

Influence of percentage of 1RM strength test on repetition performance during resistance exercise of upper and lower limbs

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Summary

Introduction: Since methods to resistance exercise (RE) prescription uses percentage of one repetition maximum test (1-RM), it is crucial checking if the same %1RM generates similar intensity and performance. Thus, the objective of this study was to compare the number of repetitions and total load in uni- vs. bilateral, upper vs. lower limbs exercises in different percentages of 1RM.

Methods: Twenty one healthy men (23.2 ± 5.8 years, 84.3 ± 7.6 kg, 182.2 ± 6.5 cm, 11.4 ± 4.8 % body fat; one year of RE experience (4-5 h/week) volunteered. After 1RM tests the maximum number of repetitions with 70%, 80% and 90 % of 1RM in uni and bi-lateral exercises were performed.

Results: Number of repetitions of uni-lateral Leg Press was significantly greater for 80% of 1RM (P<0.05), while the total load was lower for 70% of 1RM comparing with bilateral Leg Press. Increase in number of repetitions in bilateral contractions for 80% and 90% of 1RM, while the total load was increased in 70% of 1RM with Uni-lateral when compared with bilateral knee flexion. The Uni-lateral Scott exercise showed significant differences with 70% of 1RM load both in numbers of repetitions and in total load.

Conclusion: In 80% and 90% of 1RM number of repetitions is higher in lower compared with upper limbs exercises, while in 70% no differences were found. It seems that single-joint perform less repetitions than multi-joint exercises (e.g. Leg Extension vs. Leg Press) and upper limbs showed more number of repetitions and total load in 70% of 1RM.

Key words:

Muscle contraction.
Resistance training.
1RM test.

Influencia del porcentaje de test de 1RM en el rendimiento durante ejercicios de fuerza de las extremidades superiores e inferiores

Resumen

Introducción: Como los métodos para la prescripción de ejercicios con sobrecarga utilizan el porcentaje de 1 RM, son crucial verificar si el mismo porcentaje de 1 RM equivale a intensidades similares y al mismo rendimiento. Por lo tanto, el objetivo de este estudio fue comparar el número de repeticiones y la carga total en ejercicios unilaterales y bilaterales, de las extremidades superiores e inferiores, con diferentes porcentajes de 1 RM.

Método: Veintiuno varones sanos (23,2 ± 5,8 años; 84,3 ± 7,6 kg; 182,2 ± 6,5 cm; 11,4 ± 4,8% de masa grasa; 1 año de experiencia, 4-5 h por semana) participaron voluntariamente en el estudio. Después de los tests de 1 RM, los participantes realizaron tests de repeticiones máximas al 70%, 80% y 90% de 1 RM en ejercicios unilaterales y bilaterales.

Resultados: El número de repeticiones de *press* de pierna unilateral tuvo un incremento significativo con el 80% de 1RM (p<0,05). Sin embargo, la carga total al 70% de 1RM fue menor en comparación con el *press* de pierna bilateral. El incremento en el número de repeticiones en las contracciones bilaterales al 80% y al 90% de 1RM, demostraron un aumento del trabajo total cuando comparado con la condición unilateral al 70%. El ejercicio "Scott" unilateral presentó diferencias significativas al 70% de 1RM, tanto en el número de repeticiones como en el trabajo total.

Conclusión: En las condiciones de 80% y 90% de 1RM, el número de repeticiones es mayor en los miembros inferiores, mientras que al 70% no hubo diferencias significativas. Parece que sólo el grupo unilateral hacía un menor número de repeticiones cuando comparado con los ejercicios multi-articulares, por ejemplo, extensión de pierna vs. presión de pierna. Los miembros superiores mostraron un mayor número de repeticiones y carga total al 70% de 1RM.

Palabras clave:

Contracción muscular.
Ejercicio con sobrecarga
Test de 1RM.

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Introduction

Resistance exercises (RE) have been suggested in sports guidelines aiming at improving physical conditioning and health¹. RE is a combination of dynamic actions and static effort, where specific devices should be used to evaluate muscle strength and involves multiple variables that can be arranged to specifically meet training goals and individual needs, such as: exercise order, rest interval between sets, exercise mode, training frequency, movement velocity, training volume, repetitions per set, number of sets, type of muscle action, and the load intensity^{1,2}. The control of RE intensity (i.e. percentage of one maximum repetition [1RM]) should be related to a determined number of repetitions.

Some methods to measure maximal muscle strength include the use of isometric^{3,4} and isokinetic dynamometers^{5,6}, but these methods usually require expensive laboratory equipment. On the other hand, 1RM test is defined as maximal amount of weight that can be lifted through the full range of motion in only one repetition and is considered the gold standard for assessing muscle strength in non-laboratory situations and frequently used as measurement of muscular strength^{1,7,8}. The variation between the percentage of 1RM and number of repetitions seems to oscillate according to size of the muscle and types of actions (unilateral vs. bilateral)^{9,10}, and the same number of repetitions per set, considering different exercises, should not be expected.

It is supposed that uni and bilateral maximal actions are characterized concerning their neuromuscular activation, by the recruiting of many muscular groups or in many frequencies through a similar process of intermuscular coordination. It is known that the intramuscular coordination is a determining performance factor in sports in which maximal unilateral voluntary contractions are used¹¹, but cortical inhibition decreases neural drive to the activated muscles during bilateral actions, thereby resulting in force decrements^{12,13}. Bilateral maximum voluntary strength is lower than the sum of the unilateral strength of the right and left extremities^{11,13}, but relative strength (e.g. 80, 90% 1RM) between uni and bilateral exercises is not well described. Considering that most fitness coaches uses %1RM to determine the intensity of RE and it is crucial to determine the stimulus of the session, it would be reasonable to check if the same %1RM generate similar mechanical stress (i.e. number of repetitions performed). Thus, the purpose of this study was to compare the number of repetitions and total load in uni- vs. bilateral and upper vs. lower limbs exercises in different percentages of 1RM. We hypothesized that muscular performance would be different between unilateral and bilateral exercises as well as between upper and lower body muscles considering the same percentage of 1RM.

Material and method

Subjects

Twenty one healthy men (23.2 ± 5.8 years, 84.3 ± 7.6 kg, 182.2 ± 6.5 cm, 11.4 ± 4.8 % body fat) with at least one year of recreational RE experience (performing routine RE exercises at least 4-5 hours/week) participated in this study. All subjects completed the *Physical Activity Readiness Questionnaire* (PAR-Q). The following additional exclusion criteria included: 1) less than 1 year RE training, 2) smoking history during

the last three months, 3) presence of any cardiovascular or metabolic disease, 4) systemic hypertension ($\geq 140/90$ mmHg or use of antihypertensive medication), 5) use of creatine supplementation, 6) use of anabolic steroids, drugs or medication with potential effects on physical performance (self-reported), or 7) recent and not fully recovered musculoskeletal injury. This study was approved by the local institutional Ethical Committee for Human Experiments (2366/2013), and was performed in accordance with ethical standards in sports science research¹⁴. In addition, all participants signed an informed consent form.

Body mass was measured to the nearest 0.1 kg using a calibrated physician's beam scale (model 31, Filizola, São Paulo, Brazil), with volunteers dressed in shorts and height was determined without shoes to the nearest 0.1 cm using a stadiometer scale (model 31, Filizola®). Body fat percentage (%) was estimated using the seven-site skinfold method¹⁵.

1RM - One-Repetition strength Test

The leg press (LP), Scott arm (SA) and knee flexion (KF) were selected in this study due to its common use in RE programs. The 1RM strength tests were performed following the anthropometric measurements on the first day. After 48h, the 1-RM strength test was repeated to determine test-retest reliability. The 1RM loads were determined in fewer than five attempts with a rest interval of five minutes between attempts^{16,17}, and was considered the heaviest load achieved on either day test. The 1RM test has been described previously and for reliability, the following strategies were adopted¹⁶: (a) standardized instructions about the testing procedures were given to subjects prior to test; (b) subjects received standardized instructions concerning exercise technique; (c) verbal encouragement was provided during tests; (e) the mass of all weights and bars was determined using a precision scale.

All testing was performed between 1:00 PM and 3:00 PM. Coffee, tea, alcohol and tobacco intake were prohibited for 48 hours, and subjects avoided formal and strenuous exercise for 48 hours before each visit.

Resistance exercises sessions

After 1RM tests and re-tests, all volunteers attended the laboratory six times with 48h between visits. All subjects performed one set of maximum repetitions to volitional failure at 90%, 80% and 70% of their 1-RM strength test with an 8 and 10-minute rest interval, respectively. Execution of RE sessions respected the following order: 1) third and sixth visits were realized bilateral LG and unilateral LG; 2) fourth and seventh visits were realized bilateral SA and unilateral SA; 3) fifth and eighth visits were realized bilateral KF and unilateral KF. Subjects began exercising unilateral RE session with the dominant limb and immediately after voluntary fatigue (with no pause), they continued to exercise using the non-dominant limb until concentric failure.

During each RE session, subjects were verbally encouraged to perform all sets until concentric failure, using the consistent definition of a complete range of motion used for the 1-RM strength test. During all RE sessions, subjects were asked not to perform a Valsalva Maneuver. Movement velocity in all tests was controlled (~ 2 s for each -concentric/eccentric phase) through a metronome (SQ-50V, Seiko® Instruments, Chiba, Japan) and a complete range motion for the exercises had to

be completed. Additionally, similar strong verbal encouragement was given to all subjects during each test. All of the exercise sessions were preceded by a 10 minutes warm-up on an upper body ergometer (Technogym®, New Jersey, USA) with an intensity of 20 watts. Before each test, all volunteers indicated a score on perceived recovery scale (PRS)^{18,19} ranging from 0 to 10, about their relative physical recovery to ensure the same conditions in each trial.

Statistical Analysis

Shapiro–Wilk normality test and the homoscedasticity test (Bartlett criterion) were applied. To test the reliability of the 1-RM load between the test and retest, we used the intraclass correlation coefficient (ICC). To compare potential differences inter-exercise uni vs. bilateral were used a repeated measures two-way analysis of variance, with *Bonferroni* post-hoc tests. Comparisons intra-exercises for bilateral vs. unilateral were performed with ANOVA one-way repeated-measures followed by *Tukey's* post hoc tests. The level of significance was set at $\alpha \leq 0.05$ and the software used for data analysis was GraphPad® (Prism 6.0, San Diego, CA, USA).

Results

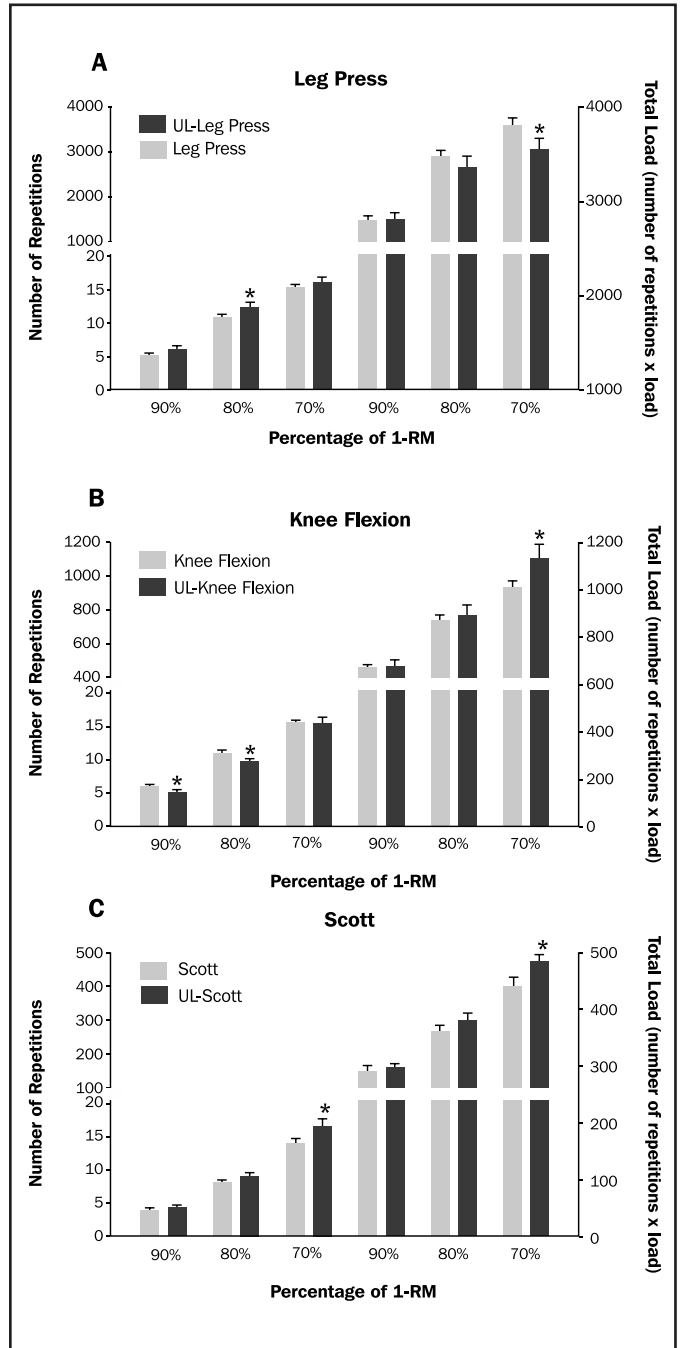
A high ICC (0.962; 95% CI = 0.949-0.981; $p = 0.019$) was found for 1 RM test and retest. No difference was found comparing PRS scale ($p=0.55$) among tests. The number of repetitions of unilateral leg press was greater in 80% of 1RM ($P < 0.05$), while the total load was lower in 70% of 1RM compared with bilateral leg press (Figure 1A). In the knee flexion exercises the number of repetitions was higher ($P < 0.05$) in bilateral in 80% and 90% than unilateral, but the total load in 70% of 1RM for unilateral was higher ($P < 0.05$) than bilateral (Figure 1B). The unilateral Scott exercise presented higher values with 70% 1RM in both number of repetitions and total load (Figure 1C).

In relation the number of repetitions among all exercises (Figure 2) we found lower values in 80% and 90% of 1RM for Scott and unilateral Scott exercises compared with knee flexion and unilateral leg press. Lower number of repetitions was found for leg press compared with unilateral leg press in 80 and 90% of 1RM. In 70% and 80% of 1RM, unilateral Scott was higher ($P < 0.05$) than Scott. Unilateral leg press presented higher ($P < 0.05$) number of repetitions compared with Scott in 70% of 1RM.

Discussion

The purpose of this study was to compare the number of repetitions and total load in uni- vs. bilateral and upper vs. lower limbs exercises in different percentages of 1RM. Our main finding is that in 80% and 90% of 1RM the number of repetitions is higher in lower compared with upper limbs exercises. These results show that major muscle group exercises perform higher number of repetitions than small ones to the same relative intensity (i.e. % of 1RM). In general, unilateral exercises showed higher number of repetitions than bilateral exercise. In relation to the total load, interestingly only with 70% of 1RM we found differences

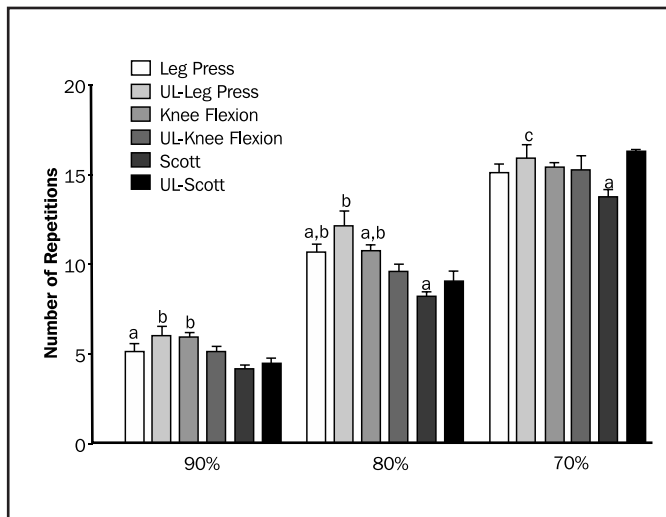
Figure 1. Mean of numbers of repetitions and total load at 90%, 80%, and 70% 1RM. Data are presented as mean ± SD. * $P < 0.05$ – significant difference when compared to bilateral contractions.



between unilateral vs. bilateral movements for all exercises (leg press, knee flexion and Scott).

Arazi *et al.*²⁰ analyzing the relationship between number of repetitions and percentage of 1RM in two groups (trained and non-trained) found no significant differences for arm exercises between groups, but when compared limbs, higher number of repetitions was described for

Figure 2. Comparisons among all exercises at 90%, 80%, and 70% 1RM. Data are presented as mean \pm SD. ^aP<0.05 vs. same UL (unilateral) exercise; ^bP<0.05 vs. Scott and UL (unilateral) Scott; ^cP<0.05 vs. Scott.



squat compared to bench press and arm curl. Hoeger *et al*¹⁰ observed a higher number of repetitions in multi-joint exercises when compared to single-joint. These results are in line with ours, corroborating the hypothesis that number of repetitions is dependent from muscular group involved and the relative intensity of exercises (% of 1RM), since we demonstrated that volunteers performed more repetitions in leg press and knee flexion in relation to elbow flexion.

The ability of force generation and support fatigue is related to the transverse section size, motor unit recruitment and action of synergist muscles^{21,22}. Early gains in strength on arm curl exercises were followed possibly by muscle hypertrophy and more complex exercises (e.g. trunk and legs) may delay longer to obtain hypertrophy²³. This relationship between complexity of exercise and delay in hypertrophy gains are described in literature²⁴⁻²⁷ and with the increasing complexity of exercises, learning and coordination become the main factors contributing to gains in lift performance²⁸. Considering that we found a higher number of repetitions for larger muscular groups and the volunteers were well trained in resistance exercises, another hypothesis could be the capacity of energetic pathway use and recovery²⁹. Since lower limbs exercise recruit larger muscles than upper limbs (i.e. leg press and knee flexion vs. Scott), may there is a alternation of fibers recruitments among the active muscle during the exercise resulting in higher number of repetitions than an exercise which depends smaller muscle. It could explain, at least in part, why our volunteers achieved more number of repetitions in leg exercises compared with arm.

Besides, resistance exercise bouts can decrease muscle glycogen content^{30,31} and result in accentuated exercise-induced muscle weakness³⁰, diminished force production⁴⁰, or reduced isometric strength³⁶, mainly using large-muscle mass with moderate loads. So, the amount of glycogen used in these exercises also appears to be related to the total amount of work and the duration of the resistance exercise bouts. Thus,

more muscle mass involved in exercise could have higher repetitions because they have more glycogen content, considering fibers type.

This difference could be explained by bilateral deficit defined as the sum of unilateral forces alone versus contralateral homologous movement in combination¹². The possible explanation are related with cortical inhibition and decreased neural recruitment of active muscles³². It is suggested the presence of such inter-hemispheric inhibitory mechanisms and transcallosal inhibitory pathways have been demonstrated between the primary motor cortices³³. The hypothesis that inter-hemisphere inhibition may result in reduction of the neural drive in bilateral efforts when compared with unilateral efforts, both in small and large muscles, being the electromyography deficit similar to the strength deficit^{33,34}. It was concluded that the reduction of neural drive was the cause of the bilateral deficit, limiting performance in maximal contractions¹³. Another explanation put forward for bilateral deficit would be that during maximum isometric and isokinetic contractions occur reduced neural drive to the agonist muscles³⁴. Besides, bilateral deficit can be expressed due to the lower trust in the non-dominant limb and that the non-dominant side presented electric activity significantly higher than the dominant side for bilateral contractions³⁵. This episode was probably reached by greater neural drive for the non-dominant limb, by the existence of possible deficiencies in the intermuscular coordination levels during movement, causing greater recruiting of motor units.

Exercises which involve the movement of multiple joints may be more sensitive to bilateral deficit than exercises which involve movement in a single joint³⁶. However, the same amount of agonist activation in submaximal unilateral and bilateral actions would result in less force in the bilateral condition³⁷. Our results showed decrease of the number of repetitions with 70% and 80% of 1RM during bilateral contractions in the Scott and leg press, respectively. Some studies demonstrated that lower iEMG values of vastus lateralis and rectus femoralis (19% and 30%, respectively) are likely to play an important role in bilateral deficit, while biceps not were observed any differences³⁸.

Leg press exercise showed decrease of the number of repetitions with 80% of 1RM during bilateral actions. Some studies shown decrease of 10% in maximal voluntary isometric strength during bilateral in leg extension possibly for greater mechanic efficiency in the recruiting of muscle fibers during unilateral actions compared with the bilateral contractions³⁹. Corroborating the previous statement, during the unilateral action seems occur greater neural activation and increased recruitment of motor units, mainly type II fibers, which cause increased production of muscle strength¹³. Another study described a deficit bilateral in leg extension 1RM, found a significant difference between bilateral and the unilateral testing (120.0 ± 11.9 vs. 135.0 ± 20.2 kg; $p < 0.05$, respectively). However, no difference in the total volume load lifted between the unilateral and bilateral RE sessions was detected. Rainers *et al.*⁴⁰ analyzed aged adults in comparing with young adults verified deficit in both groups, but more significant in aged adults, was analyzed a program of training for lower limbs included in exercises was a leg press like as in our study, since it is the same exercise used in this research is the great contribution for affirmation to our results. Another situation to be analyzed in this study is the relation of the percentage 1RM with the number of repetitions. Hoeger *et al*⁹ investigating the relationship of the percentage of 1RM with the number of repetitions,

found a mean about 15 in leg press, 8 in arm curl and 6.5 in leg curl, respectively for 80% of 1RM⁹. We found 10.7 ± 2.1 , 8.1 ± 1.5 and 10.7 ± 1.8 to respective exercise in the same intensity. Another study showed similar relationship, in trained individuals, about 9.1 ± 2.8 and 4.4 ± 1.9 repetitions for 85% and 90% of 1RM, respectively in back squat, bench press, and arm curl exercises⁴¹.

On the other hand, our study observed significant increase in number of repetitions (80% and 90% of 1RM) during bilateral contractions in knee flexion exercise when compared to unilateral contractions. Bilateral facilitation during knee flexion is related to movement learning and the decrease on central limitation of the motor coordination, thus characterizing the movement learning and the predominance of other non-neural factors^{37,42,43}.

Our study collaborate to training assembly and establishment charges, suggesting that RM could change according to the intensity and involved muscles. Once that sports scientists and professionals spend the majority of the preparatory and competition season trying to guarantee for appropriate training and recovery strategies to ensure optimal performance in the competitions⁴⁴, the ideal training loads are needful to improve performance. In addition, considering that most of sport disciplines require unilateral and bilateral actions and its performance are technique-dependent, the adjustment of specific loads for each uni or bilateral effort may result in a best performance. However, as a limitation of this study, it should be highlighted that since the volunteers were well trained in resistance exercises, the order of exercises could affect the results, consider that some adaptations to exercises occurred during experiments. However, for training sessions it should not be a problem, because usually athletes receive their planning earlier.

We conclude that in 80% and 90% 1RM the number of repetitions is higher in lower limbs exercises compared with upper limbs exercises, while in 70% no differences were found. It seems that single-joint exercises perform less repetitions than multi-joint (e.g leg extension vs. leg press) while upper limbs showed more number of repetitions and total load in 70% of 1RM.

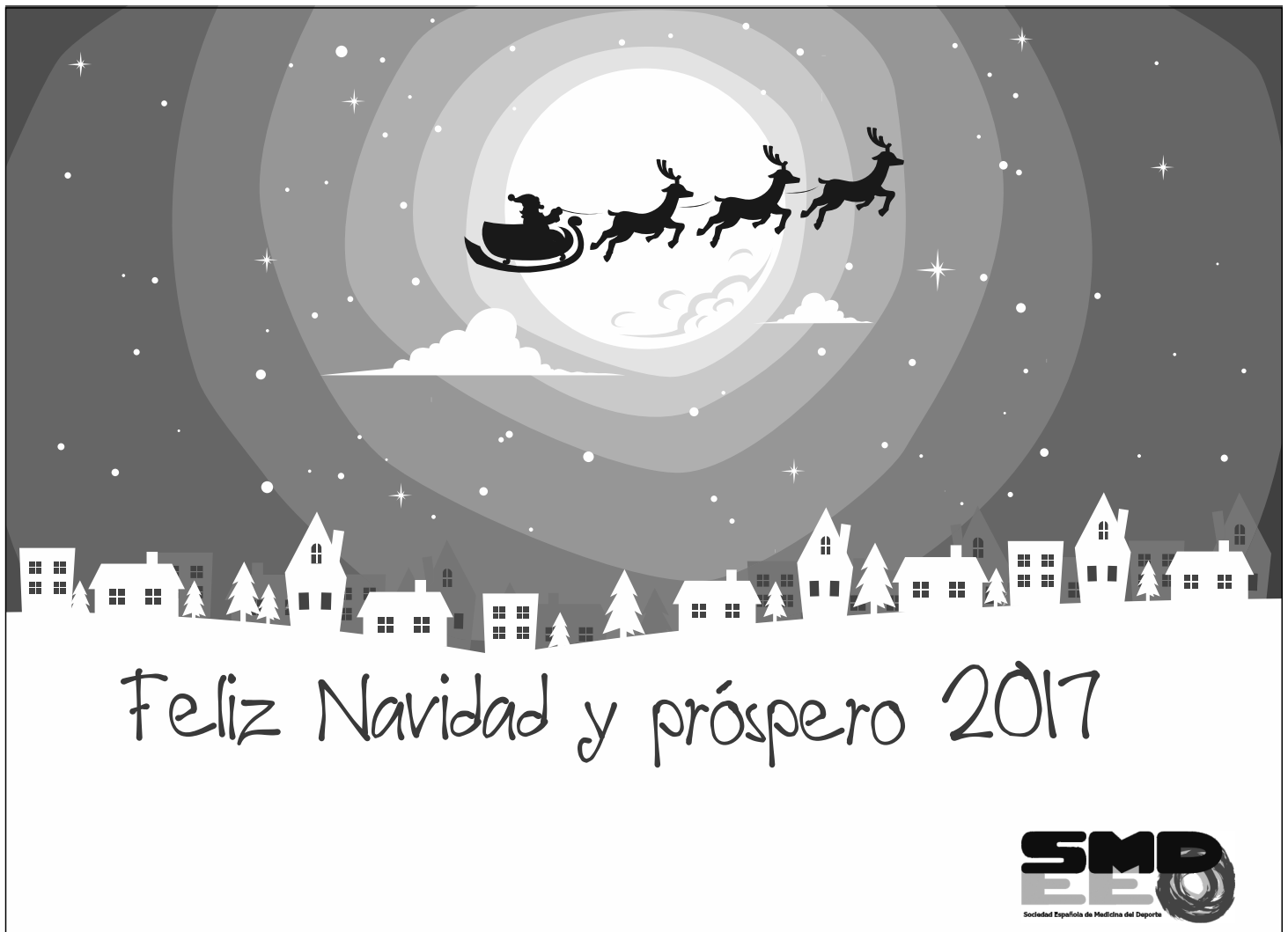
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- **Osteopatía y Terapia Manual** ⁽²⁾
- **Patología Molecular Humana** ⁽²⁾
- **Psicología General Sanitaria** ⁽¹⁾

⁽¹⁾ Presencial ⁽²⁾ Semipresencial