

## Original Article

# Evaluation of physical performance in musculoskeletal and rheumatic diseases with jumping mechanography

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### Abstract

**Objective:** Low muscle function is a component of sarcopenia. Rheumatic and musculoskeletal diseases are related to increased muscle loss and decreased muscle performance. Our purpose was to study muscle function among pre and postmenopausal women and women with rheumatic diseases. **Methods:** Two hundred fifty seven women were included in the study: Group POST OST included 61 osteoporotic postmenopausal women under treatment with osteoporotic drugs and calcium/vitamin D supplements (mean age  $65 \pm 9.6$  years), group POST HEALTH consisted of 117 healthy postmenopausal women (mean age  $62.9 \pm 9.8$  yrs), Group RHEUM included 20 women with rheumatic diseases (mean age  $58.85 \pm 13$  yrs), and group PRE included 59 healthy premenopausal women (mean age  $35 \pm 7.6$  yrs). For the measurement of objective parameters of movement (Force, velocity, Power), we used the mechanography system in Leonardo platform (Novotec, Germany). Personal Power (Power/Weight) was also calculated. **Results:** Height was decreased with age, while body mass index (BMI) and weight were significantly increased. In groups POST OST, POST HEALTH, RHEUM, all measured parameters were statistically decreased in comparison with group PRE. No statistical significance was found among POST HEALTH and POST OST women. **Conclusions:** Jumping mechanography can be proposed as a novel tool to assess physical performance in musculoskeletal and rheumatic diseases. It offers to the clinician additional information, while quantitatively assesses muscle function, for assessing sarcopenia.

**Keywords:** Sarcopenia, Jumping mechanography, Rheumatic diseases, Osteoporosis, Menopause

## Introduction

Sarcopenia, defined as the age-related loss of muscle mass, strength and/or physical performance, was recently recognized as a disease. The fact that sarcopenia was included in the ICD-10 10<sup>th</sup> revision was a major step towards the recognition of sarcopenia as a disease. Consequently, hope is rising towards an increase in the availability of the diagnostic tools (examinations and tests for the diagnoses)<sup>1,2</sup>. Previous research found a positive association between lean mass and bone mineral density (BMD) in postmenopausal women. Sarcopenia and osteoporosis may coexist and share similar risk factors. Both belong to age-related conditions and depend on hormones i.e. osteoporosis to menopausal transition<sup>3</sup>.

Locomotion in the literature is presented with several

definitions. Many of the terms used in everyday life, as well as in medical literature, which describe human movement are failing to convey the underlying concepts and rules of physics<sup>4</sup>.

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**Figure 1.** Leonardo Mechanograph GRFP (Novotec, Pforzheim, Germany).

Muscular movements should be described by terms that include the elements of Power (P), acceleration and Force (N). As the application of force causes acceleration, movement is ultimately the result of the action of a force along a distance for a given period of time, which is power. Regarding the measurements used to estimate muscle function and performance, the most commonly used have disadvantages. Isometric methods of strength do not reproduce the normal movement, isokinetic methods use movement in certain angular velocity, which is far from normal<sup>2</sup>.

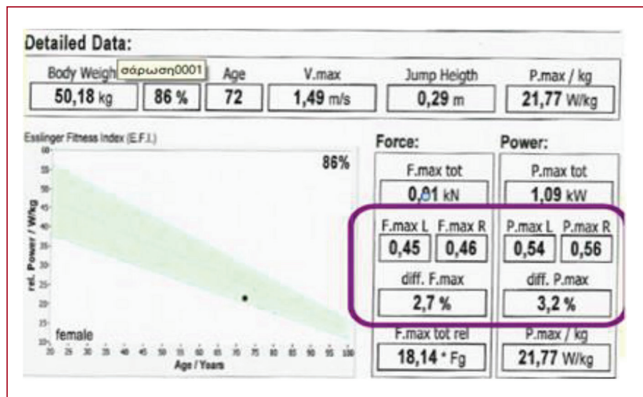
### **Jumping Mechanography (JM) - Basic operating principles**

Unlike other methods such as dynamometry-isometric and isokinetic measurements, jumping mechanography (JM) focuses on the holistic and systematic approach of the subject rather than the evaluation of parameters of individual parts of the body. The main objective of JM is to provide a highly reliable and reproducible method for objectively quantifying the parameters of human movement<sup>4,5</sup>. The method is based on observing the overall performance of the human body as assessed by evaluating motor/mechanical performance parameters. This method is based on the evaluation of free (without any limitation) normal movement and not of patterns of abnormal movements made in complex machines. The expected advantage is that the individual exercises his physical movements daily and consequently leads to high reproducibility<sup>6</sup>.

The basic principle of Leonardo Mechanograph® (Novotec, Pforzheim, Germany) consists of a ground reaction force platform (GRFP) on which the person stands, configured to record only the forces deployed on the vertical axis (Figure 1). The platform records the forces deployed on the vertical axis when moving on it, a computer, a built-in analogue-digital board, and the software needed to analyze the results. The system records the forces applied on the platform over time, and using force and velocity calculates the power of the vertical motions ( $P = F \times v$ ). A continuous recording of strength, velocity and power provides us with information on the eccentric phases of movement. Adjustments in body



**Figure 2.** All women performed jump with two legs (two leg countermovement jump - on the Leonardo Mechanograph® GRFP).



**Figure 3.** Parameter measurements are recorded separately for the right and left leg.

weight power are generally required to allow comparisons of results between different patients, as heavier and taller individuals generally have greater power. This led to the calculation of personal Power equal to Power/Weight and measured in Watt/Kg<sup>7</sup>.

The subject performs movement on the platform, (Figure 2), that is, vertical jump with the following sequence: before the jump, the participant stands in an upright position on the force platform as still as possible; the participant squats as quickly as possible before the jump; the participant jumps as high as possible; the participant begins the smooth landing stage; and the participant stands up straight and as still as possible. Finally, parameter measurements are recorded separately for the right and left leg as shown in Figure 3<sup>8</sup>.

The Leonardo Mechanograph® GRFP software analyses the measurements of this countermovement jump and presents them in a graph (Figure 4).



**Figure 4.** Graphic analysis of Leonardo Mechanograph® GRFP measurements countermovement jump<sup>9</sup>, for explanation see text (adapted from Leonardo Mechanograph® manual).

Coloured lines are depicting over time changes of parameters: blue of total force ( $F_{tot} = F_{left} + F_{right}$  in Newton), green of velocity ( $V$  in m/s) and the red of Power ( $P_{tot} = P_{left} + P_{right}$  in Watt). In the graph 5 time points are important: time  $t_0$  equivalent to the onset of the movement/jump at which the interaction force is identified with the body weight (standing upright on the platform),  $t_1$  at which  $V_{min}$  is observed (i.e. the maximum negative velocity) as the person, is moving in the opposite direction from that of the final jump,  $t_2$  at which the velocity is zero ( $V=0$ ) (at this moment is in the lower position reached),  $t_3$  at which  $V_{max}$  is reached (the maximum positive velocity as the person moves upward during jumping,  $t_4$  at which the jumping person reaches the maximum height ( $V=0$ ) and  $t_5$  at which person is landing ( $V=0$ ). At times  $t_1$ - $t_3$  the person is in the lift/off phase maintaining contact with the platform while at times  $t_4$ - $t_5$  this contact is lost as the person jumps and is at air. The graph also shows points  $t_F$  and  $t_P$  representing the time at which maximum Force ( $F_{max}$ ) and Maximum Power ( $P_{max}$ ) are achieved, respectively. Also, the  $T_{off n}$  and  $T_{on n}$  symbols indicate no contact with the ground/platform and contact respectively.  $F_{max}$  is achieved before  $V_{max}$ . As long as the feet are in the air the interaction force with the platform is obviously zero ( $F=0$ ). Returning the body from the maximum height of the jump to the ground is happening only under the influence of gravity<sup>9</sup>.

This study investigated objective locomotion parameters among pre and postmenopausal women and women with rheumatic diseases in order to evaluate their effect in physical performance, a component of sarcopenia.

## Method and material

The study included 257 women divided into 4 groups. The 1<sup>st</sup> group (POST OST) consisted of 61 osteoporotic, postmenopausal women treated with various antiosteoporotic drugs and calcium/vitamin D supplements (mean age  $65 \pm 9.6$  years); the 2<sup>nd</sup> group (POST HEALTH) consisted

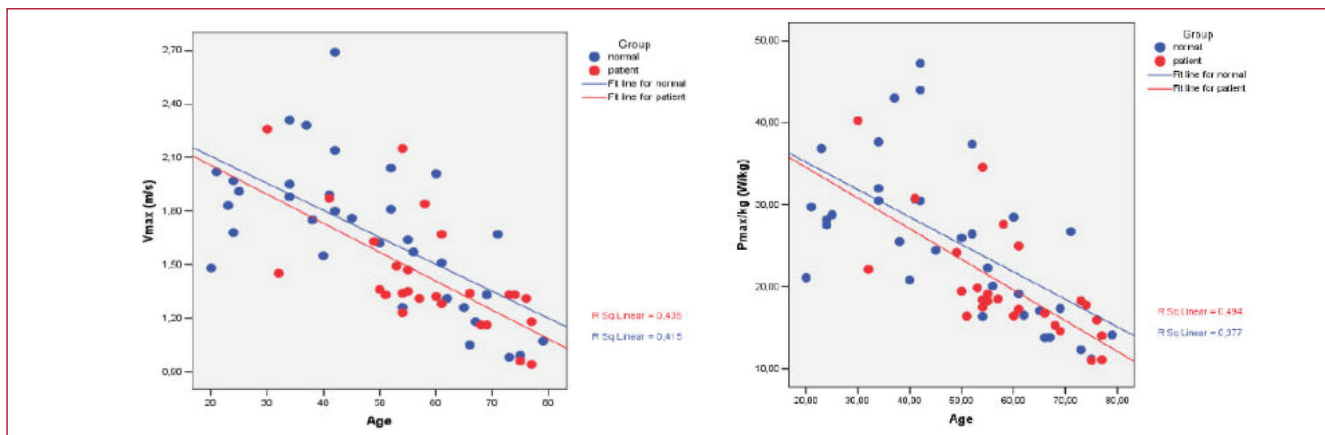
from 117 healthy women (mean age  $62.9 \pm 9.8$  yrs.), the 3<sup>rd</sup> group (RHEUM) of 20 women with various rheumatic diseases (mean age  $58.85 \pm 13$  years) and finally the 4<sup>th</sup> group (PRE) of 59 healthy premenopausal women (mean age  $35 \pm 7.6$  years). After explaining the procedure all women performed jump with two legs (two leg counter movement jump – Figure 2) on the Leonardo Mechanograph® GRFP force platform. Pre-registration of participants' anthropometric characteristics, namely weight (on the platform before jump) and height (with wall mounted measure), was preceded. Subjects not able to follow the methodology of the jump were excluded. Jumping Mechanography provides information on the following parameters: Force ( $F$ ) applied to the platform in relation to time, velocity (in m/s) and Power (in Watts using velocity and Power and according to the formula  $P = F \times V$ ). In addition to the usual parameters measured with Jumping Mechanography, personal Power was also calculated, i.e. the measured power adjusted according to the weight of the individual (personal power = power/weight). A new parameter was created: the Helios Fitness Index (Hel.F.I.). This value Hel.F.I. was based on the previous work of Dr. Runge M. in the German population (Esslinger Fitness Index - E.F.I.). A Hel.F.I. value of 100% corresponds to the average value of the Greek healthy women of our material of the same age according to power/body weight parameter ( $W/kg$ )<sup>10</sup>.

Statistical analysis of the variables among groups was done using the one factor analysis of variance with no repeated measurements model (one way ANOVA) and Bonferroni test for pair wise comparisons. Statistical analysis of the variables between the study subgroups was done using analysis of covariance model (ANCOVA) considering as dependent variable the  $V_{max}$ , factor the group and covariate the age ( $F=0.42$ ,  $p=0.838$ ). Analysis of the data was done using the Statistical Package for Social Sciences (version 10.0) software (SPSS Inc., Chicago, IL).

PARAMETERS	POST OST (n=61)	POST HEALTH (n=117)	PRE (n=59)	RHEUM (n=20)	Anova p value
Weight Kg	67.3±9.70***	63.74±9.90***	60.5±10.10	66.30±12.8**	0.008
Height cm	162±5.00**	160±4.00**	166±4.00	162±4.00**	<0.0005
BMI Kg/m <sup>2</sup>	25.7±3.69***	24.78±4.20***	21.76±3.70	25.19±3.7***	<0.0005
Force max KN	1.7±0.31**	1.86±0.31**	2.18±0.22	1.67±0.4**	0.001
Velocity m/sec	1.45±0.53***	1.6±0.42***	1.79±0.49	1.43±0.24***	<0.0005
Power/ Weight Watt	15.75±8.38***	17.47±7.9***	30.41±11.45	20±6.85*	<0.0005

\*\*\*p<0.0005, \*\*p<0.005, \*p<0.05 vs. PRE GROUP (Bonferroni post-hoc).

**Table 1.** Anthropometric, kinetic and kinematic parameters of study's population.



**Figure 5.** The correlation between Vmax, P max and Age does not differ for RHEUM and PRE+POST HEALTH groups.

## Results

Body weight and body mass index (BMI) were increased during ageing in our population. The results of this study showed that all the parameters measured by jumping mechanography showed a decrease in the POST OST, POST HEALTH and RHEUM groups compared to the PRE group. Also, there was no statistically significant difference between postmenopausal healthy versus osteoporotic postmenopausal women. All parameters are presented in Table 1.

The correlation between Vmax and Age does not differ for RHEUM and PRE+POST HEALTH groups (Figure 5) based on interaction of ANCOVA model considering as dependent variable the Vmax, factor the group and covariate the age ( $F=0.42$ ,  $p=0.838$ ) The linear regression equation for RHEUM group was  $V_{max}=2.38-0.016*Age$ . The same for the correlation between Pmax and Age, it does not differ for RHEUM and PRE+POST HEALTH groups based on Interaction of ANCOVA model considering as dependent variable the

Pmax, factor the group and covariate the age ( $F=0.105$   $p=0.747$ ).

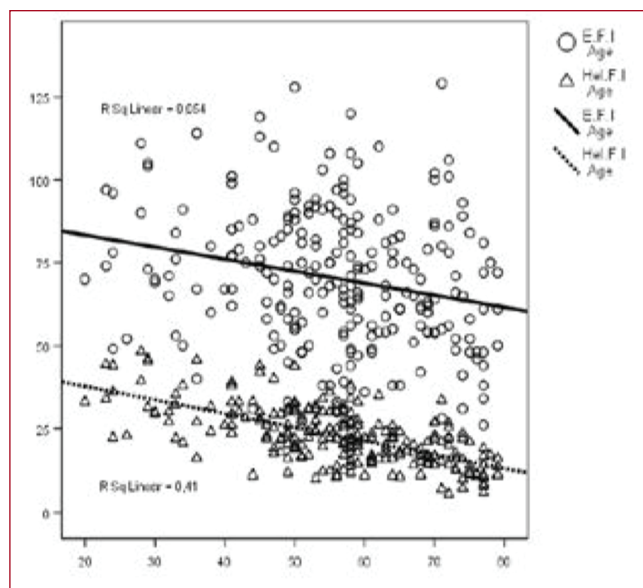
A comparison of the Helios Fitness Index and the corresponding German (Esslinger Fitness Index). Equations Power /Weight for Hel.F.I.=  $45.98-0.41*Age$ ,  $p<0.0005$  and E.F.I.=  $90.59-0.36*Age$   $p<0.0005$ , respectively, is presented in Figure 6.

## Discussion

Regarding the body measurements, body weight was increased, while height decreased with ageing. However, BMI values were below the BMI considered to signify obesity<sup>11</sup>.

Generally, women start gaining weight before the menopause. This may be caused due to decline of estrogen levels<sup>12</sup>. This may explain increased BMI values in all postmenopausal women. According to rheumatic diseases there is a debate regarding whether leflunomide is causally associated with weight loss. Cortisone therapy with high-doses of prednisone may cause weight gain. Tumor necrosis





**Figure 6.** Greek Helios Fitness Index (Hel.F.I.) vs. German Esslinger Fitness Index (E.F.I.).

factor- $\alpha$  inhibition (TNFi) therapy may be associated with weight gain<sup>13</sup>.

Regarding the kinetic and kinematic parameters, there was a statistically significant decrease in all variables and therefore a decrease in muscle performance in the POST OST, POST HEALTH and RHEUM groups compared to the PRE group. These results probably indicate that in postmenopausal women whether or not were treated for osteoporosis, as well as in women with rheumatic diseases, some significant reduction of degree of motor parameters is expected. Possible causes for the decrease in kinetic parameters in the POST and POST HEALTH groups are changes in body composition, reduction in skeletal muscle mass and tendon properties, i.e. an increase in the proportion of percent of slow twitch muscle fibers compared with fast twitch muscle fibers, which is happening during ageing and this may cause a decrease in velocity<sup>12</sup>. In the RHEUM group in which limitation in motor functions is not age dependent, possible causes are: the disease itself, the early limitation of daily activity, the effect of drugs (biological agents, corticosteroids etc.). In rheumatic diseases a loss of muscle mass (and increase in fat mass), with normal or increased body weight is expected leading to decrease of muscle strength, which may accelerate sarcopenia<sup>14</sup>.

A dependence of the maximum power/weight parameter on age with a progressively steady decrease with aging is already shown by many authors. A very good correlation between maximum power output per body weight and age for both sexes separately in a healthy sportive reference collective is already showed<sup>15</sup>.

The comparison of the Helios Fitness Index (Hel.F.I.) derived from the Greek study<sup>12</sup> and the corresponding German (Esslinger Fitness Index) showed a difference explained by the fact that in the German study the participants consisted mainly of athletic, active individuals, whereas the Greek sample was consisted from community dwelling women without any criteria according to their physical activity.

The following are observations from the comparative analysis of the results. The RHEUM versus PRE or POST HEALTH group showed a decrease in all kinetic parameters (Vmax, Fmax, Pmax/kg). Analysis of the results of the measurements considering Vmax as a dependent variable and age as a coefficient of variation showed that the correlation between Vmax (maximum velocity) and age was similar in the RHEUM and PRE and POST HEALTH groups. Similar was the conclusion from the analysis of the relationship of Pmax (maximum power) and age with the same model in the RHEUM and PRE + POST HEALTH groups.

## Conclusion

These results suggest that jumping mechanography using Leonardo Mechanograph® ground reaction force platform (GRFP) is a useful test for measurement objectively human movement in a sample of community-dwelling women. Jumping mechanography detected successfully impaired muscle function and performance. Future studies are needed to provide more data in other populations, in order to increase the power of the efficacy of this tool in sarcopenia assessment.

## Disclaimer

*Prof. G. Lyritis and Dr. Y. Dionyssiotis serve as Editor Emeritus and Co- Editor in Chief in the JFSF, respectively. Dr. J. Papathanasiou is an Editorial Board member. The manuscript underwent peer review process by independent experts.*

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