
	CG	42 (6)	43 (5)
Baseline protraction	FMG	8.8 (2.6)	8.5 (1.4)
	CG	9.0 (2.0)	7.9 (1.5)*
Maximum protraction	FMG	2.1 (0.9)	2.5 (0.9)
	CG	4.6 (1.7)	4.5 (1.5)
Change in cervical angle	FMG	−4 (4)	−4 (5)
	CG	−2 (4)	−1 (3)
Change in thoracic angle	FMG	4 (4)	5 (5)
	CG	4 (3)	3 (3)

Data are shown as mean (standard deviation).
**Statistical differences between groups ($P < 0.05$).*
CG indicates control group; FMG, fibromyalgia group; r, Pearson index for size effect.

explore the contribution of possible restrictions of the lower body to the hyperkyphosis found.

The literature has established the impact of hyperkyphosis on mechanical restriction that can impair the physical function,[24] reduce the upper limb range of motion, [25] and decrease quality of life.[24] In addition, hyperkyphosis is one of the several conditions that can cause FHP,[26] analyzed in this study with the measurement of the *Craniovertebral angle*, in turn, previously associated with neck pain.[8] Our results show that FMG subjects effectively positioned their heads abnormally forward, as they exhibited a reduction in the cervical angle that is associated with the flexion of the middle lower cervical segments and the extension of the suboccipital segments.[26] Given the importance of the deep neck muscles, such as the longus colli muscle, in postural function, this alteration may be associated with a functional impotence in supporting and straightening cervical lordosis.[27] Nevertheless, although the procedures conducted are reliable, more specific techniques (*e.g.*, radiography) could better determine the contribution of both mechanisms to FHP.

FHP may be associated with the scapular position, as the cervical posture is coupled to scapular posture.[23] For this reason, we also explored the amplitude of abduction movement of the scapula, which is the anterior movement in the transverse plane. The results demonstrate that, in a static position (*i.e.*, *Baseline shoulder protraction*), the FMG had a higher value than the CG although the significant differences barely exceed the SEM established at 5 mm.[17] However, when the maximum movement was required (*i.e.*, *Maximum shoulder protraction*), the CG showed a significantly higher value than the FMG, doubling its magnitude. These results suggest that women with FMS, besides showing an increased shoulder protraction, because of the shortening of the pectoralis minor, could have a dysfunction in the pectoral muscles and anterior serratus[27] in addition to impairment of the torso muscles as already described (*i.e.*, trapezius, interscapulum muscles, *etc.*), which impedes the forced movement in the anterior direction in the transversal plane. In fact, previous studies confirmed that patients with chronic pain, as is the case of FMS population, show an increased muscle tension in the trapezius and infraspinatus and decreased isokinetic strength compared with pain-free controls.[28] The origin of pain in FMS is not well understood but it likely originates in the musculature, in which no clear alterations have been found. Our data speculatively support that a posture of alertness sustained by certain postural muscles when a subject persistently maintains such posture,

TABLE 3. Analysis of the Reliability and Consistency of the Posture Procedures

	1 Rater, 2 Days		2 Raters, 1 Day		2 Raters, 2 Days	
	ICC	SEM	ICC	SEM	ICC	SEM
Maximum protraction (cm)	0.98	0.36	0.94	0.61	0.96	0.50
Change in cervical posture (°)	0.86	1.60	0.75	1.20	0.80	1.43
Change in dorsal posture (°)	0.86	0.91	0.83	0.83	0.89	0.73

ICC indicates intraclass correlation coefficient (no units); SEM, standard error of measurement (units of the variable).

may—at least in part—be responsible for the painful symptoms of FM.

Furthermore, we tested the capability of the trunk muscles to maintain a sitting position assessing the change in postural trunk angles over time. FMS participants revealed a progressive increase of the thoracic angle and a reduction of the cervical angle over the 5-minute period that they remained seated while performing a distracting task. This is consistent with a study in which subjects with cervical pain adopted a more forward head position when distracted.[29] These results support the hypothesis of an impaired endurance of the muscles responsible for the upright posture, in this case, not seemingly affected by a sedentary behavior as noted in Table 2. Therefore, this poor endurance may be associated with the pain experienced in this syndrome what would be in agreement with Falla *et al*[15], who previously demonstrated an influence of neck pain in muscle endurance to maintain the cervical and thoracic position. Indeed, a peripheral stimulus in the form of muscle pain induces adaptations of the central nervous system, *i.e.*, altered muscle control strategies that manifest as a different motor unit recruitment pattern.[30] Conversely, CG showed a reduction in the cervical angle and an increase of the thoracic angle only during the first minute, as an initial adjustment, after which they maintained the position of both regions.

The results of the study could be further supported with the acquisition of electromyographic or tensiomyographic data that would be helpful to relate trunk posture impairment with muscle activity and muscle properties, respectively. This would provide a better understanding of the alterations of the mechanisms responsible for trunk posture in women with FMS.

CONCLUSION

In conclusion, the results obtained from this study showed alterations in trunk posture in women with FMS. According to our results, hyperkyphosis, an anterior position of the shoulders and a forward position of the head are present in women with fibromyalgia. Moreover, the abduction movement of the shoulder and the ability to maintain an erect trunk position while sitting are impaired in this population. These results are not influenced by a sedentary lifestyle.

➢ Key Points

- ❑ New procedures for clinical assessment are proposed in women with fibromyalgia.
- ❑ Women with fibromyalgia show an upper trunk posture in a rigid pitched-forward position.
- ❑ Sedentary behavior did not influence trunk posture.

References

1. Schweiger V, Del Balzo G, Raniero D, et al. Current trends in disability claims due to fibromyalgia syndrome. *Clin Exp Rheumatol* 2017;35 (suppl 105):119–26.
2. Wolfe F. Criteria for fibromyalgia? What is fibromyalgia? Limitations to current concepts of fibromyalgia and fibromyalgia criteria. *Clin Exp Rheumatol* 2017;35 (suppl 105):3–5.
3. Rasouli O, Stensdotter A-K, Van der Meer ALH. TauG-guidance of dynamic balance control during gait initiation in patients with chronic fatigue syndrome and fibromyalgia. *Clin Biomech (Bristol, Avon)* 2016;37:147–52.
4. Segura-Jiménez V, Álvarez-Gallardo IC, Estévez-López F, et al. Differences in sedentary time and physical activity between female patients with fibromyalgia and healthy controls: the al-Ándalus project. *Arthritis Rheumatol* 2015;67:3047–57.
5. Rosario JL. Relief from back pain through postural adjustment: a controlled clinical trial of the immediate effects of muscular chains therapy (MCT). *Int J Ther Massage Bodyw* 2014;7:2–6.
6. Zabaleta H, Rodriguez-de-Pablo C, Miljkovic N, et al. sEMG-based detection of poor posture: A feasibility study. IEEE:1210-3.
7. Macovei LA, Rezuş E. Cervical spine lesions in rheumatoid arthritis patients. *Rev Med Chir Soc Med Nat Iasi* 2016;120:70–6.
8. Nejati P, Lotfian S, Moezy A, et al. The study of correlation between forward head posture and neck pain in Iranian office workers. *Int J Occup Med Environ Health* 2015; 28:295–303.
9. Müller W, Kelemen J, Stratz T. Spinal factors in the generation of fibromyalgia syndrome. *Z Rheumatol* 1998;57:36–42.
10. Talotta R, Bazzichi L, Di Franco M, et al. One year in review 2017: fibromyalgia. *Clin Exp Rheumatol* 2017;35 (suppl 105):6–12.
11. Maddali Bongi S, Del Rosso A, Di Felice C, et al. Rességuier method and Qi Gong sequentially integrated in patients with fibromyalgia syndrome. *Clin Exp Rheumatol* 2012;30:51–8.
12. Kim D, Cho M, Park Y, et al. Effect of an exercise program for posture correction on musculoskeletal pain. *J Phys Ther Sci* 2015;27:1791–4.
13. Wolfe F, Clauw DJ, Fitzcharles M-A, et al. Fibromyalgia criteria and severity scales for clinical and epidemiological studies: a modification of the ACR Preliminary Diagnostic Criteria for Fibromyalgia. *J Rheumatol* 2011;38:1113–22.
14. Lewis JS, Valentine RE. Clinical measurement of the thoracic kyphosis. A study of the intra-rater reliability in subjects with and without shoulder pain. *BMC Musculoskelet Disord* 2010; 11:39.
15. Falla D, Jull G, Russell T, et al. Effect of neck exercise on sitting posture in patients with chronic neck pain. *Phys Ther* 2007;87: 408–17.
16. Schneider CA, Rasband WS, Eliceiri KW. NIH Image to ImageJ: 25 years of image analysis. *Nat Methods* 2012;9:671–5.
17. Lewis JS, Valentine RE. The pectoralis minor length test: a study of the intra-rater reliability and diagnostic accuracy in subjects with and without shoulder symptoms. *BMC Musculoskelet Disord* 2007;8:64.
18. Borstad JD. Resting position variables at the shoulder: evidence to support a posture-impairment association. *Phys Ther* 2006;86: 549–57.
19. Nijs J, Roussel N, Struyf F, et al. Clinical assessment of scapular positioning in patients with shoulder pain: state of the art. *J Manipulative Physiol Ther* 2007;30:69–75.
20. Greenfield B, Catlin PA, Coats PW, et al. Posture in patients with shoulder overuse injuries and healthy individuals. *J Orthop Sports Phys Ther* 1995;21:287–95.
21. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. *Psychol Bull* 1979;86:420–8.
22. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res* 2005; 19:231–40.
23. Gaffney BM, Maluf KS, Curran-Everett D, et al. Associations between cervical and scapular posture and the spatial distribution of trapezius muscle activity. *J Electromyogr Kinesiol* 2014;24: 542–549.

24. Takahashi T, Ishida K, Hirose D, et al. Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people. *Osteoporos Int* 2005;16:273–9.
25. Lee ST, Moon J, Lee SH, et al. Changes in activation of serratus anterior, trapezius and latissimus dorsi with slouched posture. *Ann Rehabil Med* 2016;40:318–25.
26. Khayatzadeh S, Kalmanson OA, Schuit D, et al. Cervical spine muscle-tendon unit length differences between neutral and forward head postures: biomechanical study using human cadaveric specimens. *Phys Ther* 2017;97:756–66.
27. Sahrmann S. *Diagnosis and Treatment of Movement Impairment Syndromes*. St Louis: Elsevier Health Sciences; 2002.
28. Elert J, Kendall SA, Larsson B, et al. Chronic pain and difficulty in relaxing postural muscles in patients with fibromyalgia and chronic whiplash associated disorders. *J Rheumatol* 2001;28:1361–8.
29. Szeto GP, Straker LM, O'Sullivan PB. A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work—2: neck and shoulder kinematics. *Man Ther* 2005;10:281–91.
30. Borchers AT, Gershwin ME. Fibromyalgia: a critical and comprehensive review. *Clin Rev Allergy Immunol* 2015;49:100–51.

ANEXO X: COPIA ORIGINAL DEL ESTUDIO 3

Physical condition factors that predict a better quality of life in women with fibromyalgia, en la revista *International Journal of Environmental Reasearch and Public Health*

International Journal of
Environmental Research and Public Health

MDPI

Article

Physical Condition Factors that Predict a Better Quality of Life in Women with Fibromyalgia

Núria Sempere-Rubio [1], Marta Aguilar-Rodríguez [1], Marta Inglés [2], Ruth Izquierdo-Alventosa [1] and Pilar Serra-Añó [1,*]

[1] Unidad de Biomecánica Clínica (UBIC Research Group), Department of Physiotherapy, Faculty of Physiotherapy, Universitat de València, 46010 València, Spain
[2] Freshage Research Group, Department of Physiotherapy, Faculty of Physiotherapy, Universitat de València, Centro de Investigación Biomédica en Red Fragilidad y Envejecimiento Saludable (CIBERFES-ISCIII), Fundación Investigación del Hospital Clínico Universitario de Valencia (INCLIVA), 46010 València, Spain
* Correspondence: pilar.serra@uv.es

Received: 21 July 2019; Accepted: 28 August 2019; Published: 30 August 2019

Abstract: What physical qualities can predict the quality of life (QoL) in women with fibromyalgia (FM)? QoL is a very complex outcome affected by multiple comorbidities in people with fibromyalgia. This study aims to determine which physical qualities can predict the quality of life in women with FM. Also, a comparison between the physical qualities of women with FM and healthy counterparts was conducted. In total, 223 women participated in this cross-sectional study, 123 with FM, with ages ranging between 45 and 70 years. The study was conducted at several fibromyalgia associations and specialized medical units. QoL was measured as the main outcome. In addition, functional capacity, muscular strength, maintenance of thoracic posture, postural control, flexibility, pain threshold, and anxiety were measured. Prediction of the QoL was conducted with multiple linear regression analysis and comparison between groups, using the Mann–Whitney U test. There were significant differences between groups in all the variables measured ($p < 0.01$). The multiple linear regression model showed that factors influencing QoL in women with FM for all the variables measured were functional capacity, handgrip strength and bicep strength, maintenance of thoracic posture, pain threshold, and anxiety ($R^2 = 0.53$, $p < 0.05$). To conclude, women with FM show a significantly lower QoL than their healthy counterparts, and the factors that predict their perceived QoL are functional capacity, muscular strength, postural maintenance, pain threshold, and anxiety.

Keywords: quality of life; fibromyalgia; functional capacity; cardiorespiratory fitness; muscle strength; postural balance; pain threshold; anxiety

1. Introduction

Fibromyalgia (FM) is a common chronic pain condition that has a significant impact on quality of life (QoL) [1], possibly due to its interference with physical ability, function, work, and social activities [2]. Previous studies revealed that the global physical condition (PC) in FM patients is impaired, since, compared to healthy counterparts, strength is reduced [3], postural control is altered [4,5], body posture is misaligned [6], or functional capacity is poor [1]. Furthermore, another important factor closely related to PC is flexibility, which is known to influence postural maintenance [7] and was independently associated with pain in this population [8], which was also associated with postural maintenance [6]. All these altered physical conditions could, in turn, possibly affect their perceived QoL.

The etiology and pathogenesis of FM are still unknown, but the syndrome is claimed to be multifactorial [9] and, therefore, physiotherapeutic programs must contemplate different approaches in order to improve well-being and QoL in FM patients.

Physical exercise was proposed as a suitable intervention for a variety of chronic pain populations, including FM, with the purpose of reducing pain severity, improving PC, and enhancing QoL. Nevertheless, based on a recent review [10], the evidence on the effects of physical exercise is of low quality because of the small sample sizes, short length of the intervention programs, or the short follow-ups used in the studies. This, together with the lack of adherence [11] and the fatigue experienced with physical effort in this population, suggests the need for a thorough study of the correlations between QoL and PC to focus the interventions mainly on the development of the physical variables most related to QoL, avoiding fatigue as much as possible.

Physiotherapeutic interventions in people with FM most usually focus on the improvement of PC [12–14] and some other variables related to PC, such as anxiety [15], commonly present in people with FM, and those related to the perceived pain experience [16]. However, as mentioned above, it becomes necessary to establish which of the basic physical abilities or psychomotor qualities are more related to QoL and are likely to be addressed by physiotherapy. In this way, more personalized physiotherapy treatments could be carried out, providing better care for patients with FM.

This study was aimed at identifying predictors of QoL related to PC and anxiety. Additionally, it strove to determine the differences in PC of people with FM compared to healthy counterparts.

2. Methods

2.1. Participants

This cross-sectional study used purposive modal instance sampling to select the participants. The sample size calculation was conducted to ensure 80% of power, setting the type I error at 5%. A medium-size effect (d = 0.5) and seven independent variables were predicted. With these requirements, 103 people were required.

The FM group (FMG) was composed of 123 women diagnosed with FM who were recruited from several fibromyalgia associations and specialized medical units over a year and a half. The inclusion criteria for the FMG were women between 45 and 70 years of age diagnosed according to the 2010 American College of Rheumatology criteria [17]. The control group (CG) was composed of 100 age-matched women without symptoms.

Exclusion criteria for both groups were as follows: history of fractures or surgery over the past six months, inflammatory rheumatic disease, neurological disorder, peripheral neuropathy, or suffering any acute and terminal illness.

2.1.1. Assessment Procedures

Several features of the participants' PC were included as the dependent variables: functional capacity, muscular strength, maintenance of thoracic posture, postural control, and flexibility. Additionally, their pain threshold, QoL, and anxiety were measured.

2.1.2. Quality of Life Measures

QoL was assessed using the Spanish version of the Short Form-36 Health Survey (SF-36) [18] whose internal consistency and reliability was validated (Cronbach's α >0.70 and Intraclass correlation coefficient (ICC) >0.90, respectively) [19], and it is commonly used to measure physical, social, role, and emotional functioning. The score ranges from 0–100. Scores above or below 50 indicate better or worse health status, respectively, than the mean of the reference [20].

2.1.3. Functional Capacity

The two-minute walk test (2MWT) was used to measure the functional capacity. This test consists of determining the maximum distance (in meters (m)) that can be walked in 2 min. This test shows a good correlation with the six-minute walk test (6MWT), which was extensively used as a reliable measure of functional capacity in individuals with a variety of characteristics [21,22], including

individuals with fibromyalgia [8]. However, this test is less fatiguing and better tolerated [23]. It was carried out following the instructions of the study conducted by Johnston and colleagues [24].

2.1.4. Upper Limb Strength

Maximal isometric strength was assessed using two portable dynamometers, NedDFM/IBV (Instituto de Biomecánica de Valencia, Valencia, Spain), to assess the bicep strength, and NedVEP/IBV (Instituto de Biomecánica de Valencia, Valencia, Spain), to assess the handgrip strength. To conduct these two measures, the participants remained seated without any back support and with their feet on the floor. When bicep strength was assessed, the individuals had to attempt to flex their elbow with their palm upward as hard as they could against the evaluator's equal resistance without moving their trunk. The dynamometer was placed on the distal portion of the arm. When handgrip strength was assessed, the participants were required to tightly grasp the dynamometer as hard as they could. Three repetitions of each measurement were performed consecutively with a 30-s rest between them, and the mean of the three repetitions was calculated. The order of the two strength measurements was counterbalanced.

2.1.5. Maintenance of Thoracic Posture

To measure the participants' ability to maintain the thoracic position for 5 min, the change in thoracic angle in a sitting position was calculated. For this purpose, the participants sat with a computer placed in front of them with the upper frame of the screen just below the height of the eyes and handled the mouse with the dominant hand. Adhesive markers were then positioned on the tragus, C7, and the spinous process of the seventh thoracic vertebra (T7).

To measure changes in thoracic posture, a photograph was taken each minute, using the same procedure as described in a previous study of our group [6]. The photographs were also analyzed with the software ImageJ (National Institutes of Health, Bethesda, Maryland, USA) [25], and we computed the difference between the last and the first photograph. A higher angle of change denotes a poorer the ability to maintain the posture.

2.1.6. Postural Control

The postural control test was performed using the Wii Balance Board (WBB) (Nintendo, Kyoto, Japan) force platform [26]. Subjects were asked to place their feet hip-width apart, toes pointing forward, and arms relaxed at their sides in all the tests. A reference point was situated 2 m in front of the subject at eye level. All the subjects had to maintain the bipedal standing position with their eyes open during the test. The subjects performed two consecutive 60-s repetitions, and the mean was used for subsequent analyses. They rested for 30 s between repetitions, unless they needed extra time. The procedures were further explained in a previous study of our group [5].

Two variables derived from this test were measured: (i) ellipse: a measure of the area that the centre of pressure (COP) traverses, determined by taking the radius of the major and minor axes and then fitting an ellipse that would include 95% of the points [27]; (ii) sample entropy (SampEn), indicating the regularity of a time series (i.e., COP path) by calculating the probability of it having repeated itself. The calculation of SampEn was conducted following the description given by Randami et al. [28].

2.1.7. Flexibility

V-sit and reach (VSR) was used to measure the global flexibility of the participants [29]. The procedure requires that the individual be placed sitting on the floor in a V-sit position with their feet 30 cm apart. At the midpoint of that distance, the evaluator places a measuring tape starting from 23 cm. Two repetitions of each measurement were performed consecutively with a 30-s rest between them, and the mean of the repetitions was calculated.

2.1.8. Pain Threshold

The pain threshold of the trapezius was measured with a Wagner FPK 20 algometer (Wagner Instruments, Greenwich, CT, USA) with a contact area of 1 cm^2 applied perpendicularly to the skin following the protocol of Slater and colleagues [30], locating the upper trapezius in the mid-point between the C7 spinous process and the acromion. Three repetitions of each measurement were performed consecutively with a 60-s rest between them, and the mean of the repetitions was calculated.

2.1.9. Anxiety

Anxiety was evaluated with the Hamilton anxiety rating scale (HARS), translated and validated in Spanish with good internal consistency [31]. Scores for the entire scale (emotional distress) ranged from 0–56, with higher scores indicating greater distress.

2.2. Data Analysis

Data analysis was performed using SPSS (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL, USA) software, version 22. The Mann–Whitney U test was used to compare the previously described dependent variables between groups (i.e., FMG and CG) since the normality was not satisfied (using Kolmogorov–Smirnov analysis). This test was also used to compare the age and body mass index (BMI) between groups. Furthermore, multiple linear regression analysis, with the backward method, was used to determine the influence on the QoL (measured with the SF-36) of the variables thought to be most influential. The following assumptions required for this analysis were checked: (i) independence of observations with Durbin–Watson, (ii) linear relationship between the dependent variable and the independent variables using Spearman correlation analysis, and (iii) multicollinearity with variance inflation factor (VIF). A probability value of $p < 0.05$ was considered statistically significant.

2.3. Ethical Approval

The project was approved by the Ethics Committee on Human Research of the University of Valencia (reference number: H1449048793044). All enrolled participants provided informed written consent prior to the study. The procedures were performed in accordance with the principles of the Declaration of Helsinki.

3. Results

3.1. Participants

A total of 123 women with FM were studied with a mean (SD) age of 54.40 (6.75) years. The CG was composed of 100 women with a mean (SD) age of 54.27 (6.08) years. Nevertheless, due to a technical failure in the postural control test, only 114 women with FM completed all the measurements. Therefore, the statistical power was lower in the two variables derived from the postural control (Table 1), although 80% of power was assured. There were no significant differences between groups in age ($p > 0.05$). The BMI was significantly higher in the FMG than in the CG (mean difference = 1.73 points; U = 7.31, Z = −2.41, $p = 0.02$), although both groups belonged to the "overweight" category.

3.2. Between-Group Comparisons

Table 1 shows that there were significant differences between groups in all the variables measured ($p < 0.01$). The QoL, functional capacity, isometric strength (both bicep strength and handgrip strength), SampEn, flexibility, and pain threshold were significantly lower, whilst the changes in maintenance of thoracic posture, the excursion of center of pressure (represented by the ellipse), and anxiety were significantly higher ($p < 0.01$).

Int. J. Environ. Res. Public Health 2019, 16, 3173

Table 1. Results of the comparison between women with fibromyalgia and their healthy counterparts.

	FMG		CG		Group Comparison	
	Mean (SD)	Median	Mean (SD)	Median	Z	*p*
QoL	32.49 (15.10)	30.97	78.76 (12.81)	83.33	−12.29	<0.01
Functional capacity (m)	162.06 (27.8)	165.00	212.36 (25.54)	210.00	−10.72	<0.01
Bicep strength (kp)	52.49 (18.68)	47.33	95.92 (25.67)	95.94	−11.35	<0.01
Handgrip strength (kp)	82.13 (56.86)	71.83	155.24 (49.8)	156.80	−8.40	<0.01
Maintenance of thoracic posture (cm)	4.83 (4.66)	4.18	3.13 (3.03)	2.55	−2.92	<0.01
Ellipse (mm^2)	360.14 (495.2)	151.88	155.26 (171.88)	96.37	−4.20	<0.01
SampEn	0.69 (0.15)	0.69	0.77 (0.1)	0.78	−3.86	<0.01
Flexibility (cm)	−1.28 (12.65)	−2.00	9.82 (9.9)	11.00	−7.04	<0.01
Pain threshold ($kg{\cdot}cm^{-2}$)	2.61 (0.65)	2.40	4.16 (1.2)	4.18	−10.18	<0.01
Anxiety	28.88 (9.52)	29.00	9.96 (6.82)	8.50	−11.72	<0.01

FMG—fibromyalgia group; CG—control group; QoL—quality of life; SampEn—sample entropy; Z—Mann whitney u test z value; *p*—significance value.

3.3. Quality of Life Prediction

Table 2 shows the results of the multiple regression model to estimate the factors that affect QoL in women with FM. As noted, of all the variables measured, those able to predict QoL in women with FM were as follows: functional capacity, handgrip strength and bicep strength, maintenance of thoracic posture, pain threshold, and anxiety ($R = 0.73$, $R^2 = 0.53$, $p < 0.05$). The assumption of independence of observations was satisfied (Durbin–Watson = 1.89), as was the multicollinearity analysis (VIF ranged from 1.04–1.93). The linear relationships between the dependent and the included independent variables were significant ($p < 0.05$).

Table 2. Multiple regression model for quality of life in women with fibromyalgia.

Predictor for Quality of Life	Unstandardized Coefficient Beta	Standard Error	Standardized Coefficient Beta	Confidence Interval
Constant	22.53	8.85	-	4.99 to 40.07
Functional capacity	0.14	0.04	0.26	0.07 to 0.21
Bicep strength	0.06	1.72	0.07	−0.09 to 0.21
Handgrip strength	0.03	0.07	0.11	−0.02 to 0.08
Maintenance of thoracic posture	−0.22	0.02	−0.07	−0.65 to 0.22
Pain threshold	1.64	0.22	0.07	−1.77 to 5.05
Anxiety	−0.74	0.12	−0.48	−0.97 to −0.51

4. Discussion

The current study shows that functional capacity, upper limb muscular strength, postural maintenance, pain threshold, and anxiety are important predictive factors of QoL in women with FM. To the best of our knowledge, this is the first study that selected, from a variety of variables that can be treated by the physiotherapist, those that can predict changes in the QoL of women with fibromyalgia, in order to establish the appropriate therapeutic guidelines.

All the variables studied showed a significantly different score between women with FM and their healthy counterparts, as disclosed in the results. Women with FM were observed to have a poorer functional capacity, lower isometric strength, a poorer ability to maintain thoracic posture and to maintain postural control, as well as a lower pain threshold, reduced flexibility, and increased self-reported anxiety. Of these, however, postural control and flexibility did not show a significant contribution to QoL, as demonstrated by the regression analysis.

With regard to functional capacity, our findings are in accordance with previous studies showing that there are differences between women with FM and healthy women [1,3,32–34]. According to our

study, functional capacity rendered a lower value in women with FM. This datum could be due, on the one hand, to lack of physical fitness, as these patients often adopt a more sedentary lifestyle [35], which might include frequently resting in bed when suffering from symptoms. On the other hand, this could be due to lower cardiorespiratory fitness in this population. In this regard, more accurate methods, such as the graded exercise test, to determine maximal oxygen uptake (VO_2 max,) which is the gold standard for cardiorespiratory fitness (thus indicating the maximal aerobic power), would have been desirable. However, due to the particular characteristics of this population (i.e., pain, fatigue), such exhausting measures are often difficult to implement. Thus, submaximal field exercise tests, such as the two-minute walking test, provide a feasible, safe, easy-to-administer, and inexpensive technique for the prediction of VO_2 max [36], and may be considered as an indirect measure of maximal aerobic power or cardiorespiratory fitness in this population. Indeed, the two-minute walking test was shown to have a moderate-to-strong correlation with VO_2 max consumption [37]. Our results are in agreement with previous studies showing that the cardiorespiratory fitness of women with FM was even lower than that of healthy sedentary women [38]. In addition, previous studies observed that these people reflect lower respiratory muscle resistance, lower strength in inspiratory muscles, and less chest mobility, which in turn could contribute to lower aerobic capacity [39].

Our results suggest that an increase in functional capacity implies an increase in the QoL score in this population. There is some controversy regarding the relationship between functional capacity and QoL. Two previous studies did not show a clear relationship between QoL and functional capacity, although their sample was small [33,34]. However, Carbonell-Baeza et al., with a sample size similar to ours, found a relationship between functional capacity and QoL in FM [40]. Nevertheless, an adequate functional capacity is necessary to perform many daily life activities which imply a moderate level of physical activity. Diminished capacity could inevitably have an impact on the level of participation in this type of activity, which in turn would lead to a poorer QoL and even a dependence on other people [41].

With regard to muscle strength, previous studies found reduced muscle strength in women with FM compared to healthy women, both in grip strength [3,32,42], linked to a state of sarcopenia [43], and in upper limb strength [3,32], linked to functional limb capacity [44]. The results of our study are consistent with those of the aforementioned studies, since, in our study, muscle strength was lower in people with FM; specifically, isometric grip strength was 47% lower than that of healthy subjects, and isometric strength of the upper limb was 45% lower than the control group. This decrease in muscle strength could be due, as noted by previous studies, to physiological and neuromuscular factors typically found in FM, such as alterations in blood circulation and changes in neuromuscular control mechanisms caused by pain [45].

Our study shows that an increase in isometric muscle strength, both in grip and the upper limb, can predict an improved QoL. In fact, a given study already established in this population a direct relationship between grip strength and upper limb strength with QoL in FM patients [46]. This result implies that it would be useful for therapeutic intervention plans in this population to include strength training programs that could contribute to improve QoL. Furthermore, since FM women are over the age of 50, the strength training may contribute, in turn, to preventing or postponing as much as possible the onset of sarcopenia and eventual frailty [47].

Parallel to the loss of strength, there is evidence in our study of an inability of the postural muscles to maintain posture, as reflected in the variable maintenance of thoracic posture. Our group previously confirmed a relationship between pain and poor sitting posture in FM [6], as already established in populations with pain [48]. Postural disorders are observed in women with FM, such as positioning the head abnormally forward; these are aggravated by the muscular and joint rigidity of the spine present in this syndrome, thus increasing pain and preventing normal activities of daily and working life [49]. This difficulty in maintaining the upright posture of the trunk and neck may be due to altered muscle control strategies. This is because, by positioning the head abnormally forward, resistance of the muscles responsible for the upright posture deteriorates and peripheral muscle pain appears,

inducing changes in the adaptation of the central nervous system and producing impaired control strategies [6]. Furthermore, some emotional states often present in women with FM, such as depression and anxiety, necessarily influence QoL [42] and may induce postural dealignment [50,51]. Indeed, depression significantly affects posture [52,53], as evidenced by an increased flexion thoracic kyphosis found in individuals with depression [53].

Our results show that a reduced ability to maintain trunk posture can predict a decline in QoL. The distribution of tonic muscle activity ("posture"] depends on the system of posture control [54]. In turn, postural control impairment can affect balance and the performance of daily living activities, and may eventually lead to falls [55], thus negatively affecting their quality of life, as reported in other populations [56,57]. In addition, stress and anxiety may affect postural control [5,58]. These findings are interesting for a better physiotherapeutic approach to patients with FM; neuromuscular control management through training with trunk and neck posture control exercises, as demonstrated in other pain populations, is an important point [48,59]. Furthermore, improving thoracic kyphosis and adopting an upright position was shown to reduce fatigue and stress [60,61], both key factors that should be improved in women with FM [2,62].

Other physical conditions that showed differences between women with FM and healthy subjects are balance and flexibility. However, none of these showed any significant influence on QoL. Our results, regarding the postural control and flexibility variables, are consistent with Kibar's research [63], which conducted balance and flexibility training and found no improvement in QoL in women with FM. Previous studies suggested that balance in people with FM may be mediated by other factors such as anxiety, depression, and fatigue, and may, therefore, mask the relationship with QoL [55]. Future studies should analyze in greater depth the effect of balance alterations on QoL in this population to better understand the effect of possible confounding variables.

Parallel to the alteration of these physical properties, women with FM suffer from generalized pain, which affects the day-to-day activities of women with FM and their participation in society. Pain adversely affects their QoL and limits their daily life activities [64]. According to our results, a lower pain threshold implies a lower QoL score. These data are consistent with previous studies in FM [16,65] and chronic pain populations [65]. Previous studies showed that pain in FM patients can be reduced through physiotherapy intervention-based exercise programs with strength training or moderate aerobic exercise combined with health education, resulting in an improvement in QoL [15,66]. Thus, being aware of its impact on QoL, it is essential to address the subject not only using these approaches but also seeking for other specific intervention plans aimed at reducing pain, in order to improve as much as possible the quality of life of women with FM.

As discussed, chronic pain experience is linked to anxiety in these people [67,68]. Our study confirms that women with FM have significantly greater anxiety levels than their healthy counterparts. It was also noted from the regression analysis that anxiety predicts QoL, since an increase in anxiety results in a decrease in QoL. Although there are no previous studies that attempted to predict QoL in women with FM using these types of variables, there were approximations that measured the correlation between the two variables. In this respect, the study by Ozcetin failed to show a correlation between the global score in the SF-36 with anxiety; however, they did find a negative relationship between anxiety and scores related to the physical and somatic function subscales of the SF-36 QoL questionnaire [68], demonstrating the link between physical state and the emotional component. It is useful for the physiotherapist to know how to objectively quantify the anxiety reported by patients with FM, in order to improve their symptoms through regular physical training. Moderate aerobic training, as well as strength training in FM patients, was shown to be helpful in treatments to improve and reduce anxiety symptoms [15].

5. Limitations

Studies of this type involve some limitations worth considering. Firstly, this was a cross-sectional study and, although regression analyses were used to predict causal direction, the results should be

taken cautiously. Nevertheless, it would still be useful to establish if differences in QoL between people with FM and the control group could to some extent be related to the variables described. Secondly, this was a modal instance sample of patients, in an attempt to get a representative or typical expression of fibromyalgia phenomenology in only one region of the world. Broader, more representative samples of patients could have advantages. Finally, we controlled only for physical confounding variables; therefore, other confounding variables could be involved.

6. Conclusions

The results obtained from this study show that women with FM present differences in their overall physical condition compared to their healthy counterparts. The predictive factors of QoL in women with FM are functional capacity, muscle strength, postural maintenance, pain threshold, and anxiety.

Author Contributions: Data curation, N.S.-R., M.I., M.A.-R., and P.S.-A.; Formal analysis, P.S.-A.; funding acquisition, P.S.-A.; Investigation, N.S.-R., M.I., M.A.-R., and R.I.-A.; Methodology, N.S.-R., M.I., M.A.-R., and R.I.-A.; Project administration, P.S.-A.; supervision, P.S.-A.; Writing—original draft, N.S.-R. and M.A.-R.; Writing—review and editing N.S.-R., M.A.-R., and P.S.-A.

Funding: This work was supported by the Conselleria d'Educació, Ciència, i Esports (Valencian Regional Department of Education, Science and Sports), València, Spain (Grant GV2016/140).

Acknowledgments: We thank the Spanish fibromyalgia associations for their willingness to contribute to the dissemination of the study.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Costa, I.D.; Gamundí, A.; Miranda, J.G.; França, L.G.; de Santana, C.N.; Montoya, P. Altered Functional Performance in Patients with Fibromyalgia. *Front. Hum. Neurosci.* **2017**, *11*, 14. [CrossRef] [PubMed]
2. Clauw, D.J. Fibromyalgia a clinical review. *JAMA* **2014**, *311*, 1547–1555. [CrossRef] [PubMed]
3. Larsson, A.; Palstam, A.; Bjersing, J.; Löfgren, M.; Ernberg, M.; Kosek, E.; Gerdle, B.; Mannerkorpi, K. Controlled, cross-sectional, multi-center study of physical capacity and associated factors in women with fibromyalgia. *BMC Musculoskelet. Disord.* **2018**, *19*, 121. [CrossRef] [PubMed]
4. Pérez-de-Heredia-Torres, M.; Huertas-Hoyas, E.; Martínez-Piédrola, R.; Palacios-Ceña, D.; Alegre-Ayala, J.; Santamaría-Vázquez, M.; Fernández-de-las-Peñas, C. Balance deficiencies in women with fibromyalgia assessed using computerised dynamic posturography: A cross-sectional study in Spain. *BMJ Open* **2017**, *7*, e016239. [CrossRef] [PubMed]
5. Sempere-Rubio, N.; López-Pascual, J.; Aguilar-Rodríguez, M.; Cortés-Amador, S.; Espí-López, G.; Villarrasa-Sapiña, I.; Serra-Añó, P. Characterization of postural control impairment in women with fibromyalgia. *PLoS ONE* **2018**, *13*, e0196575. [CrossRef] [PubMed]
6. Sempere-Rubio, N.; Aguilar-Rodríguez, M.; Espí-López, G.V.; Cortés-Amador, S.; Pascual, E.; Serra-Añó, P. Impaired Trunk Posture in Women with Fibromyalgia. *Spine* **2018**, *43*, 1536–1542. [CrossRef] [PubMed]
7. Muyor, J.M.; López-Miñarro, P.A.; Alacid, F. The relationship between hamstring muscle extensibility and spinal postures varies with the degree of knee extension. *J. Appl. Biomech.* **2013**, *29*, 678–686. [CrossRef] [PubMed]
8. Soriano-Maldonado, A.; Ruiz, J.R.; Aparicio, V.A.; Estévez-López, F.; Segura-Jiménez, V.; Álvarez-Gallardo, I.C.; Carbonell-Baeza, A.; Delgado-Fernández, M.; Ortega, F.B. Association of Physical Fitness with Pain in Women with Fibromyalgia: The al-Ándalus Project: Physical Fitness and Pain in Fibromyalgia. *Arthritis Care Res.* **2015**, *67*, 1561–1570. [CrossRef]
9. Higgs, J.B. Fibromyalgia in Primary Care. *Prim. Care* **2018**, *45*, 325–341. [CrossRef]
10. Geneen, L.J.; Moore, R.A.; Clarke, C.; Martin, D.; Colvin, L.A.; Smith, B.H. Physical activity and exercise for chronic pain in adults: An overview of Cochrane Reviews. *Cochrane Database Syst. Rev.* **2017**, *1*, CD011279. [CrossRef]
11. Ang, D.C.; Kaleth, A.S.; Bigatti, S.; Mazzuca, S.; Saha, C.; Hilligoss, J.; Lengerich, M.; Bandy, R. Research to Encourage Exercise for Fibromyalgia (REEF): Use of motivational interviewing design and method. *Contemp. Clin. Trials* **2011**, *32*, 59–68. [CrossRef] [PubMed]

12. Assumpcao, A.; Matsutani, L.A.; Yuan, S.L.; Santo, A.S.; Sauer, J.; Mango, P.; Marques, A.P. Muscle stretching exercises and resistance training in fibromyalgia: Which is better? A three-arm randomized controlled trial. *Eur. J. Phys. Rehabil. Med.* **2018**, *54*, 663–670. [CrossRef] [PubMed]
13. De Lorena, S.B.; de Lima, M.D.; Ranzolin, A.; Duarte, Â.L. Effects of muscle stretching exercises in the treatment of fibromyalgia: A systematic review. *Rev. Bras. Reumatol.* **2015**, *55*, 167–173. [CrossRef] [PubMed]
14. Tits, M. Fibromyalgia and physical therapy. *Rev. Med. Brux.* **2011**, *32*, 393–397. [PubMed]
15. McDowell, C.P.; Cook, D.B.; Herring, M.P. The Effects of Exercise Training on Anxiety in Fibromyalgia Patients: A Meta-analysis. *Med. Sci. Sports Exerc.* **2017**, *49*, 1868–1876. [CrossRef] [PubMed]
16. Gormsen, L.; Rosenberg, R.; Bach, F.W.; Jensen, T.S. Depression, anxiety, health-related quality of life and pain in patients with chronic fibromyalgia and neuropathic pain. *Eur. J. Pain* **2010**, *14*, 127.e1–128.e1. [CrossRef]
17. Wolfe, F.; Clauw, D.J.; Fitzcharles, M.A.; Goldenberg, D.L.; Katz, R.S.; Mease, P. The American College of Rheumatology preliminary diagnostic criteria for fibromyalgia and measurement of symptom severity. *Arthritis Care Res.* **2010**, *62*, 600–610. [CrossRef]
18. Alonso, J.; Prieto, L.; Anto, J.M. The spanish version of the sf-36 health survey (the sf-36 health questionnaire): An instrument for measuring clinical results. *Med. Clin.* **1995**, *104*, 771–776.
19. Vilagut, G.; Ferrer, M.; Rajmil, L.; Rebollo, P.; Permanyer-Miralda, G.; Quintana, J.M.; Santed, R.; Valderas, J.M.; Ribera, A.; Domingo-Salvany, A.; et al. The Spanish version of the Short Form 36 Health Survey: A decade of experience and new developments. *Gac. Sanit.* **2005**, *19*, 135–150. [CrossRef]
20. Vilagut, G.; María Valderas, J.; Ferrer, M.; Garin, O.; López-García, E.; Alonso, J. Interpretación de los cuestionarios de salud SF-36 y SF-12 en España: Componentes físico y mental. *Med. Clin.* **2008**, *130*, 726–735. [CrossRef]
21. Çimen, Ö.B.; Deviren, S.D.; Yorgancıoğlu, Z.R. Pulmonary Function Tests, Aerobic Capacity, Respiratory Muscle Strength and Endurance of Patients with Rheumatoid Arthritis. *Clin. Rheumatol.* **2001**, *20*, 168–173. [CrossRef] [PubMed]
22. Steffen, T.; Seney, M. Test-Retest Reliability and Minimal Detectable Change on Balance and Ambulation Tests, the 36-Item Short-Form Health Survey, and the Unified Parkinson Disease Rating Scale in People With Parkinsonism. *Phys. Ther.* **2008**, *88*, 733–746. [CrossRef] [PubMed]
23. Alfano, L.N.; Lowes, L.P.; Dvorchik, I.; Yin, H.; Maus, E.G.; Flanigan, K.M.; Mendell, J.R. The 2-min walk test is sufficient for evaluating walking abilities in sporadic inclusion body myositis. *Neuromuscul. Disord.* **2014**, *24*, 222–226. [CrossRef] [PubMed]
24. Johnston, K.N.; Potter, A.J.; Phillips, A.C. Minimal important difference and responsiveness of 2-minute walk test performance in people with COPD undergoing pulmonary rehabilitation. *Int. J. Chronic Obstr. Pulm. Dis.* **2017**, *12*, 2849–2857. [CrossRef] [PubMed]
25. Schneider, C.A.; Rasband, W.S.; Eliceiri, K.W. NIH Image to ImageJ: 25 years of image analysis. *Nat. Methods* **2012**, *9*, 671–675. [CrossRef] [PubMed]
26. Wikstrom, E.A. Validity and reliability of Nintendo Wii Fit balance scores. *J. Athl. Train.* **2012**, *47*, 306–313. [CrossRef] [PubMed]
27. Prieto, T.E.; Myklebust, J.B.; Hoffmann, R.G.; Lovett, E.G.; Myklebust, B.M. Measures of postural steadiness: Differences between healthy young and elderly adults. *IEEE Trans. Biomed. Eng.* **1996**, *43*, 956–966. [CrossRef]
28. Ramdani, S.; Seigle, B.; Lagarde, J.; Bouchara, F.; Bernard, P.L. On the use of sample entropy to analyze human postural sway data. *Med. Eng. Phys.* **2009**, *31*, 1023–1031. [CrossRef]
29. Plowman, S.A.; Meredith, M.D. (Eds.) *The Prudential FITNESSGRAM Test Administration Manual*; Cooper Institute for Aerobics Research: Dallas, TX, USA, 1992.
30. Slater, H.; Paananen, M.; Smith, A.J.; O'Sullivan, P.; Briggs, A.M.; Hickey, M.; Mountain, J.; Karppinen, J.; Beales, D. Heightened cold pain and pressure pain sensitivity in young female adults with moderate-to-severe menstrual pain. *Pain* **2015**, *156*, 2468–2478. [CrossRef]
31. Lobo, A.; Chamorro, L.; Luque, A.; Dal-Ré, R.; Badia, X.; Baró, E.; Grupo de Validación en Español de Escalas Psicométricas. Validación de las versiones en español de la Montgomery-Asberg Depression Rating Scale y la Hamilton Anxiety Rating Scale para la evaluación de la depresión y de la ansiedad. *Med. Clín.* **2002**, *118*, 493–499. [CrossRef]

32. Álvarez-Gallardo, I.C.; Carbonell-Baeza, A.; Segura-Jiménez, V.; Soriano-Maldonado, A.; Intemann, T.; Aparicio, V.A.; Estévez-López, F.; Camiletti-Moirón, D.; Herrador-Colmenero, M.; Ruiz, J.R.; et al. Physical fitness reference standards in fibromyalgia: The al-Andalus project. *Scand. J. Med. Sci. Sports* **2017**, *27*, 1477–1488. [CrossRef] [PubMed]
33. Latorre-Román, P.; Santos-Campos, M.; Heredia-Jimenez, J.; Delgado-Fernández, M.; Soto-Hermoso, V. Analysis of the performance of women with fibromyalgia in the six-minute walk test and its relation with health and quality of life. *J. Sports Med. Phys. Fit.* **2014**, *54*, 511–517.
34. Homann, D.; Stefanello, J.M.F.; Góes, S.M.; Leite, N. Impaired functional capacity and exacerbation of pain and exertion during the 6-minute walk test in women with fibromyalgia. *Rev. Bras. Fisioter.* **2011**, *15*, 474–480. [CrossRef] [PubMed]
35. McLoughlin, M.J.; Colbert, L.H.; Stegner, A.J.; Cook, D.B. Are women with fibromyalgia less physically active than healthy women? *Med. Sci. Sports Exerc.* **2011**, *43*, 905–912. [CrossRef] [PubMed]
36. American College of Sports Medicine. *ACSM's Health-Related Physical Fitness Assessment Manual*; Lippincott Williams and Wilkins: Philadelphia, PA, USA, 2013.
37. Bernstein, M.L.; Despars, J.A.; Singh, N.P.; Avalos, K.; Stansbury, D.W.; Light, R.W. Reanalysis of the 12-Minute Walk in Patients with Chronic Obstructive Pulmonary Disease. *Chest* **1994**, *105*, 163–167. [CrossRef] [PubMed]
38. Sañudo Corrales, B.; Galiano Orea, D. Relationship between cardio-respiratory parameters and women with fibromyalgia. *Reumatol. Clin.* **2008**, *4*, 8–12. [CrossRef]
39. Forti, M.; Zamunér, R.A.; Andrade, C.P.; Silva, E. Lung Function, Respiratory Muscle Strength, and Thoracoabdominal Mobility in Women with Fibromyalgia Syndrome. *Respir. Care* **2016**, *61*, 1384–1390. [CrossRef]
40. Carbonell-Baeza, A.; Ruiz, J.R.; Aparicio, V.A.; Ortega, F.B.; Delgado-Fernandez, M. The 6-Minute Walk Test in Female Fibromyalgia Patients: Relationship with Tenderness, Symptomatology, Quality of Life, and Coping Strategies. *Pain Manag. Nurs.* **2013**, *14*, 193–199. [CrossRef]
41. Galvez-Sánchez, C.M.; Duschek, S.; Reyes Del Paso, G.A. Psychological impact of fibromyalgia: Current perspectives. *Psychol. Res. Behav. Manag.* **2019**, *12*, 117–127. [CrossRef]
42. Sener, U.; Ucok, K.; Ulasli, A.M.; Genc, A.; Karabacak, H.; Coban, N.F.; Simsek, H.; Cevik, H. Evaluation of health-related physical fitness parameters and association analysis with depression, anxiety, and quality of life in patients with fibromyalgia. *Int. J. Rheum. Dis.* **2016**, *16*, 763–772. [CrossRef]
43. Koca, I.; Savas, E.; Ozturk, Z.A.; Boyaci, A.; Tutoglu, A.; Alkan, S.; Yildiz, H.; Kimyon, G. The evaluation in terms of sarcopenia of patients with fibromyalgia syndrome. *Wien. Klin. Wochenschr.* **2016**, *128*, 816–821. [CrossRef] [PubMed]
44. Jones, J.; Rutledge, D.N.; Jones, K.D.; Matallana, L.; Rooks, D.S. Self-assessed physical function levels of women with fibromyalgia: A national survey. *Women's Health Issues* **2008**, *18*, 406–412. [CrossRef] [PubMed]
45. Gerdle, B.; Grönlund, C.; Karlsson, S.J.; Holtermann, A.; Roeleveld, K. Altered neuromuscular control mechanisms of the trapezius muscle in fibromyalgia. *BMC Musculoskelet. Disord.* **2010**, *11*, 42. [CrossRef] [PubMed]
46. Cardoso, F.d.S.; Curtolo, M.; Natour, J.; Lombardi JúAnior, I. Assessment of quality of life, muscle strength and functional capacity in women with fibromyalgia. *Rev. Bras. Reumatol* **2011**, *51*, 338–343. [CrossRef]
47. Nascimento, C.M.; Ingles, M.; Salvador-Pascual, A.; Cominetti, M.R.; Gomez-Cabrera, M.C. Sarcopenia, frailty and their prevention by exercise. *Free Radic. Biol. Med.* **2019**, *132*, 42–49. [CrossRef] [PubMed]
48. Falla, D.; Jull, G.; Russell, T.; Vicenzino, B.; Hodges, P. Effect of neck exercise on sitting posture in patients with chronic neck pain. *Phys. Ther.* **2007**, *87*, 408–417. [CrossRef] [PubMed]
49. Kim, D.; Cho, M.; Park, Y.; Yang, Y. Effect of an exercise program for posture correction on musculoskeletal pain. *J. Phys. Ther. Sci.* **2015**, *27*, 1791–1794. [CrossRef] [PubMed]
50. Grammer, K.; Fink, B.; Oberzaucher, E.; Atzmüller, M.; Blantar, I.; Mitteroecker, P. The representation of self reported affect in body posture and body posture simulation. *Coll. Antropol.* **2004**, *28* (Suppl. 2), 159–173.
51. Canales, J.Z.; Fiquer, J.T.; Campos, R.N.; Soeiro-de-Souza, M.G.; Moreno, R.A. Investigation of associations between recurrence of major depressive disorder and spinal posture alignment: A quantitative cross-sectional study. *Gait Posture* **2017**, *52*, 258–264. [CrossRef]
52. Rosario, J.L.; Bezerra Diógenes, M.S.; Mattei, R.; Leite, J.R. Differences and similarities in postural alterations caused by sadness and depression. *J. Bodyw. Mov. Ther.* **2014**, *18*, 540–544. [CrossRef]

53. Canales, J.Z.; Cordás, T.A.; Fiquer, J.T.; Cavalcante, A.F.; Moreno, R.A. Posture and body image in individuals with major depressive disorder: A controlled study. *Braz. J. Psychiatry* **2010**, *32*, 375–380. [CrossRef] [PubMed]
54. Ivanenko, Y.; Gurfinkel, V.S. Human Postural Control. *Front. Neurosci.* **2018**, *12*, 171. [CrossRef] [PubMed]
55. Jones, K.D.; Horak, F.B.; Winters, K.S.; Morea, J.M.; Bennett, R.M. Fibromyalgia is associated with impaired balance and falls. *J. Clin. Rheumatol.* **2009**, *15*, 16–21. [CrossRef] [PubMed]
56. Miyakoshi, N.; Kudo, D.; Hongo, M.; Kasukawa, Y.; Ishikawa, Y.; Shimada, Y. Comparison of spinal alignment, muscular strength, and quality of life between women with postmenopausal osteoporosis and healthy volunteers. *Osteoporos. Int.* **2017**, *28*, 3153–3160. [CrossRef] [PubMed]
57. Pavão, S.L.; Nunes, G.S.; Santos, A.N.; Rocha, N.A.C.F. Relationship between static postural control and the level of functional abilities in children with cerebral palsy. *Braz. J. Phys. Ther.* **2014**, *18*, 300–307. [CrossRef] [PubMed]
58. Doumas, M.; Morsanyi, K.; Young, W.R. Cognitively and socially induced stress affects postural control. *Exp. Brain Res.* **2018**, *236*, 305–314. [CrossRef]
59. Jang, H.J.; Hughes, L.C.; Oh, D.W.; Kim, S.Y. Effects of Corrective Exercise for Thoracic Hyperkyphosis on Posture, Balance, and Well-Being in Older Women: A Double-Blind, Group-Matched Design. *J. Geriatr. Phys. Ther.* **2017**, *42*, E17–E27. [CrossRef]
60. Wilkes, C.; Kydd, R.; Sagar, M.; Broadbent, E. Upright posture improves affect and fatigue in people with depressive symptoms. *J. Behav. Ther. Exp. Psychiatry* **2017**, *54*, 143–149. [CrossRef]
61. Nair, S.; Sagar, M.; Sollers, J.; Consedine, N.; Broadbent, E. Do slumped and upright postures affect stress responses? A randomized trial. *Health Psychol.* **2015**, *34*, 632–641. [CrossRef]
62. Fischer, S.; Doerr, J.M.; Strahler, J.; Mewes, R.; Thieme, K.; Nater, U.M. Stress exacerbates pain in the everyday lives of women with fibromyalgia syndrome—The role of cortisol and alpha-amylase. *Psychoneuroendocrinology* **2016**, *63*, 68–77. [CrossRef]
63. Kibar, S.; Yıldız, H.E.; Ay, S.; Evcik, D.; Ergin, E.S. New Approach in Fibromyalgia Exercise Program: A Preliminary Study Regarding the Effectiveness of Balance Training. *Arch. Phys. Med. Rehabil.* **2014**, *96*, 1576–1582. [CrossRef] [PubMed]
64. Clauw, D.J.; Essex, M.N.; Pitman, V.; Jones, K.D. Reframing chronic pain as a disease, not a symptom: Rationale and implications for pain management. *Postgrad. Med.* **2019**, *31*, 185–198. [CrossRef] [PubMed]
65. Laursen, B.S.; Bajaj, P.; Olesen, A.S.; Delmar, C.H.; Arendt-Nielsen, L. Health related quality of life and quantitative pain measurement in females with chronic non-malignant pain. *Eur. J. Pain* **2005**, *9*, 267–275. [CrossRef] [PubMed]
66. Van Oosterwijck, J.; Meeus, M.; Paul, L.; De Schryver, M.; Pascal, A.; Lambrecht, L.; Nijs, J. Pain physiology education improves health status and endogenous pain inhibition in fibromyalgia: A double-blind randomized controlled trial. *Clin. J. Pain* **2013**, *29*, 873–882. [CrossRef] [PubMed]
67. Lee, J.W.; Lee, K.E.; Park, D.J.; Kim, S.H.; Nah, S.S.; Lee, J.H.; Kim, S.K.; Lee, Y.A.; Hong, S.J.; Kim, H.S.; et al. Determinants of quality of life in patients with fibromyalgia: A structural equation modeling approach. *PLoS ONE* **2017**, *12*, e0171186. [CrossRef]
68. Ozcetin, A.; Ataoglu, S.; Kocer, E.; Yazycy, S.; Yildiz, O.; Ataoglu, A.; Ycmeli, C. Effects of depression and anxiety on quality of life of patients with rheumatoid arthritis, knee osteoarthritis and fibromyalgia syndrome. *West Indian Med. J.* **2007**, *56*, 122–129. [CrossRef] [PubMed]