UNIVERSIDAD MIGUEL HERNÁNDEZ DE ELCHE
DEPARTAMENTO DE PSICOLOGÍA DE LA SALUD

Programa de Doctorado en Psicología de la Salud

Effects of the Menstrual Cycle Phases on Different Strength Manifestations

Doctoral thesis

A dissertation presented by

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Graduate in Physical Activity and Sports Science

Elche, 2017

El Dr. D. Juan Carlos Marzo Campos, director del Departamento de Psicología de la Salud de la Universidad Miguel Hernández de Elche.

AUTORIZA:

Que el trabajo de investigación titulado: "EFFECTS OF THE MENSTRUAL CYCLE PHASES ON DIFFERENT STRENGTH MANIFESTATIONS" realizado por Dña. Alicia Martínez Cantó, bajo la dirección de Dr. D. Manuel Moya Ramón y Dr. D. Diego Pastor Campos, sea depositado en el departamento y posteriormente defendido como Tesis Doctoral en esta Universidad ante el tribunal correspondiente.

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"Ni el más sabio conoce el fin

de todos los caminos"

J.R.R. Tolkien

Dedicada a mi Enfermera y mi Bióloga.

Por allanarme el camino,

por hacerme aprender de vuestros errores

y seguir los pasos de vuestros éxitos.

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por enseñarme que el mundo es mejor con gente como tú.

A mi madre, fuerte y luchadora.

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ATP	Adenosin-Tri-Phosphate
BMI	Body Mass Index
BBT	Basal Body Temperature
BP	Breast Pain
CHO	Carbohydrate
CK	Creatine Kinase
CL	Confident Limits
CMJ	Counter-Movement Jump
CSA	Cross-Sectional Area
CV	Coefficient of Variation
E2	Estradiol
F	Force
Fdm	Fibre Diameter
FFA	Free Fatty Acids
FP	Follicular Phase
FSH	Follicle Stimulating Hormone
gFP	Group that start measurements in FP
GH	Growth Hormone
gLP	Group that start measurements in LP
gMEN	Group that start measurements in MEN
GnRH	Gonadotrophin-releasing Hormone
H	Days with Headache per cycle
ICC	Intraclass Correlation Coefficient
Kg-OP	Kilograms for optimal load
KSD	Karolinska Sleep Diary
LBM	Lean Body Mass
LBP	Low Back Pain
LH	Luteinizing Hormone
LP	Luteal Phase
m	Meters in 20-sec-all out test
M	Days with menstruation per cycle
MBI	Magnitude Based Inferences
Mdm	Muscle Diameter
MEN	Menstruation
MP	Menstrual Pain
MPP	Mean Power during Propulsive Phase
MPV	Mean Velocity during Propulsive Phase

MVC	Maximal Voluntary Contraction
No BP	No Breast Pain
No LBP	No Low Back Pain
No MP	No Menstrual Pain
OCP	Oral Contraceptive
OV	Ovulation
p	Statistical Signification
P	Power
P_{max}	Maximal Power
P_{mean}	Mean Power in 20-sec-all-out test
PMS	Pre-menstrual Syndrome
POMS	Profile of Mood States
P4	Progesterone
r	Pearson´s Correlation Coefficient
Repts-OP	Repetitions within optimal velocity
RFD	Ratio of Force Development
RPE	Reported Perception of Effort
SD	Standard Deviation
SSC	Stretch Shortening Cycle
V	Velocity
VBRT	Velocity-Based Resistance Training
VLDL	Very Low Density Lipoprotein
V_{max}	Maximal Velocity
VO_2max	Maximal Oxygen Consumption
%RM	Percentage of 1-RM
%RM-OP	Percentage of 1-RM in which P_{max} was achieved
1-RM	One Repetition Maximum
5 m	Acceleration in the first five linear meters
20 m	Twenty meters lineal sprint

Abstract

The purpose of this thesis was to investigate the effect of menstrual cycle phases on strength training in both lower and upper body exercises, on dynamic and kinematic responses and on the adaptations produced after a training period using the velocity-based resistance training (VBRT). It was also to analyze the impact of the discomfort associated with menstruation on this type of training. The main findings of this thesis include: (1) different performance tests executed at maximum velocity to evaluate the power output, as well as an indirect test to evaluate the 1-RM can be performed indistinctly at any phase of the menstrual cycle; (2) the maximal velocity (V_{max}) and the mean velocity during the propulsive phase (MPV) are higher in the follicular phase (in the moments prior to ovulation); (3) discomfort associated with menstruation and premenstrual syndrome adversely affect the performance test results; (4) the reported perception of effort (RPE) by the participants is greater at the time of menstruation and prior to it; (5) better results were obtained in the follicular phase in all the applied tests after two-weeks of intervention in each phase of the menstrual cycle; (6) the group reporting no discomfort associated with menstruation, obtained greater improvements in all tests in the follicular phase after two weeks of intervention, while both groups improved equally in the luteal phase. The results of this thesis indicate that the tests to evaluate strength and the power produced can be used in any phase of the cycle without affecting the results, but when a program of velocity-based resistance training is performed, it would be more productive to concentrate training loads in the first two weeks of the menstrual cycle. In addition, women who report suffering from dysmenorrhea or pain associated with menstruation, obtain worse results in the applied tests with and without an intervention program. This implies that the use of oral contraceptives can be evaluated to reduce this symptomatology and to increase the performance after analyzing if the effect of exogenous hormonal load does not affect this type of training.

Key Words: Menstrual Cycle, dysmenorrhea, strength training, velocity training, power output.

Resumen

El propósito de esta tesis fue investigar el efecto de las fases del ciclo menstrual sobre el entrenamiento de fuerza tanto en ejercicios de tren inferior como de tren superior sobre respuestas dinámicas y cinemáticas, y las adaptaciones producidas después un periodo de entrenamiento de fuerza basado en la velocidad. También se analizó el impacto que tiene sobre este tipo de entrenamiento las molestias asociadas a la menstruación. Los principales hallazgos de esta tesis incluyen: (1) diferentes test de rendimiento ejecutados a máxima velocidad para evaluar la potencia producida y, así como un test indirecto para evaluar el 1-RM pueden ser realizados indistintamente en cualquier fase del ciclo menstrual; (2) la velocidad máxima y la velocidad media durante la fase propulsiva son mayores en la fase folicular (en los momentos previos a la ovulación); (3) las molestias asociadas a la menstruación, y el síndrome pre-menstrual afectan negativamente a los resultados de los test de rendimiento cuando se aplicaron en diferentes fases del ciclo menstrual; (4) la percepción de esfuerzo de los sujetos es mayor en los momentos de la menstruación y previos a ella; (5) tras intervenir en cada una de las fases del ciclo menstrual, se obtuvieron mejores resultados en la fase folicular en todos los test aplicados; (6) el grupo que indicó no tener molestias asociadas a la menstruación, obtuvo mayores mejoras en todos los test en la fase folicular tras dos semanas de intervención, mientras que ambos grupos mejoraron por igual en la fase lútea. Los resultados de esta tesis indican que los test para evaluar la fuerza y la potencia pueden ser utilizados en cualquier fase del ciclo sin que el resultado se pueda ver afectado por él, pero a la hora de realizar un entrenamiento de fuerza basado en la velocidad, sería más conveniente concentrar las cargas de entrenamiento en las dos primeras semanas del ciclo menstrual. Además, las mujeres que sufren dismenorrea o dolores asociados a la menstruación, obtienen peores resultados en los test de rendimiento con o sin la aplicación de un programa de fuerza. Esto implica que se pueda valorar el uso de anticonceptivos orales para disminuir esta sintomatología y aumentar el rendimiento tras analizar si el efecto de la carga hormonal exógena no afecta a este tipo de entrenamiento.

Palabras clave: Ciclo menstrual, dismenorrea, entrenamiento de fuerza, entrenamiento de velocidad, potencia producida.

Chapter 1. General Introduction

1.1. Definition of the menstrual cycle.

The menstrual cycle is the result of the sexual maturation in the woman, that promotes the transition from childhood to adulthood. Sexual maturation is determined by an increase in ovarian hormonal concentrations and a development of secondary sexual characteristics, such as the growth of the breasts, genital organs and pubic hair (Isacco, Duché, & Boisseau, 2012).

Regarding hormonal concentrations, it fluctuation leads to menstrual cycle. This is characterized by two distinct phases lasting approximately 14 days: the follicular phase (FP) and the luteal phase (LP). The follicular phase begins with the onset of bleeding (menstruation, MEN) and lasts until the ovulation (OV) process occurs. The luteal phase begins after ovulation and lasts until the onset of the next bleeding (Constantini, Dubnov, & Lebrun, 2005; Isacco, Thivel, Pereira, Duclos, & Boisseau, 2014).

1.1.1. Hormonal changes.

There are several hormones involved in the regulation of the menstrual cycle (Figure 1). The most important hormones are: follicle stimulating hormone (FSH), luteinizing hormone (LH), estradiol (E2) and progesterone (P4) (Oosthuyse & Bosch, 2010). These hormones are divided into two groups:

- Pituitary Hormones (adenohypophysis or pituitary gland). Both FSH and LH are gonadotropic hormones produced by the anterior lobe of the pituitary gland and have effects on the gonads. FSH stimulates follicular cells and the secretion of estrogens; LH favors the maturation of oocytes and the secretion of estrogens and progesterone. During FP there is a gradual increase in FSH, and around the 14th day of the cycle, a peak of LH occurs giving rise to ovulation.

- Gonadal hormones (ovaries). Estrogens (such as 17β-estradiol or E2, which is the most common estrogen in a woman's body), and progestogens (such as progesterone or P4) are two types of steroid hormones secreted by the ovaries. During FP, an increase of E2 occurs, while P4 is kept at low levels. In LP, both E2 and P4 remain high.

The hypothalamic-pituitary-ovarian axis connects both types of hormones. Gonadotrophin-releasing hormones (GnRH) are secreted from the hypothalamus, which in turn stimulate the gonadotropic cells of the adenohypophysis, releasing FSH and LH. These are poured into the bloodstream and perform their actions on the ovaries to stimulate the production of P4 and E2.

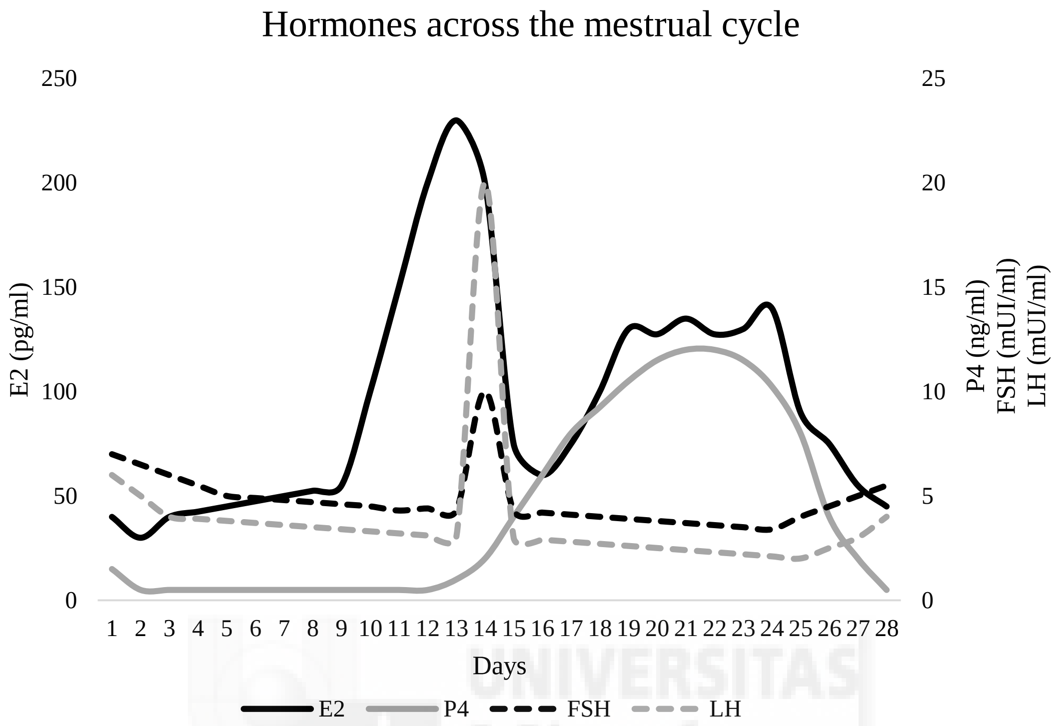

Figure 1. *Fluctuation of the most important hormones through the menstrual cycle* (adapted from Oostehuyse & Bosch, 2010).

E2 = Estradiol; P4 = Progesterone; FSH = Follicle Stimulating Hormone; LH = Luteinizing Hormone.

1.1.2. Determination of the menstrual cycle phases.

To investigate the effects of the menstrual cycle phases on performance, it is fundamental to be able to establish those phases. Janse de Jonge (2003) described four methods to establish the menstrual cycle phases:

- The technique of counting days. It is assumed that the participant has a regular ovulatory menstrual cycle. For this, data from previous cycles are recorded, and days will be counted from the day of onset of bleeding (day 1). The problem with this technique is that FP is much more variable than in the luteal period, so we will certainly not know if ovulation has occurred within 14 days of the start of the menstruation. What is known is that the luteal phase is more stable, so if the next menstruation is recorded, it can be confirmed that a measurement has been performed in the LP if it has been within the last 14 days of the cycle.

- Basal body temperature (BBT) record: The BBT increases approximately 0.3º C after ovulation and is maintained during the LP (Horvath & Drinkwater, 1982; Labour & Marshall, 1963). Thus, by recording the body temperature at the time of rising, it can be detected if ovulation has occurred, and therefore know whether the participant is in the luteal phase.

- Urine LH concentration: It is possible to know the concentration of LH in the urine through an ovulation predictor kit. If a peak of LH is detected, it can be assumed with a confidence level of 95% that ovulation will occur within the next 14-26 hours (Miller & Soules, 1996).

- Progesterone and Estradiol concentrations: Knowing the fluctuation of both hormones during the cycle, it can be known in which phase the participant will be, based on the concentration of these hormones. Concentrations can be obtained by serum or saliva, and the metabolites of both hormones can also be measured in urine.

The determination method used must be kept in mind to compare or interpret results in bibliography.

1.1.3. Menstrual Cycle and Sport: The Hormones Effect.

Estrogens regulate a lot of body functions that can affect exercise tolerance. Some examples of these body functions are the regulation of fat levels, blood glucose levels, insulin sensitivity, salt and water balance, cell proliferation, vascular tone and oxygen levels in cells (Kraemer, Francois, & Castracane, 2012). Estrogens have been shown to increase lipolysis (Constantini et al., 2005; Lebrun, 1993; Oosthuyse & Bosch, 2010) and the production of very low density lipoprotein (VLDL) (Ellis, Lanza-Jacoby, Gow, & Kendrick, 1994; Godsland, 1996) increasing lipid availability as an energy source (Braun & Horton, 2001). In addition, through this enhanced lipid synthesis and improved lipolysis in the muscle, estradiol promotes glycogen uptake and storage in the liver (Constantini et al., 2005; Redman & Weatherby, 2004), tending to save glycogen stores by driving more metabolism towards free fatty acids (FFA) (Redman & Weatherby, 2004). Estradiol increases levels of growth hormone (GH) inducing lipolysis, and progesterone decreases glycogenolysis, which complements the effect of estradiol (Braun & Horton, 2001; Ellis et al., 1994). The fact that less carbohydrate (CHO) and higher lipid are used, was demonstrated during the phase when estradiol and progesterone are high (LP), with an increased endurance performance during this phase due to the availability of fat substrate, which would explain why women have a greater relative ultra-endurance performance compared to men (Constantini et al., 2005; Lebrun, 1993).

On the other hand, it has been demonstrated that estradiol has an anabolic effect against the catabolic effect of progesterone (Constantini et al., 2005; Ekenros, Hirschberg, Heijne, & Fridén, 2013; Fridén, Hirschberg, & Saartok, 2003; McClung, Davis, & Carson, 2007; McClung, Davis, Wilson, Goldsmith, & Carson, 2006; Sakamaki, Yasuda, & Abe, 2012). Myoblasts of skeletal muscle, myotubes and mature fibers express estrogen receptors, which implies that the skeletal muscle is sensitive to estrogen signaling (Kahlert et al., 1997; McClung et al., 2006). Estrogens can regulate the mass of the skeletal muscle in rats (Kobori & Yamakuro, 1889; McClung et al., 2006) and have positive effects on muscle contractile function (Carson & Manolagas, 2015; Enns, Iqbal, & Tiidus, 2008; Enns & Tiidus, 2008)

Associated with muscle atrophy, estrogens can regulate various processes of accumulation and regeneration of skeletal muscle mass such as extracellular matrix remodeling, myofibre regeneration and growth, inflammation or sarcolemma damage (McClung et al., 2006). Based on all these ideas, it could mean that there may be a greater strength gain when estradiol is high and progesterone is low (FP in moments prior to ovulation).

1.2. Performance across the menstrual cycle.

1.2.1. Aerobic endurance.

Due to the metabolic action of estradiol and its interaction with progesterone, we can expect a higher performance of aerobic capacity during the LP. Different authors have corroborated these data, showing an increase in muscle glycogen in this phase (Hackney, Muoio, & Meyer, 2000), decreasing lactate in blood (Bemben, Salm, & Salm, 1995; McCracken, Ainsworth, & Hackney, 1994), or increasing excess post-exercise oxygen consumption (EPOC) and resting metabolic rate, as well as a decrease in post-exercise respiratory exchange rate (RER), suggesting a greater use of fats in LP with respect to FP (Matsuo, Saitoh, & Suzuki, 1999). A recent study also showed a longer time to exhaustion (Tenan, Hackney, & Griffin, 2016). However very few studies have reported changes in maximal oxygen consumption (VO_{2max}) between the phases (Lebrun, McKenzie, C. Prior, & E. Taunton, 1994), compared to a larger number of studies which found that VO_{2max} does not vary between phases (Beidleman et al., 1999; Bemben et al., 1995; Dombovy, Bonekat, Williams, & Staats, 1987; Isacco et al., 2014; Jurkowski, Jones, Toews, & Sutton, 1981). Although there may be differences in different aerobic variables showing a higher performance in LP, these changes do not imply an alteration of VO_{2max} (Constantini et al., 2005; Janse de Jonge, 2003).

1.2.2. Anaerobic capacity.

Among the parameters analysed there are variables such as the mean or peak power output in different tests such as the Wingate test, running test on treadmill or bicycle and jumps, or variables such as peak torque in isokinetic protocols.

The anaerobic capacity is dependent on the anaerobic metabolism, that is to say, the use of phosphagens, anaerobic glucose consumption and the reserves of adenosine tri phosphate (ATP), with an activation of type II fibres (Constantini et al., 2005). Taking into account that estradiol favors the metabolism of lipids, and progesterone decreases glycogenolisis, it could be expected that there would be an anaerobic performance increase when the E2 was low. However, there is controversy regarding the analysis of the variables used to assess anaerobic performance. Some studies have found no differences in anaerobic power in a 20-second maximal cycling sprint test (Wiecek, Szymura, Maciejczyk, Cempla, & Szygula, 2016), 30-second maximum sprint on treadmill (Tsampoukos, Peckham, James, & Nevill, 2010), time to exhaustion in intermittent exercise with sprints of 8 seconds (Giacomoni, Bernard, Gavarry, Altare, & Falgairette, 2000), 15 seconds (Miskec, Potteiger, Nau, & Zebas, 1997) or 20 seconds (Lynch & Nimmo, 1998), neither in a jump test (Fridén, Hirschberg, & Saartok, 2003; Giacomoni et al., 2000), in a Wingate test (Bushman, Masterson, & Nelsen, 2006) or in peak torque in isokinetic muscle strength of the knee flexors (Fridén, Hirschberg, & Saartok, 2003). However, other studies have found better results in FP in anaerobic power in rowers (10-seconds all-out effort) and in anaerobic capacity (1000-m row) (Redman & Weatherby, 2004), and also in different jump tests (Davies, Elford, & Jamieson, 1991; Sipavičiene, Daniusevičiute, Kliziene, Kamandulis, & Skurvydas, 2013; Wikström-Frisén, Boraxbekk, & Henriksson-Larsén, 2015) and in isokinetic peak torque (Wikström-Frisén et al., 2015).

Summarizing, it does not seem clear whether the menstrual cycle could affect the results of different tests to measure anaerobic performance.

1.2.3. Strength.

Estradiol has an anabolic effect (Carson & Manolagas, 2015), in addition, it favors the synthesis of GH (Bernardes & Radomski, 1998; Leung, Johannsson, Leong, & Ho, 2004). Progesterone, however, has the opposite effect, being considered catabolic (Reis, Frick, & Schmidtbleicher, 1995). Therefore, it could be expected that there would be greater strength gains when estradiol is high and progesterone is low.

Some articles support this assumption. A recent study (Wikström-Frisén et al., 2015) found a significant height increase in squat jump (SJ) and in counter-movement jump (CMJ), peak torque values in hamstrings, and mean values of lean body mass (LBM) in legs in the group that trained in FP with respect to LP. Sung et al., (2014) found a greater maximal strength and muscle diameter (Mdm) after the training intervention in FP with respect to LP. Pallavi, Souza, & Shivaprakash (2017) found a greater handgrip strength and lower fatigue rate percentage in FP with respect to MEN and LP. Other studies have found better maximum voluntary contraction (MVC) in FP (Phillips, Sanderson, Birch, Bruce, & Woledge, 1996; Sarwar, Niclos, & Rutherford, 1996; Tenan et al., 2016), and increased overall strength decrease and higher muscle damage parameters (such as Creatine Kinase, CK) in the luteal group (Markofski & Braun, 2014).

However, different studies have found no differences between the phases in the handgrip strength, in the isokinetic muscle leg strength (Fridén, Hirschberg, & Saartok, 2003), in the cross-sectional area (CSA), in the one-repetition maximum (1-RM) and in the MVC of brachial biceps (Sakamaki-Sunaga, Min, Kamemoto, & Okamoto, 2016). In addition, beyond our assumption, Sakamaki et al., (2012) found greater hypertrophy and muscle gain with a blood flow-restricted training in the group that trained in LP. Therefore, the effects of menstrual cycle phases on strength are unclear.

Relative to strength training, there is a new training methodology called velocity-based resistance training (VBRT). This new trend tries to look for the load (1-RM percentage) in which the Maximal Power (P_{max}) is generated in a specific movement (Cormie, Mccaulley, Triplett, & Mcbride, 2007; Dugan, Doyle, Humphries, Hasson, & Newton, 2004; Kawamori et al., 2005; Kawamori & Haff, 2004). This %RM is used to train until the speed declines, trying to minimize the processes of fatigue in the participants. Different methodologies have been used in this type of training: more than 10% speed loss (Fry, 2004), 20% or 40% (Pareja-Blanco et al., 2016). This %RM is known as ‘optimal’ load, trying to find a balance between load and velocity to generate the peak-power. Training with the 'optimal' load provides an effective stimulus to generate improvements in P_{max} for a specific movement (McBide, Triplett-McBride, Davie, & Newton, 2002). There are no studies that have analyzed the effect of menstrual cycle on this training methodology.

1.3. The aim of the thesis and research hypotheses.

The menstrual cycle is divided into two phases. Many authors have focused their study on the comparison of both FP and LP phases, but controversy exists when studying FP. A large majority of authors focused their study on the FP without differentiating the moment of menstruation (MEN) from the rest of the phase. We see that there are authors who talk about "follicular phase" when they are actually collecting their data at the moment of bleeding, and these results have been compared with other studies that were performed in the follicular phase (post-menstruation). For this reason, it is observed that several studies compared FP (not including menstruation) versus LP, missing an important moment of the cycle (in which the hormonal concentration is low) to compare with the rest.

The aim of this thesis is to analyze the effects of menstrual cycle (including MEN phase) in different exercises to evaluate power training and strength.

Three studies were proposed to carry out this Project:

1. Effects of the menstrual cycle on the power output: a pilot study.

2. Could the menstrual hormones affect strength and velocity?

3. The use of Velocity-Based Resistance Training in elite rowers at different menstrual cycle phases affects performance improvements.

The main objectives of each study, with their respective hypothesis (H), were:

1. The aim of the first study was to analyze different power tests including executions at maximum speed in MEN compared to LP using the technique of counting days to determine the phases of the menstrual cycle and to check if the results can be affected by the presence of discomfort associated with the menstruation.

H1: According to Davies et al. (1991), Markofski & Braun (2014), and Redman & Weatherby (2004), better results will be found at the time of bleeding phase (MEN).

H2: Menstrual pain adversely affects test results. In addition, the increase of pain in a specific area (due to dysmenorrhea) affects the exercises in which this area intervenes (Constantini et al., 2005; Fridén, Saartok, Bäckström, Leanderson, & Rendström, 2003).

2. The purpose of the second study was to analyze the action of the MEN, FP and LP in different performance tests that include actions at maximum speed, assuring that the phases are well established through hormonal values, and the interaction of pre-menstrual and menstrual syndrome with these results.

H3: According to Carson & Manolagas (2015), Gleeson & Shalet (2005), Kraemer et al. (2012) and Reis et al. (1995), high concentrations of estradiol and low concentrations of progesterone in FP (moments prior to ovulation) produce a better performance in velocity and strength.

H4: In line with Constantini et al. (2005), Fridén, Saartok, Bäckström, Leanderson, & Renström (2003), and Giacomoni et al. (2000), dysmenorrhoea, bad sleep quality or negative states of moods across de menstrual cycle, negatively affect the performance of velocity and strength.

3. The main purpose of the third study was to analyze the effects after an intervention with a velocity-based resistance training program in FP and LP:

H5: Training in the first two weeks of the menstrual cycle (FP) induces greater improvements in performance compared to training in the last two weeks (LP) in high performance athletes (Pallavi et al., 2017; Reis et al., 1995; Sung et al., 2014; Wikström-Frisén et al., 2015).

H6: According with Pareja-Blanco et al. (2016), velocity-based resistance training is a good method to improve power and strength for female elite rowers, and it also has a transfer to specific demands of the sport.

Chapter 2. Study 1

Effects of the menstrual cycle on the power output: a pilot study.

2.1. Introduction.

The menstrual cycle is divided into two major phases with approximately 14 days of duration: the follicular phase (PF) and the luteal phase (LP) (Constantini et al., 2005; Isacco et al., 2012).

Several studies have analyzed the response of different tests in each phase of the menstrual cycle, trying to know if the performance could change based on the phase. In some sports, like weightlifting, training the maximum strength is essential, but in the majority of sports, performance is strongly marked by the ability to carry out an action or sporting movement in the shortest possible time (McBride, Triplett-McBride, Davie, & Newton, 1999), so the power output is a very important factor (Gabbet, Kelly, & Pezet, 2007). Several authors have shown that the ability to generate higher power leads to an improvement in performance (Baker, Nance, & Moore, 2001a, 2001b; Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004). Therefore, it is important to know whether the phases of the menstrual cycle can affect the power output.

In this line, most articles have focused their analysis on anaerobic power, using different tests such as the Wingate test (Bushman et al., 2006; Masterson, 1999), and several studies have also used jump tests, sprints or isokinetic protocols (Fridén, Hirschberg, & Saartok, 2003; Giacomoni et al., 2000; Lebrun et al., 1994; Redman & Weatherby, 2004; Tsampoukos et al., 2010; Wikström-Frisén et al., 2015). Davies et al (1991) found an increase in the handgrip during bleeding and attributed it to low levels of progesterone (P4) and estrogens (E2). Redman and Weatherby (2004) used two types of oral contraceptives in rowers: one with low doses of E2 and P4, and another with a high dose of both hormones. They found better results in 10-s all-out test and in 1000 m in the group with low hormone concentration (with similar concentrations to menstruation). In addition, Markofski and Braun (2014) found that participants with lower E2 concentrations during the menstrual phase would exhibit a less severe strength decrease, although the opposite hypothesis was considered in that study.

However, no research has been found about the use of the velocity-based resistance training (VBRT) in the strength training sessions close or in the bleeding phase of the menstrual cycle. This concept about weight and the highest possible power output (Castillo et al., 2012) tries to find a balance between the load (% RM) and execution speed. In this way, mechanical power could be defined as the force multiplied by the movement velocity (Knudson, 2009). Even though there is no evidence that the velocity levels may vary acutely depending on the hormonal concentration of each phase of the menstrual cycle, this new training tendency could be a more specific methodology to test the power output and the execution speed during the menstrual cycle, and because of the evidence that there may be a greater performance when the hormonal concentration is low, we hypothesized that there may be better results in the bleeding phase of the menstrual cycle.

There are few articles on the aforementioned that also collect the influence of other causes that could affect the performance, such as the premenstrual syndrome (PMS) and dysmenorrhea. There are many symptoms that encompass premenstrual syndrome (Constantini et al., 2005). Although not all women suffer from it, in some cases their overall performance capacity may be influenced, or even increase the risk of injury (Fridén, Hirschberg, Saartok, & Renström, 2006; Möller-Nielsen & Hammar, 1989). With respect to dysmenorrhea, it affects 45% to 80% of the general female population (Warren & Shangold, 1997). Therefore, it is necessary to know if factors such as sleep, or discomfort associated with menstruation could influence performance.

Therefore, the aim of this study was to analyze different power tests including executions at maximum speed during the phases of the menstrual cycle, and determine whether these phases can contribute to change the velocity levels, obtaining better results in the bleeding phase, and if the results can be affected by the presence of discomfort associated with the menstruation.

2.2. Methods.

2.2.1. Participants

Five women, all physically active and sport science students took part in this study. The inclusion criteria were: they did not suffer from injuries, they showed no hormonal irregularities, they had a regular menstrual cycle, they were non-smokers and they had not used oral contraceptives (OCP) during the last six months. The descriptive data of the sample are shown in table 1.

The study was approved by the university ethical committee and was implemented in accordance with the Declaration of Helsinki. Written informed consent was completed by participants.

Table 1. *Participants descriptive data. Data are shown as Means ± SD.*

n	Age (y)	Body mass (kg)	Height (m)	B.M.I.	Fat mass (%)	Vo2max (ml/kg/min)	Menstrual cycle (days)
Total (n = 5)	20.33 ± 2.58	54.58 ± 6.19	1.69 ± 0.05	21.33 ± 2.75	22.57 ± 5.20	48.71 ± 7.38	31.20 ± 1.82

2.2.2. Procedures

Participants attended four laboratory sessions. The first day included the anamnesis, the menstrual pain questionnaire (Larroy, Crespo, & Meseg, 2001) and the familiarization session. In the familiarization session, the participants carried out all performance tests of the session two and three, in order to familiarize with the protocol and to ensure they had no problems with the execution of the exercises.

In the second and third day, two questionnaires were performed: Karolinska Sleep Diary (SKD) (Torbjörn, Hume, Minors, & Waterhouse, 1994) and Profile of Mood States (POMS) (Fuentes, Balaguer, Meliá, & García-Merita, 1995). After the questionnaires, four performance tests (20 m sprint, Counter Movement Jump (CMJ), parallel half squat and bench press throw) were performed. Thirty minutes after the end of session, the participants completed a Rating of the Perceived Exertion (RPE) using the 12-point Borg scale (0 to 10) (Borg, 1990). This can be seen in the annex 4. Before testing, participants performed a standardized warm up (15 min including aerobic exercise, general mobilization and ballistic exercises).

In these two sessions, the sample was divided into two groups for a counterbalance. The first day of testing was at the time of MEN (n = 3) for one group, and in LP (n = 2) for the other group.

The fourth day included an anthropometry and a maximal oxygen uptake test. The experimental design of the study is shown in figure 2.

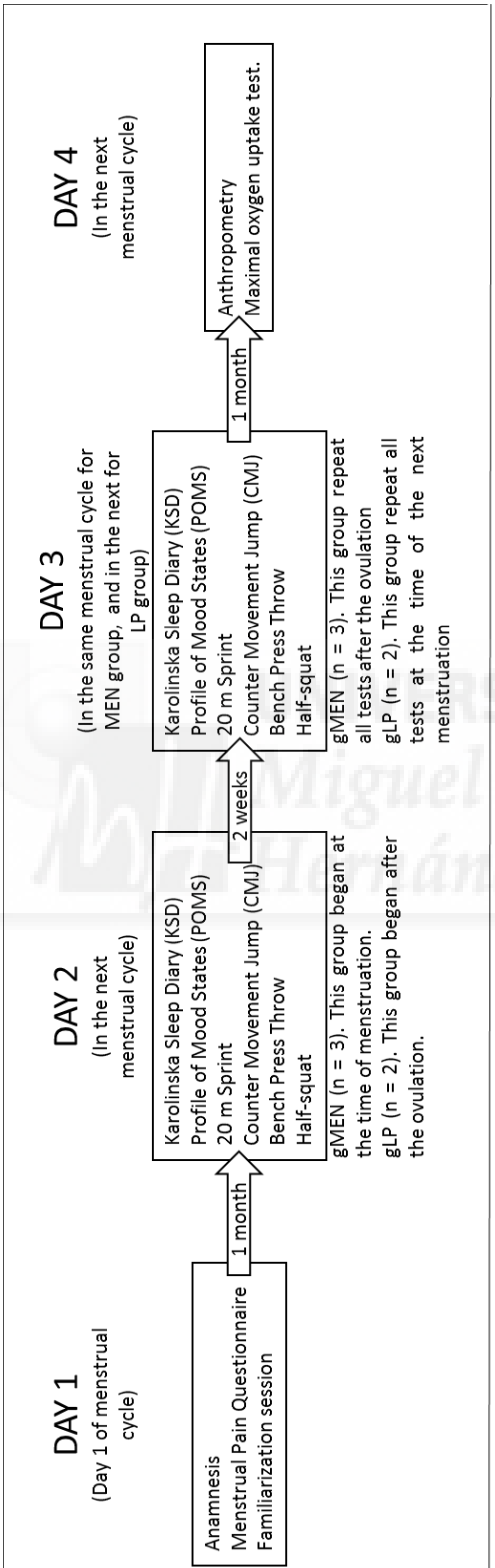

Figure 2. Experimental design for Study 1.

Menstrual cycle determination.

Participants were monitored during the three months prior to the experiment. Menstrual cycle was recorded to be sure it was regular and ovulation was established by the technique of counting days (Janse de Jonge, 2003).The measure in MEN was made 24-48 hours after the onset of menses. The measure in LP was made 18-20 days after the first day of the cycle, and it was confirmed monitoring that the date of the next menstruation was in the next 14 days at most (Janse de Jonge, 2003).

Menstrual pain questionnaire.

This questionnaire about perception of pain during menstruation (annex 1) asked about the most common symptoms throughout the menstrual cycle (Larroy et al., 2001). It included information about different variables grouped into six dimensions: 1) factors that may influence menstrual pain (number of children, years since first menstruation); 2) characterization of menstrual pain (intensity and location of pain, number of painful menses, time of onset of pain); 3) request for professional help due to menstrual pain; 4) symptoms associated with menstrual pain; 5) strategies used to relieve pain (medication and rest); 6) other symptoms and disorders.

The questionnaire consists of 19 questions, nine with two-six options to choose from, depending on the question (discrete variables). Three of these questions are composed of several items (each item corresponds to one symptom), and the participant had to underline all of those symptoms that appeared. For their subsequent analysis, a 0 was used if the symptom was not present, and 1 if it was. In the remaining six questions, the participant had to choose a single possible option. Four of these questions had 2 options (yes or no); one had 4 options (which were transcribed to the database as 0, 1, 2 and 3); and the last one had six options (which were transcribed to the database as 0, 1, 2, 3, 4 and 5).

From the other 10 questions which are about continuous variables, the first three were age, number of pregnancies and number of children. Another of the ten questions was answered using a 0-10 scale, four using a 0-12 scale and the remaining 2 were answered in time (years) since this variable was presented. This questionnaire showed an α-Crombach of 0.99.

Karolinska Sleep Diary (SKD).

This questionnaire (annex 2) consists of 7 questions about the sleep quality of the previous night (Torbjörn et al., 1994). Each question had 5 options. The final score was obtained as the average of the 7 questions. Cervelló et al. (2014) showed an α-Crombach that ranged between 0.66-0.85.

Profile of Mood States (POMS).

The reduced version of 29 items has been used (Fuentes et al., 1995). Each item was answered by scoring 0-4. Those 29 items were grouped into 5 dimensions or profiles (stress, depression, anger, vigour and fatigue). The score for each profile was obtained by adding the scores of all items corresponding to each profile. A t-score for each dimension was calculated using a conversion table. Finally, the profile obtained for the participant is represented (annex 3). This questionnaire showed an α-Crombach of 0.93.

20 m sprint test.

Time during a twenty metre (20 m) straight line sprint was measured by photocell gates placed 1 m above the ground level (Globus, Ergo Timer. Italy). Also, the acceleration during the first five metre (5 m) was recorded. Each sprint was initiated from a standing position, 50 cm behind the photocell gate, which started a digital timer. Each participant performed two maximal 20 m sprints with one minute of passive recovery, and the fastest time in both 5 m and 20 m were registered for the analysis.

Fernandez-Fernandez, Sanz-Rivas, & Moya, (2016) checked the validity and reliability of this test, showing a Intraclass Correlation Coefficient (ICC) value of 0.91 (0.89-0.93) and Moir, Button, Glaister, & Stone, (2004) showed a Coefficient of Variation (CV) value of 1.9%.

CMJ test.

Height, peak force, Ratio of Force Development (RFD), peak power and take off speed was measured. The participant was placed on a piezoelectric force platform (Kistler, Winterthur, Switzerland), in akimbo position, and instructed to vertically jump as high as possible, after a knee flexion to leverage the stretch shortening cycle (SSC). It was recorded during 8 seconds at 1000 Hz. Each participant performed two

CMJ with one minute of passive recovery. This test showed a ICC = 0.95 (0.93-0.97) (Fernandez-Fernandez et al., 2016) and a CV = 2.4 % (Moir et al., 2004).

1-RM for Parallel Half Squat and Bench Press.

Maximal dynamic strength was assessed through an indirect protocol to estimate 1-RM using an isoinertial dynamometer (T-Force Dynamic Measurement System; Ergotech; Murcia, Spain) (González-Badillo & Sánchez-Medina, 2010) and comparing the results using the Brzycki´s formula (Brzycki, 1993). The participants carried out a warm up set of 12 repetitions with 50 % and 20 % of their body weight in parallel half squat and bench press throw respectively. Then, three to four sets (the weight was increased in each set) were performed until the participant could not perform more than 4-6 reps. Between sets, passive recoveries of three to five min. were used to ensure complete recovery.

Both exercises were performed in a Smith machine (Technogym; Cesena FC, Italia), and to standardize the movement, in the bench press throw an anthropometric box (45x35x15 cm) was placed in front of the bench so the participant could support his feet (to prevent lumbar hyperlordosis). To confirm elbow flexion and shoulder abduction of 90 degrees, an elastic band was situated under the bench, and the participant was instructed to touch it in each rep with his elbows. The movement began with the participant holding a barbell with a total extension of his elbows, and the barbell descended until the participant touched the elastic band with the elbows. In the parallel half-squat, the participant was standing with the barbell placed on her shoulders. An elastic band was placed behind the participant so she could touch it with her gluteus during the eccentric phase to ensure a 90-degree knee flexion in each rep.

Maximal Power output test.

Four different 1-RM percentages (30%, 40%, 50% and 60% for supine bench press throw; 40%, 50%, 60% and 70% for parallel half squat) were measured in the concentric portion actions of both exercises using an isoinertial dynamometer (T-Force Dynamic Measurement System; Ergotech; Murcia, Spain). The supine bench press was performed by throwing the bar, and the half-squat was made lifting the heel off the ground (on tip toe). Jumping was not allowed because a high risk of knee injury after the jump cushion with high loads was observed in the familiarization session.

One set of three repetitions was performed with each percentage with a two a minute rest to find the peak-power in each percentage. Instantaneous mechanical power output (P) was calculated as the product of vertical force and barbell velocity ($P = F \cdot V$). Peak-power was taken as the maximum value of the power-time curve (González-Badillo & Sánchez-Medina, 2010).

Maintenance of the optimal velocity test.

Once identified the percentage at which the highest peak-power was obtained (%RM-OP), this load (Kg-OP) was used to perform a set of as many repetitions as possible (Repts-OP) until peak velocity values declined more than 10% for two consecutive repetitions (Fry, 2004). The participants had a visual feed-back system on the laptop screen, provided by the isoinertial dynamometer software (T-Force Dynamic Measurement System; Ergotech; Murcia, Spain), for the velocity achieved in each repetition, in which the green colour meant a correct repetition and the red colour a wrong repetition.

Maximal oxygen uptake (VO_2max) test.

VO_2max was determined during an incremental treadmill running test on a motorized treadmill (Technogym, Run Med). After a three-minute warm-up at 6 $km \cdot h^{-1}$ and a 1% gradient, the treadmill speed was set at 8 $km \cdot h^{-1}$ and increased by 1.5 $km \cdot h^{-1}$ every two minutes while the gradient remained constant, until exhaustion. Gas exchange was continuously measured during the test using a breath-by-breath analyzer (Oxycom, MasterScreenCPX, Jaeger, Germany). The gas-analysis system was calibrated before each test using the manufacturer's recommendations. During the incremental test, the breath-by-breath gas samples were averaged every 15 s and heart rate (HR) was monitored (Oxycom, MasterScreenECG, Jaeger, Germany). To ensure the test was maximal, a plateau in VO_2 (Astorino et al., 2005) and a RER greater than 1.1 (Howley, Bassett, & Welch, 1995) were established in all tests.

Anthropometric test.

Body Max Index (BMI), % Fat Mass, weight and height was determined. Anthropometry was performed by an ISAK 2 technician, taking data of 4 diameters (humerus, wrist, femur and ankle), 12 perimeters (relaxed arm, contracted arm, forearm, wrist, neck, minimum abdominal, hip, 1cm-thigh, mid-thigh, calf, ankle and mesoesternal) and 10 skinfolds (triceps, subscapular, biceps, pectoral, axillary, supracrestal, supraspinal, abdominal, anterior thigh and mid-calf).

2.2.3. Statistical Analysis

Data is presented as mean ± standard deviation (SD). A paired *t*-test was used to find differences between sessions two and three in all variables. Relationships between the performance variables and continuous variables of the questionnaires were calculated using a Pearson´s correlation coefficient (r). The strength of the correlation coefficient was determined on the basis of the classifications outlined by Cohen (1988) in which r = trivial (0.0), small (0.1), moderate (0.3), strong (0.5), very strong (0.7), nearly perfect (0.9), and perfect (1.0). For the discrete variables, an independent t-test was done between groups, using the discrete variable to divide the group and looking for a difference between the means. Statistical signification was set at $p<0.05$.

2.3. Results.

Performance variables.

Significant differences were found between parallel half-squat 1-RM and its calculated %RM, being higher in the session with menstruation (Table 2). No differences were found in any other variable (Table 3 and 4).

Table 2. *Load and power performance in parallel half squat and bench press throw during menstruation and luteal phase. Data are shown as Mean ± SD.*

	Half-squat				Bench press throw			
	Load (kg)		Peak Power (W)		Load (kg)		Peak Power (W)	
	MEN	LP	MEN	LP	MEN	LP	MEN	LP
1-RM	74.6 ± 5.2	69.0 ± 8.2**			33.8 ± 5.6	32.4 ± 5.6		
30%					10.5 ± 1.1	9.5 ± 2.1	169.4 ± 41.7	162.2 ± 48.5
40%	30.7 ± 2.4	27.5 ± 2.5*	377.0 ± 40.8	381.8 ± 79.9	13.5 ± 1.4	12.5 ± 2.5	184.0 ± 38.6	180.2 ± 48.8
50%	37.0 ± 3.3	34.0 ± 4.5*	456.8 ± 42.5	439.2 ± 116.4	16.5 ± 1.4	16.0 ± 3.4	190.8 ± 42.8	191.8 ± 46.2
60%	44.5 ± 3.3	41.0 ± 5.2*	517.6 ± 87.5	491.2 ± 130.9	20.0 ± 2.5	19.0 ± 3.8	187.2 ± 50.5	213.6 ± 83.1
70%	52.0 ± 3.3	49.0 ± 5.8	566.4 ± 102.2	519.0 ± 147.4				

MEN = Menstruation; LP = Luteal phase; *p<0.05; **p<0.01.

Table 3. *Maintenance of the optimal velocity in parallel half squat and bench press throw during menstruation and luteal phase. Data are shown as Mean ± SD.*

	Half-squat		Bench press throw	
	MEN	LP	MEN	LP
%RM-OP	69.73 ± 0.61	68.78 ± 5.09	53.58 ± 5.74	53.20 ± 4.30
Kg-OP	52.00 ± 3.26	47.50 ± 7.07	18.10 ± 2.61	17.20 ± 3.33
Repts-OP	7.40 ± 1.67	6.40 ± 2.19	2.60 ± 0.89	5.00 ± 2.45

MEN = Menstruation; LP = Luteal phase; %RM-OP = %RM of optimal velocity; Kg-OP = Kg of optimal load; Repts-OP = Repetitions within optimal velocity.

Table 4. *20 m sprint and CMJ performance during menstruation and luteal phase. Data are shown as Mean ± SD.*

	MEN	LP
5 m (s)	1.360 ± 0.092	1.346 ± 0.078
20 m (s)	3.762 ± 0.223	3.722 ± 0.170
Height CMJ (m)	0.238 ± 0.049	0.245 ± 0.053
Peak force CMJ (BW)	2.262 ± 0.286	2.159 ± 0.307
RFD_{max} CMJ (BW/s)	23.737 ± 7.039	21.694 ± 4.604
Peak power CMJ (W/Kg)	40.463 ± 5.976	41.032 ± 7.212
Take-off speed CMJ (m/s)	2.150 ± 0.226	2.181 ± 0.238

MEN = Menstruation; LP = Luteal phase; CMJ = Counter-Movement Jump.

Questionnaire variables.

Significant differences were found in Vigour (p = 0.016) across the cycle (Figure 3). No differences were found in any other profile, or KSD (MEN = 3.40 ± 0.39, LP = 3.68 ± 0.07; p = 0.153), neither in RPE (MEN = 6.20 ± 2.49, LP = 5.60 ± 2.07; p = 0.761).

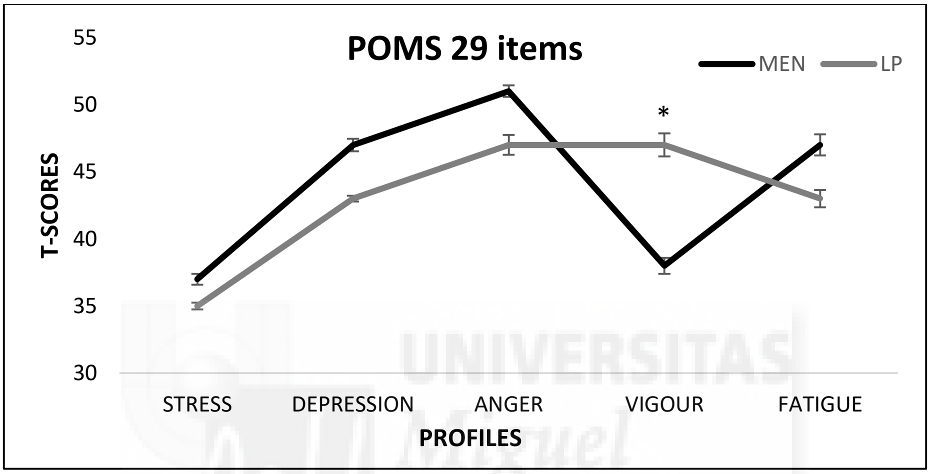

Figure 3. Differences between menstruation and luteal phase in POMS. Data are shown as mean ± SD. MEN = Menstruation; LP = Luteal Phase; *p<0.05.

Analyzing the discrete variables, only two differences were obtained. When dividing the group according to whether they answered that their menstruation was painful or not, the group that answered that they presented pain (n = 2), obtained a worse result in the bench press throw in the LP with respect to the group that did not present pain (n = 3). The variables that obtained significant differences were represented in the table 5a.

The other discrete variable in which differences were found when dividing the group was in low back pain. The participants which showed low back pain (n = 3), obtained a worse result in the parallel half squat in both MEN and LP. The variables in MEN and LP were represented in table 5b.

In the rest of the test there were no differences when dividing the group based on any discrete variable.

Table 5a. *Differences due to menstrual pain in each phase of the menstrual cycle. Data are shown as Mean ± SD.*

EXERCISE	PHASE	SYMPTOM	1-RM	W at 30% RM	Kg at 40% RM	Kg at 50% RM	Kg at 60% RM
Bench Press	MEN	MP (n = 2)	32.0 ± 2.83	147.5 ± 13.4	12.5 ± 0.00	16.3 ± 1.8	18.8 ± 1.8
		No MP (n = 3)	35.0 ± 3.46	184.0 ± 50.9	14.2 ± 1.4	16.7 ± 1.44	20.8 ± 2.9
	LP	MP (n = 2)	26.5 ± 0.7	115.0 ± 14.1	10.0 ± 0.0	12.5 ± 0.0	15.0 ± 0.0
		No MP (n = 3)	36.3 ± 2.1 **	193.7 ± 30.0 *	14.2 ± 1.4 *	18.3 ± 1.4 *	21.7 ± 1.4 **

MEN = Menstruation; LP = Luteal Phase; MP = Menstrual Pain; No MP = No Menstrual Pain; *p<0.05; **p<0.001.

***Table 5b**. Differences due to low back pain in each phase of the menstrual cycle. Data are shown as Mean ± SD.*

EXERCISE	PHASE	SYMPTOM	1-RM	W at 40% RM	Kg at 40% RM	W at 50% RM	Kg at 50% RM	Kg at 60% RM	Kg at 70% RM	Kg-OP
Paralell Half-Squat	MEN	LBP	71.3 ± 3.8	348.3 ± 13.5	29.2 ± 1.4	427.0 ± 13.0	35.0 ± 2.5	42.5 ± 2.5	50.0 ± 2.5	50.0 ± 2.5
		No LBP	79.5 ± 0.71	420.0 ± 11.3 **	33.0 ± 0.7 *	501.5 ± 14.9 **	40.0 ± 0.0	47.5 ± 0.0	55.0 ± 0.0	55.0 ± 0.0
	LP	LBP	63.3 ± 3.5	358.0 ± 33.5	25.8 ± 1.4	365.0 ± 58.9	30.8 ± 1.4	37.5 ± 2.5	45.0 ± 2.5	42.5 ± 2.5
		No LBP	77.5 ± 0.7 *	417.5 ± 137.9	30.0 ± 0.0 *	550.5 ± 77.1	38.8 ± 1.7 *	46.3 ± 1.4 *	55.0 ± 0.0 *	55.0 ± 0.0 **

MEN = Menstruation; LP = Luteal Phase; LBP = Low Back Pain; No LBP = No Low Back Pain; *p<0.05; **p<0.001.

Regarding continuous variables, no correlations were found with the bench press, nor in the 20 m sprint test. In parallel half squat, Vigour in MEN was correlated with W at 60% RM in MEN (.892*); and Vigour in LP was correlated with: 1-RM in LP (.899*), Kg at 50% RM in LP (.944*), W at 50% RM in LP (.962**), Kg at 60% RM in LP (.934*), W at 60% RM in LP (.956*) and W at 70% RM in LP (.919*). In CMJ, correlations were found in vigour in LP with: height in LP (.913*), take-off speed in LP (.899*), peak force in LP (.957*), and RFD in LP (.916*).

2.4. Discussion and Conclusion.

The main objective of this study was to analyze power and strength throughout menstrual cycle. It is important to know if there are variations during the menstrual cycle in those variables we use to define training loads and competition calendar. 1-RM is essential to establish percentages that determine manifestation of strength, and therefore if 1-RM varies, relative loads must be adjusted. In our study, according to our hypothesis we found an increase of 1-RM in parallel half-squat in the MEN, and therefore in all percentages. 1-RM in bench press was also higher during the MEN, but not significant, showing a trend that can mobilize more kg during this phase. In the same line as our results, different studies found better responses at the time of menstruation (Davies et al., 1991; Markofski & Braun, 2014; Redman & Weatherby, 2004).

However, different authors found that the MVC increases during FP, right in the moments before ovulation, coinciding with high levels of estradiol (Phillips et al., 1996; Sarwar et al., 1996) and several authors have shown that estrogens had a positive effect on muscle contractile function in rats (Enns et al., 2008; Enns & Tiidus, 2008).

Regarding maximal power test, we found that the P_{max} was within the established ranges (Castillo et al., 2012). These ranges were 60-70% RM for the half squat, and 50-60% RM for the bench press. In our study, the 'optimal load' was acutely evaluated to know if the phase of the menstrual cycle may affect the percentage of 1-RM in which the P_{max} was achieved and the number of repetitions performed within the range of maximum velocity execution. Despite finding differences in 1-RM, power data in each %RM was unchanged. This was probably because the change in the 1-RM was very small, so the difference in the load was not so great as to produce a significant power increase, so this test could be performed at any time of the menstrual cycle.

Jump and sprint showed no differences either. These data were in accordance with literature. Several studies have not found differences in power tests as the Wingate (Bushman et al., 2006) or tests to determine maximum power in cycle ergometer (Giacomoni et al., 2000); neither in tests to determine different performance variables collected during sprints, such as fatigue index, anaerobic power, peak power, average power, peak speed, average speed or time to exhaustion (Isacco et al., 2012; Lynch & Nimmo, 1998; Miskec et al., 1997; Tsampoukos et al., 2010) nor variables as height, distance or maximal jump power in multi-jump or jumping tests (Fridén, Hirschberg, & Saartok, 2003; Giacomoni et al., 2000).

In line with other studies (Miskec et al., 1997; Stephenson, Kolka, & Wilkerson, 1982), RPE remained unchanged between sessions of the different phases of the menstrual cycle. There were no changes in KSD neither. The vigour (one of five dimensions of POMS) changed between phases, decreasing during the menses. In a review, Lebrun (1993) reported that many of the women studied associated premenstrual and menstrual symptoms with a loss in performance. In our study, the menstrual pain questionnaire asked the participants to rate on a scale of 0 to 10 which was her pain in the last menstruation, with a score of 4.5 ± 2.35 (coinciding with menstruation in which the data were collected), and they reported that during the 12 periods of the year, 4.17 ± 1.94 were painful. Probably the loss of vigour was due to their feelings of discomfort, although curiously it occurred when 1-RM was higher. It was possible that the participant's perception of pain does not interfere with strength development, and the decrease in concentration of hormones in the bleeding phase may lead to increased performance.

Taking into account the discomfort or pain associated with menstruation, in our study different correlations were found between malaise variables and test results. In this line, Giacomoni et al. (2000) suggested that the presence of pre-menstrual syndrome (PMS) and menstrual symptoms could have a negative effect on performance, and Möller-Nielsen and Hammar (1989) showed that women playing soccer with PMS had an increased risk of injury. In addition, different authors (Constantini et al., 2005; Möller-Nielsen & Hammar, 1989) suggested that the use of oral contraceptives may exert a beneficial effect on performance, since these reduce PMS and dysmenorrhea. Agreeing with this, some questionnaire variables (such as painful menstruation or low back pain) showed a negative correlation in the bench press and in the parallel half squat respectively. Painful menstruation causes a drop in performance in the bench press throw during LP. During MEN, the results of the group with pain were also worse, although not significant. It was observed that there was a difference between these two groups, showing better results in the group that did not have pain. But the most important thing was that when comparing the means of both groups (pain and not pain) with their results in MEN, it was observed that the group that did not have pain, presented a very similar RM in both MEN and LP phase respectively (35.0 ± 3.46 VS 36.3 ± 2.08), while the pain group decreased from 32.0 ± 2.83 kg to 26.5 ± 0.70 kg. This difference was not significant, although it was probably due to the fact that the sample was very small, but it could be said that the group that had pain presented a decrease in performance, while the group that did not present pain had stable results during the menstrual cycle in bench press.

In addition, it was found that low back pain affected performance in the parallel half squat, both in MEN and LP. One of the main symptoms associated with dysmenorrhea is low back pain (Al-Jefout et al., 2015; Constantini et al., 2005). The same trend as in the bench press was found in this exercise it. The group that had low back pain had worse results in MEN and LP, but also presented a decrease in 1-RM from 71.33 ± 3.75 to 63.33 ± 3.51, while the group that did not have pain had a similar value in 1-RM (79.5 ± 0.71 VS 77.50 ± 0.71). It was observed that there was a fall in performance in the squat and in the bench press when the group was analyzed as a whole, but when the group was separated according to different painful variables, this decrement was only observed in the pain group, so this tendency of decrement in 1-RM in LP in both exercise, could be explained by greater sensations of discomfort during this phase. In addition, vigour in LP (which increased with respect to values in MEN) correlates with 1-RM, Kg and watts in parallel half squat in LP. Even so, probably the negative effects of the discomforts discussed above contributed more to the decline in performance than the increase in vigour.

These data should be treated with caution because there were two major limitations in our study. The sample was very small and there were no hormonal data to confirm the cycle phases. Maybe the differences found in the 1-RM were due to the intra-participant variation or the feelings of discomfort commented, and not caused by a difference in the concentration of hormones, since differences were not found in any other test.

In conclusion, 1-RM varies through the menstrual cycle, but there were no differences in power and velocity related variables. In addition, our results support the idea that menstrual symptoms may determine the subjective perception of the performance in women, and in some cases these symptoms might adversely affect athletic performance, or conversely, they feel discomfort but this discomfort does not really affect their results.

For future research, it would be necessary to include measurements at more times of the menstrual cycle and to corroborate the phase of the menstrual cycle by hormonal data.

Chapter 3. Study 2

Could the menstrual hormones affect strength and velocity?

3.1. Introduction

During the menstrual cycle in eumenorrheic women, there is a hormonal fluctuation. Progesterone (P4) and Estradiol (E2) are the most important of these hormones, and their fluctuation determine two phases: Follicular Phase (FP) which begins with menstruation (MEN), and Luteal Phase (LP), both being separated by the time of ovulation (OV) (Constantini et al., 2005; Isacco et al., 2012; Oosthuyse & Bosch, 2010).

Different studies have analysed the biological effects of these hormones, showing that estrogen can influence the cardiovascular system and substrate metabolism. Progesterone seems to affect thermoregulation, ventilation and energy substrate. (Constantini et al., 2005). Related with exercise, the menstrual cycle could affect the maximum oxygen uptake (VO_2max) since E2 and P4 cause effects in the availability of fuel, oxygen transport system and ventilation (Janse de Jonge, 2003), and therefore it produces a better performance in endurance exercise during LP (Lebrun, 1993).

The effect of these hormones in different manifestations of resistance training has also been studied. Some steroid hormones such as testosterone, promote size, maintenance of muscle mass and exert beneficial effects on metabolic function of skeletal muscles. In addition, estrogens have a positive effect on muscle contractile function (Carson & Manolagas, 2015), and affect the release of growth hormone (GH) (Kraemer et al., 2012). Several authors (Gleeson & Shalet, 2005; Juul et al., 1997) have shown a positive correlation between GH and E (just prior to ovulation, and during the LP). That means estrogen could be an anabolic influence for the muscle, while progesterone may have a catabolic effect (Reis et al., 1995). Therefore, an increased performance during the days prior to ovulation could be expected, due to high levels of estradiol. In fact, maximum voluntary contraction (MVC) seemed to be affected by hormonal cycle, increasing during FP (Phillips et al., 1996; Sarwar et al., 1996). However, a recent study showed that muscle hypertrophy was not strongly affected by hormonal variations that occurred during the cycle (Sakamaki-Sunaga et al., 2016), so the effect of menstrual cycle on strength is unclear.

In relation to other types of strength manifestations and their relation to the menstrual cycle, there are some studies that have focused on the analysis of power (Giacomoni et al., 2000; Wikström-Frisén et al., 2015), although none of them focused on the analysis of mechanical velocity maintenance and whether the phases of the menstrual cycle could affect it. In most sports, performance is strongly marked by the athlete's ability to perform movements in the shortest possible time (Baker et al., 2001a; Sleivert & Taingahue, 2004; Tonnessen, Shalfawi, Haugen, & Enoksen, 2011), hence power output is a key element for training, and therefore new research trends arise focusing on this term. Velocity-based resistance training (VBRT) is a new training trend based on the ‘optimal load’, that is, the load with which the participant is able to generate the P_{max}, with an optimal number of repetitions in each set so that velocity does not decline more than 5-10%, and with a recovery that could maximize the training result, so that optimal volume, intensity and density were controlled individually for each participant (Cormie, McGuigan, & Newton, 2011; Kawamori & Haff, 2004). However, we did not find studies focusing on this method of training and if it would be necessary to adjust it according to the hormonal load of the menstrual cycle phases. Our research group conducted a pilot study on this area (Study 1) analyzing only the bleeding phase and the luteal phase in different tests that have to be executed at maximum speed, but no differences were found.

In our previous study the phases were not detected by hormonal analysis. However, the best way to corroborate the phases of the cycle is through hormonal analysis (Janse de Jonge, 2003), and therefore to be able to know exactly if there was a relationship between the performance obtained in the test and the phase in which the participants were performing them. Therefore, it is necessary to measure performance at MEN, FP and LP, and to analyze the moments in which both hormones E2 and P4 are low, E2 is higher than P4, and finally the phase in which both are high.

Due to the action of estradiol on muscle contraction previously mentioned, we think that better results will be found in moments in which this hormone is high (FP). Therefore, the purpose of our study was to analyze the acute action of the three most important phases of the menstrual cycle in different performance tests that include actions at maximum speed, assuring that the phases are well established through hormonal values.

3.2. Methods.

3.2.1. Participants

Eighteen women, all physically active and involved in collective sports, took part in this study. All trained 3 days per week, with a two-hour length per training session. At the weekend, they carried out the competition or an extra training.

For the inclusion, it was required that they did not suffer from injury, they showed no hormonal irregularities, they had a regular menstrual cycle, they were non-smokers and they had not used oral contraceptives (OCP) during the last six months. It was indicated that they continued their usual diet and did not take caffeine on the day of the tests or on the day before. The descriptive data of the sample are shown in table 6.

Written informed consent was obtained from the participants before the investigation. The present study was approved by the institutional research ethics committee of the University, and conformed to the recommendations of the Declaration of Helsinki.

Table 6. *Participants descriptive data. Data are shown as Mean ± SD.*

n	Age (y)	Body mass (kg)	Height (m)	B.M.I.	Fat mass (%)	Vo2máx (ml/kg/min)	Menstrual cycle (days)
Total (n = 18)	22.78 ± 3.80	60.99 ± 8.97	1.64 ± 0.09	22.57 ± 1.33	17.95 ± 3.53	49.07 ± 5.74	29.14 ± 3.12

3.2.2. Procedures

Each participant performed five laboratory sessions. The first day, there was a questionnaire in which the participant had to answer about her menstrual history (menstrual pain questionnaire), a general anamnesis and the familiarization session, in which the participants performed all the tests (the same test that they would do in session two, three and four) in order to learn the protocol.

In the second, third and fourth sessions, two questionnaires were made: Karolinska Sleep Diary (KSD) and Profile of Mood States (POMS). After this, four performance tests (20 m sprint, Counter Movement Jump (CMJ), parallel half squat and bench press throw) were performed. Thirty minutes after the end of the session, the participants answered a Rating of the Perceived Exertion (RPE), using the 0-10 Borg-scale (Borg, 1990). This can be seen in the annex 4. Before the tests, participants performed a standard warm-up (15 min including aerobic exercise, general mobilization and ballistic exercises).

In these three sessions, the sample was counterbalanced into 3 groups. The first day of measurement was at a different time for each group: group MEN (gMEN, n = 6) started during menstruation. Group FP (gFP, n = 6) and group LP (gLP, n = 6) started during the follicular phase and the luteal phase respectively. In order to control that the effects of their usual training did not interfere with our results, the study was performed at a time of the season in which they did not have to improve the maximum strength, and their strength training was limited to train the specific and preventive strength. In their training sessions, twenty minutes were used for general warm-up, thirty minutes in preventive training and specific strength, and one hour of strategic and tactical skills that included general fitness. The remaining ten minutes were used for the final stretching. Counterbalance also blocked the training interference.

The fifth day included an anthropometry and a maximal oxygen uptake. The experimental design is shown in figure 4.

Determination of the menstrual cycle.

Participants were monitored for three months before starting the first measurement to ensure they had a regular menstrual cycle. To confirm the phases, saliva samples were collected in order to establish the concentration of progesterone in each phase, and it was analyzed using an ELISA kit (Salivary Progesterone ELISA kit from Salimetrics Assay (1-1502)). In addition, 3 days before ovulation was predicted (according to data from previous cycles), the participants began to use a luteinizing hormone (LH) KIT in urine every day, until the time of ovulation was identified. The reagent sensibility was 20 mIU/ml. Measurement in MEN was made within 1-4 days after the onset of menses; the FP was made between 10-12 days after the first day of the cycle (depending on whether the cycle was more or less long); and LP was done 7-9 days after the ovulation. Descriptive data about the times of the measurement in each phase and progesterone in each of them are shown in Table 7.

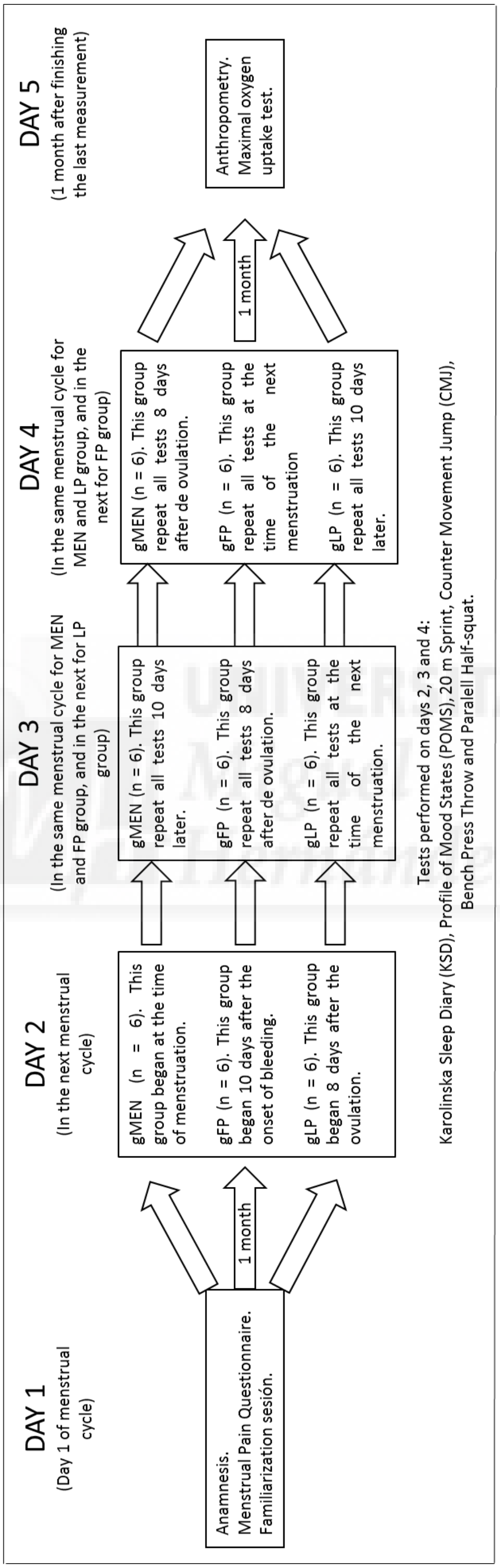

Figure 4. Experimental design for Study 2.

Table 7. *Menstrual cycle descriptive data. Data are shown as means ± SD.*

n = 18	MEN	FP	OV	LP
Time (days)	2.78 ± 1.26	11.33 ± 1.19	16.44 ± 3.36	24.89 ± 3.51
Progesterone (pg/ml)	92.81 ± 60.43*#	73.91 ± 46.52 ƚ	-	174.05 ± 115.72

Time was shown as days after bleeding appears. MEN = Menstruation; FP = Follicular Phase; OV = Ovulation; LP = Luteal Phase; * Significant difference between MEN and FP. # Significant difference between MEN and LP. ƚ Significant difference between FP and LP.

Menstrual pain questionnaire (Larroy et al., 2001).

This questionnaire provides information of different feelings of discomfort caused by menstruation (annex 1). It includes variables that were grouped in 6 dimensions: 1. factors that may influence menstrual pain (number of children, years since first menstruation); 2. characterization of menstrual pain (intensity and location of pain, number of painful menses, time of onset of pain); 3. request for professional help due to menstrual pain; 4. symptoms associated with menstrual pain; 5. strategies used to relieve pain (medication and rest); 6. other symptoms and disorders.

The questionnaire consists of 19 questions. Nine were discrete variables with 2-6 options to choose from, depending on the question. Three of these questions are composed of several options (each option corresponds to one symptom), and the participant had to underline all of those symptoms that were presented. For their subsequent analysis, a 0 was used if the symptom was not present, and 1 if it was. In the remaining six questions, the participant had to choose a single possible option. Four of these questions had 2 options (yes or no); one had 4 options (which were transcribed to the database as 0, 1, 2 and 3); and the last one had six options (which were transcribed to the database as 0, 1, 2, 3, 4 and 5).

From the other 10 questions which are about continuous variables, the first three were age, number of pregnancies and number of children. Another of the ten questions was answered using a 0-10 scale, four using a 0-12 scale and the remaining 2 were answered in time (years) since this variable was presented. This questionnaire showed an α-Crombach of 0.99.

Karolinska Sleep Diary (KSD) (Torbjörn et al., 1994).

This questionnaire consists of 7 questions about the quality of sleep the previous night. Each option had 5 answers, and the final score was obtained by averaging the 7 questions (annex 2). Cervelló et al, (2014) showed an α-Crombach that oscillated between 0.66-0.85.

Profile of Mood States (POMS) (Fuentes et al., 1995).

The reduced version of 29 items was used. All items were grouped into five profiles (stress, depression, anger, vigour and fatigue). The score for each profile was obtained by the addition of the scores of each item that make up each profile, and then a t-score was calculated using a conversion table. The abbreviated form of 29 items explains 92.9% of the total variance of the complete questionnaire (58 items), reducing the number of items by half, making it easier for the participants (annex 3). This questionnaire showed an α-Crombach of 0.93.

20 m sprint test.

Twenty meters (20 m) in straight line, and acceleration during the first five meters (5 m) were measured by photocells (Globus, Ergo Timer; Italy) placed on the ground. Each sprint was initiated with the participant positioned 50 cm behind the photocell in the standing position. Two maximal sprints were performed with one minute of passive recovery, and the fastest time of both 5 m and 20 m were collected. The validity and reliability of this test have been previously established, with a Intraclass Correlation Coefficient (ICC) value of 0.91 (Fernandez-Fernandez et al., 2016) and a Coefficient of Variation (CV) value of 1.9% (Moir et al., 2004).

CMJ test.

Height, peak force, RFD, peak power and take-off speed were measured. The participant was placed on a piezoelectric forces platform (Kistler, Winterthur, Switzerland) in akimbo position, and was instructed to jump as high as possible after performing a knee flexion. The jump was recorded for 8 seconds at 1000 Hz. Each participant performed two CMJ with one minute of passive recovery. The best jump data was collected. Moir et al (2004) showed a ICC = 0.93 and a CV = 2.4 % in this test.

1-RM for Parallel Half Squat and Bench Press.

The maximum dynamic force was measured using an indirect protocol to estimate 1-RM using an isoinertial dynamometer (T-Force Dynamic Measurement System; Ergotech; Murcia, Spain). The isoinertial dynamometer measures the velocity at which the bar was being displaced. González-Badillo & Sánchez-Medina (2010) analyzed the loads of 30-100% 1-RM with increments of 5%, showing that there was a change between 0.07 and 0.09 $m \cdot s^{-1}$ in each relative load. That is, when the participant increased the mean velocity of propulsive phase (MVP) between 7 - 9 hundredths in a relative load, an improvement of 5% in the value of the absolute load (1-RM) can be estimated. According to this, 1-RM was estimated using the isoinertial dynamometer, and then the result was compared with the Brzycki formula (Brzycki, 1993).

The participants started the test with one warm-up series of twelve repetitions with 50% and 20% of their body weight for the parallel half squat and bench press respectively. Then, three to four sets were carried out, increasing the weight mobilized in each series, until the participant could not perform more than four to six repetitions. A passive recovery of three to five minutes between sets was used.

Both exercises were performed on a Smith machine (Technogym; Cesena FC, Italia). In the bench press, the movement was standardized by placing an anthropometric box (45x35x15cm) in front of the bench, so the participant could support his feet and avoid lumbar hyperlordosis. In addition, an elastic band was placed under the bench, and the participant was instructed to touch it with her elbows in each repetition, ensuring a 90-degree of elbow flexion and shoulder abduction. The movement began with the participant holding the barbell with her elbows extended, and she lowered the barbell until she touched the elastic band with her elbows. In the half squat, the participant started standing with the barbell placed on her shoulders. For this exercise, the elastic band was placed behind the participant in order to touch it with her gluteus ensuring a 90-degree knee flexion. The elastic band was placed individually for each participant depending on her leg length.

Maximal Power output test.

Four percentages of the 1-RM (40%, 50%, 60% and 70% for parallel half squat; and 30%, 40%, 50% and 60% for bench press throw) were measured in the concentric phase of both exercises using an isoinertial dynamometer in a Smith Machine. The bench press was performed by throwing the barbell to achieve the highest possible speed, and the parallel half squat was done lifting the heels of the floor (until standing on tip toe). The parallel half squat was performed without a jump since in the pilot study a great risk of knee injury after cushioning the fall with high loads was observed.

One set of three repetitions was performed for each percentage to find the peak-power (Baker et al., 2001a, 2001b). A two-minute passive recovery between sets was made. Instantaneous mechanical power output (P) was calculated as the product of vertical force and barbell velocity (P = F · V). Peak-power was taken as the maximum value of the power-time curve. González-Badillo & Sánchez-Medina, (2010) checked the validity and reliability of this system, showing ICC values ranging from 0.81 to 0.91 and a CV < 3.6%.

Maintenance of the optimal velocity test.

Once the percentage in which a higher peak-power was found (%RM-OP), a single set was performed with this load (Kg-OP) in order to perform as many repetitions as possible (Repts-OP) until the velocity dropped by 10% during two consecutive repetitions. The participants had a visual feed-back system on the laptop screen, provided by the isoinertial dynamometer software, for the power achieved in each repetition, in which the green colour meant a correct repetition and the red colour an incorrect repetition. Then, the repetition in which there was a higher peak-power (P_{max}) and peak-velocity (V_{max}) was searched for, and the average of the mean-power (MPP) and mean-velocity (MPV) of the propulsive phase (in those repetitions that were within the range of optimal speed) were calculated.

Maximal oxygen uptake (VO_2max) test.

VO_2max was determined during an incremental treadmill running test on a motorized treadmill (Technogym, Run Med). After a three-minute warm-up at 5 km·h^{-1} and 1% gradient, the treadmill speed was set at 6 km·h^{-1} and increased by 1.5 km·h^{-1} every two minutes while the gradient remained constant, until 15 km·h^{-1}. From that point on, the speed remained constant and the gradient was increased by 1.5 degrees every two minutes until exhaustion. Gas exchange was continuously measured during the test using a breath-by-breath analyzer (Oxycom, MasterScreenCPX, Jaeger, Germany). The gas-analysis system was calibrated before each test using the manufacturer's recommendations. During the incremental test, the breath-by-breath gas samples were averaged every 15 s and HR was monitored (Oxycom, MasterScreenECG, Jaeger, Germany). To ensure the test was maximal, a plateau in the VO2 (Astorino et al., 2005) and a RER greater than 1.1 (Howley et al., 1995) were established in all tests.

Anthropometric test.

Body Max Index (BMI), % Fat Mass, weight and height were determined. Anthropometry was performed by an ISAK 2 technician, taking data of 4 diameters (humerus, wrist, femur and ankle), 12 perimeters (relaxed arm, contracted arm, forearm, wrist, neck, minimum abdominal, hip, 1cm-thigh, mid-thigh, calf, ankle and mesoesternal) and 10 skinfolds (triceps, subscapular, biceps, pectoral, axillary, supracrestal, supraspinal, abdominal, anterior thigh, mid-calf).

3.2.3. Statistical Analysis

Data are presented as mean ± standard deviation (SD). Data were analyzed to determine their practical significance using magnitude bases inferences (MBI). This method contemplates a new trend of data analysis based on the use of confidence intervals to calculate the probability that a difference was significant. The threshold of inferences was set at 0.35, which according to Rhea (2004), was the value assigned for the analysis of strength data. Subsequently, the probability that any change in performance was greater / similar / lower between menstrual cycle phases, and between groups divided according to discrete variables of the questionnaires, was calculated with its 90% confidence limits (CL). The qualitative probability was assigned by the following quantitative chances: < 0.5%, most unlikely; 0.5% to 5%, very unlikely; 5% to 25%, unlikely; 25% to 75%, possibly; 75% to 95%, likely; 95% to 99.5%, very likely; and >99.5%, most likely. In addition, the clinical inference was represented as unclear, trivial, beneficial or harmful (Batterham & Hopkins, 2006). Beneficial or harmful are related with change direction, and not necessarily with positive or negative effects.

Relationships between the performance variables and variables of the questionnaires were calculated using a Pearson´s correlation coefficient (r). The strength of the correlation coefficient was determined on the basis of the classifications outlined by Cohen (1988) in which r = trivial (0.0), small (0.1), moderate (0.3), strong (0.5), very strong (0.7), nearly perfect (0.9), and perfect (1.0). Statistical signification was set at $p < 0.05$.

3.3. Results.

Performance variables.

When the MBI was used analysing the whole group, only differences in V_{max} and MPV in the maintenance of the optimal velocity test between the 3 moments of the menstrual cycle were found (Table 8).

However, when dividing the group according to the discrete variables of the questionnaires, two major differences were found: the group with low back pain (LBP; n = 7) presented worse results (Figure 5a, 5b and 5c) in almost all the variables of the parallel half squat, the linear sprint and the CMJ regarding the group that did not have that annoyance (No LBP; n = 11); and the group that showed breast pain (BP; n = 6) had worse results (Figure 6a, 6b and 6c) in the bench press throw variables, compared to the non-painful group (No BP; n = 12). Each group showed no internal differences throughout the three measurements of the menstrual cycle.

Table 8. *Inferences between the 3 phases in the velocity variables of the maintenance of the optimal velocity test in all groups.*

VARIABLE	Mean ± SD in MEN	Mean ± SD in FP	MEN with FP: Standardized difference (90% C.L.)	MEN with FP: Chances	MEN with FP: Clinical difference
MPV in Parallel Half Squat	0.497 ± 0.05	0.513 ± 0.05	0.31 (0.12 ± 0.74)	67/30/3	Possibly Harmful
V_{max} in Bench Press Throw	0.988 ± 0.11	1.047 ± 0.13	0.49 (-0.01; 0.99)	84/15/1	Likely Harmful
	Mean ± SD in MEN	**Mean ± SD in LP**	**MEN with LP: Standardized difference (90% C.L.)**	**MEN with LP: Chances**	**MEN with LP: Clinical difference**
MPV in Parallel Half Squat	0.497 ± 0.05	0.498 ± 0.08	-0.03 (-0.72; 0.63)	27/39/35	Unclear
V_{max} in Bench Press Throw	0.988 ± 0.11	1.039 ± 0.12	0.44 (-0.07; 0.94)	79/19/2	Likely Harmful
	Mean ± SD in FP	**Mean ± SD in LP**	**FP with LP: Standardized difference (90% C.L.)**	**FP with LP: Chances**	**FP with LP: Clinical difference**
MPV in Parallel Half Squat	0.513 ± 0.05	0.498 ± 0.08	0.36 (0.30; 1.01)	8/26/66	Possibly Beneficial
V_{max} in Bench Press Throw	1.047 ± 0.13	1.039 ± 0.12	-0.06 (-0.43; 0.46)	4/59/27	Possibly Beneficial

MEN = Menstruation; FP = Follicular Phase; LP = Luteal Phase; MPV = Mean Propulsive Velocity.

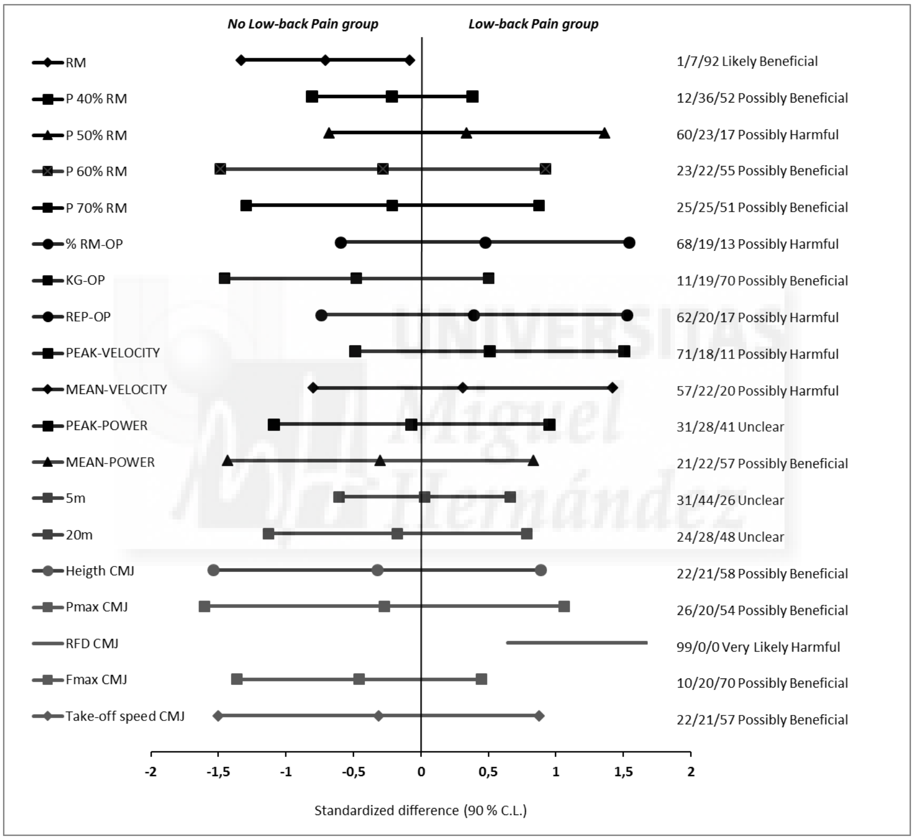

Figure 5a. Inferences between the low back pain group and the non-low back pain group in MEN phase in parallel half-squat, 20 m and CMJ.

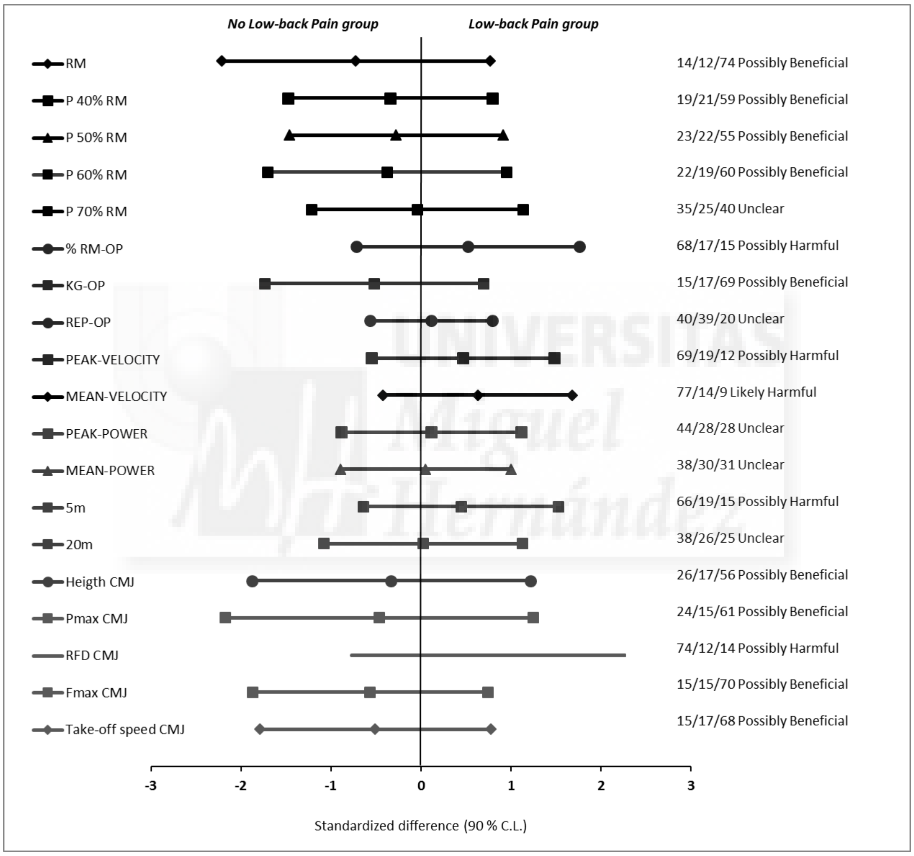

Figure 5b. Inferences between the low back pain group and the non-low back pain group in FP phase in parallel half-squat, 20 m and CMJ.

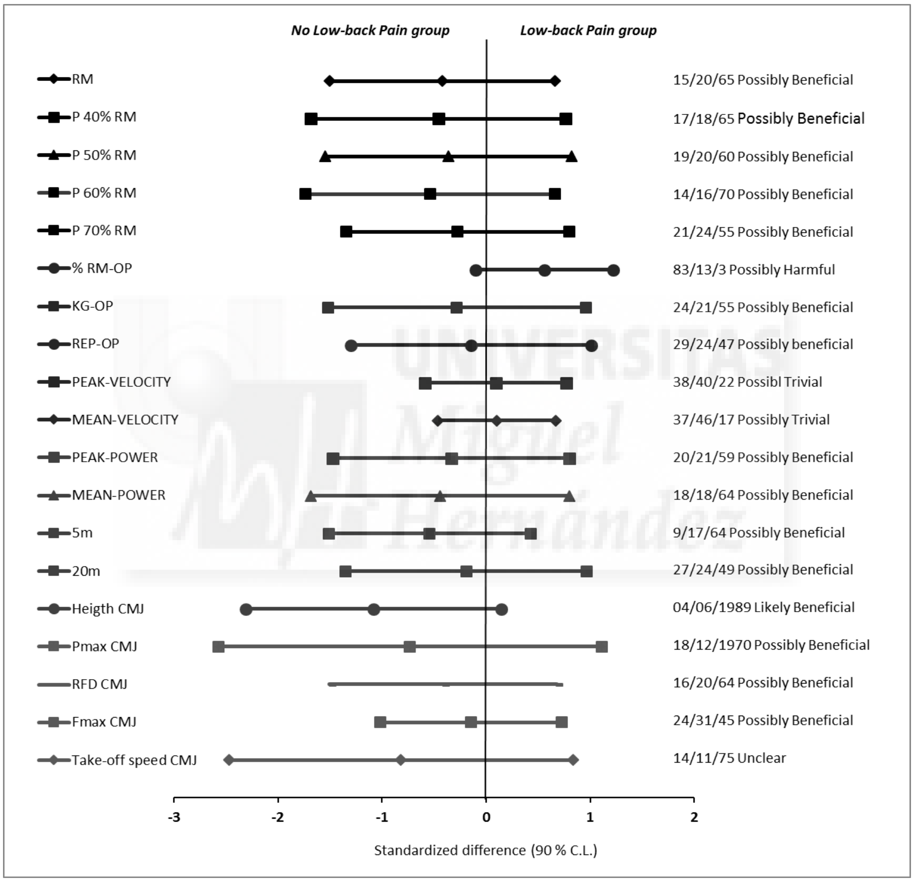

Figure 5c. Inferences between the low back pain group and the non-low back pain group in LP phase in parallel half-squat, 20 m and CMJ.

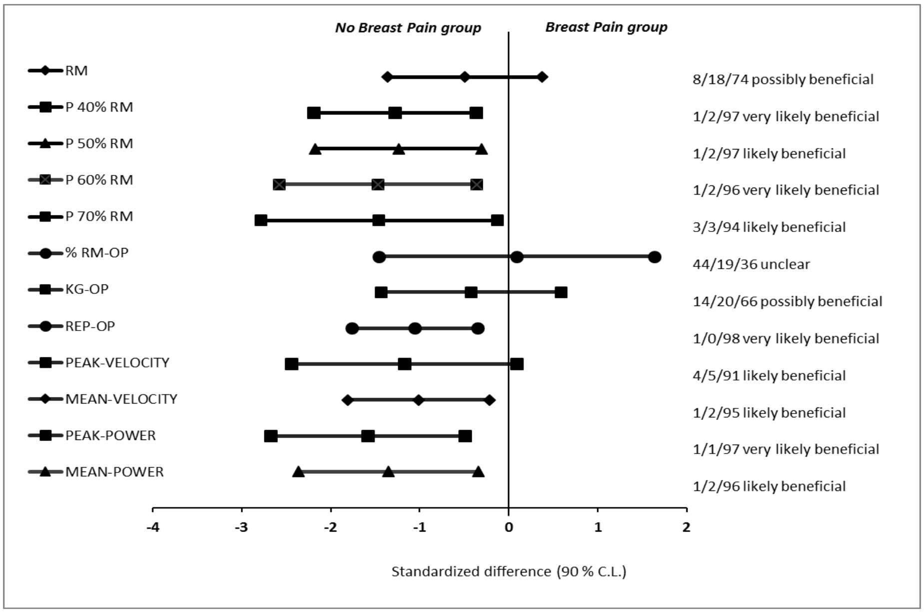

Figure 6a. Inferences between the breast pain group and the non-breast pain group in MEN phase in bench press throw.

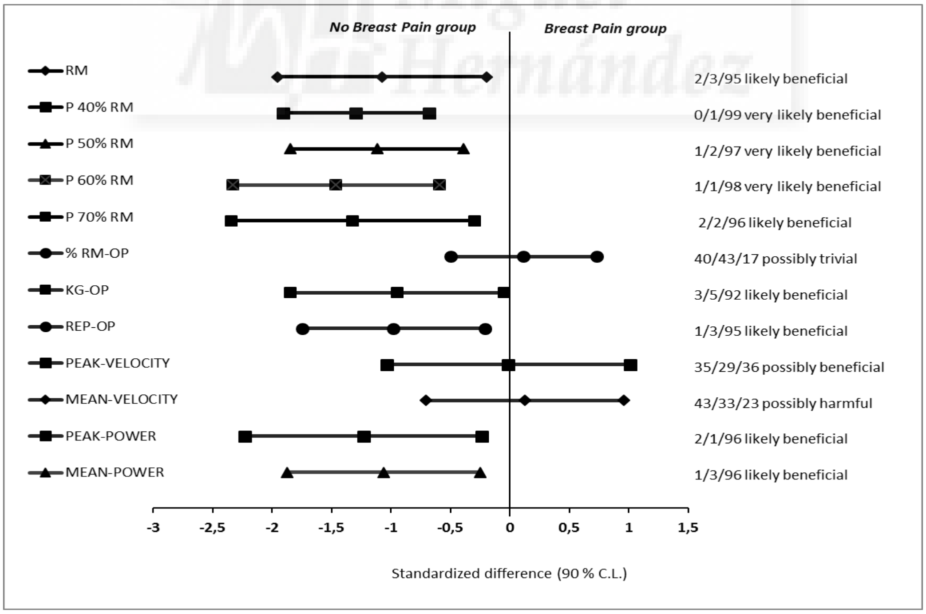

Figure 6b. Inferences between the breast pain group and the non-breast pain group in FP phase in bench press throw.

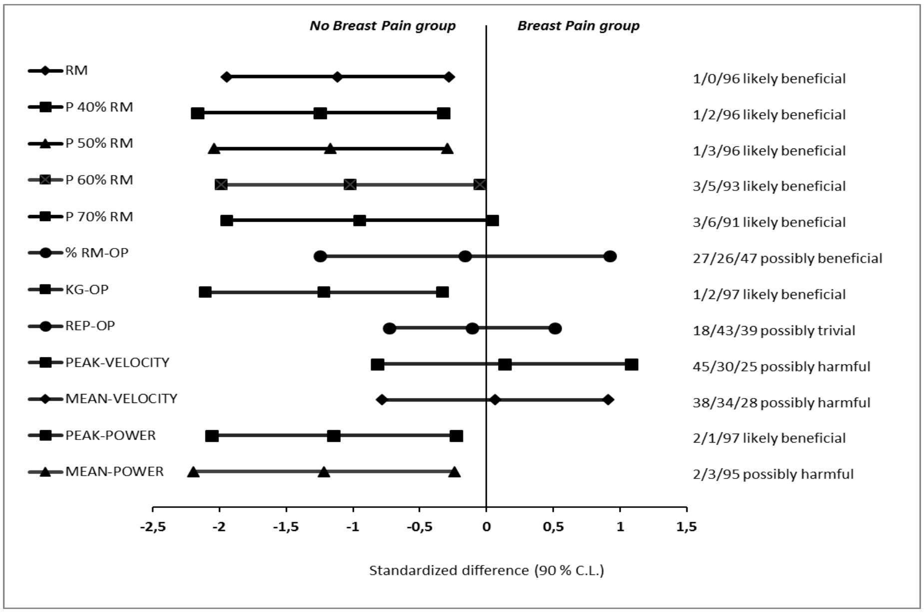

Figure 6c. Inferences between the breast pain group and the non-breast pain group in LP phase in bench press throw.

Questionnaire variables.

The dimensions of POMS and KSD did not show differences between the phases of the menstrual cycle. The means ± SD of the t-scores of each dimension for each phase respectively were: Stress (41.71 ± 8.89; 40.44 ± 6.25; 41.72 ± 9.48), Depression (45.64 ± 6.01; 43.11 ± 6.08; 45.89 ± 5.68), Anger (53.06 ± 10.87; 51.33 ± 8.81; 51.72 ± 9.25), Vigour (46.99 ± 7.33; 48.50 ± 6.19; 47.30 ± 9.40) and Fatigue (47.00 ± 9.11; 45.11 ± 6.82; 46.39 ± 8.53). The results for KSD were 3.30 ± 0.79, 3.41 ± 0.77 and 3.32 ± 0.54 for each phase respectively (MEN, FP, LP).

The RPE showed differences between phases (Table 9a and 9b) with a minor perception of effort in the moments previous to the ovulation (in FP). In addition, separating the group according to the painful menstruation, an increase of the RPE in the phase of bleeding is observed in the pain group.

Table 9a. *Inferences between the 3 phases in RPE in all groups.*

VARIABLE	Mean ± SD	Mean ± SD	Standardized difference (90% C.L.)	Chances	Clinical difference
RPE (MEN vs. FP)	5.33 ± 1.93	4.54 ± 1.33	-0.37 (-0.74; 0.00)	0/46/53	Possibly Harmful
RPE (MEN vs LP)	5.33 ± 1.93	5.78 ± 1.49	0.28 (-0.08; 0.65)	38/62/0	Possibly Beneficial
RPE (FP vs LP)	4.54 ± 1.33	5.78 ± 1.49	-0.65 (-1.04; -0.27)	0/9/91	Likely Beneficial

MEN = Menstruation; FP = Follicular Phase; LP = Luteal Phase; RPE = reported perception of effort.

Table 9b. *Inferences between pain and no pain group across the menstrual cycle in RPE.*

	Mean ± SD in no Pain Group	Mean ± SD in Pain group	Standardized difference (90% C.L.)	Chances	Clinical difference
RPE in MEN	4.75 ± 2.06	6.06 ± 1.57	0.67 (0.08; 1.26)	83/16/01	Likely Beneficial
RPE in FP	4.60 ± 1.49	4.44 ± 1.21	0.05 (-0.59; 0.70)	21/66/14	Possibly Trivial
RPE in LP	5.70 ± 1.65	5.88 ± 1.36	0.30 (-0.62; 1.21)	82/17/1	Possibly Beneficial

MEN = Menstruation; FP = Follicular Phase; LP = Luteal Phase; RPE = reported perception of effort.

In addition, correlations were found between some continuous variables of the questionnaires and performance variables (Table 10a, 10b, 10c, 11 and 7).

Table 10a. *Correlations between performance variables of Bench Press Throw and questionnaires variables in MEN.*

	Days with BP	1-RM	W 30% RM	Kg 30% RM	W 40% RM	Kg 40% RM	W 50% RM	W 60% RM	P_{max}	MPP
Days with BP	1	**-.484***	**-.582***	**-.598****	**-.543***	**-.538***	**-.477***	**-.482***	**-.532***	**-.573***
1-RM		1	.907**	.959**	.920**	.987**	.832**	.815**	.777**	.828**
W 30% RM			1	.954**	.977**	.920**	.940**	.928**	.942**	.949**
Kg 30% RM				1	.938**	.958**	.866**	.846**	.837**	.865**
W 40% RM					1	.927**	.970**	.954**	.948**	.949**
Kg 40% RM						1	.833**	.821**	.797**	.855**
W 50% RM							1	.982**	.969**	.917**
W 60% RM								1	.956**	.898**
P_{max}									1	.949**
MPP										1

BP = Breast Pain; MPP = Mean Propulsive Power; *p<0.05; **p<0.01.

Table 10b. *Correlations between performance variables of Bench Press Throw and questionnaires variables in FP.*

	A	B	C	1-RM	W 30% RM	Kg 30% RM	W 40% RM	Kg 40% RM	W 50% RM	Kg 50% RM	W 60% RM	Kg 60% RM	% RM-OP	Kg-OP	P_{max}	MPP
A	1	-.002	-.044	**-.533***	**-.584***	**-.568***	**-.524***	**-.541***	**-.520***	**-.469***	-.434	**-.539***	.131	-.435	-.370	**-.517***
B		1	-.459	**.526***	.431	.440	.407	**.482***	**.505***	**.516***	**.570***	**.503***	.395	**.685****	**.540***	.436
C			1	.011	.019	.051	.101	.019	-.003	.048	-.104	.027	**-.705****	-.358	-.036	-.146
1-RM				1	.908**	.948**	.908**	.987**	.884**	.985**	.824**	.988**	-.100	.852**	.852**	.847**
W 30% RM					1	.955**	.950**	.905**	.961**	.907**	.907**	.877**	-.179	.714**	.910**	.871**
Kg 30% RM						1	.906**	.947**	.882**	.949**	.809**	.912**	-.255	.724**	.824**	.813**
W 40% RM							1	.896**	.973**	.890**	.940**	.904**	-.180	.699**	.937**	.881**
Kg 40% RM								1	.870**	.962**	.809**	.964**	-.147	.822**	.825**	.820**
W 50% RM									1	.865**	.980**	.870**	-.062	.744**	.973**	.908**
Kg 50% RM										1	.800**	.972**	-.115	.830**	.845**	.832**
W 60% RM											1	.809**	.061	.747**	.971**	.908**
Kg 60% RM												1	-.060	.860**	.837**	.842**
% RM-OP													1	.425	.016	.139
Kg-OP														1	.751**	.820**
P_{max}															1	.919**
MPP																1

BP = Breast Pain; MPP = Mean Propulsive Power; A = Days with breast pain per month; B = Vigour; C = Fatigue; *p<0.05; **p<0.01.

Table 10c. *Correlations between performance variables of Bench Press Throw and questionnaires variables in LP.*

	A	1-RM	W 30% RM	Kg 30% RM	W 40% RM	Kg 40% RM	W 50% RM	Kg 50% RM	W 60% RM	Kg 60% RM	% RM-OP	Kg-OP	P_{max}	MPP
A	1	**-.588***	**-.596****	**-.625****	**-.506***	**-.588***	**-.503***	**-.524***	**-.478***	**-.599****	.155	**-.506***	**-.555***	**-.621****
1-RM		1	.947**	.973**	.924**	.987**	.907**	.987**	.896**	.986**	-.141	.884**	.918**	.867**
W 30% RM			1	.934**	.976**	.929**	.976**	.942**	.957**	.946**	-.084	.863**	.982**	.964**
Kg 30% RM				1	.883**	.957**	.889**	.961**	.871**	.944**	-.194	.836**	.903**	.867**
W 40% RM					1	.916**	.986**	.915**	.973**	.924**	-.070	.850**	.962**	.960**
Kg 40% RM						1	.897**	.966**	.887**	.963**	-.149	.873**	.897**	.851**
W 50% RM							1	.900**	.987**	.905**	-.073	.829**	.970**	.978**
Kg 50% RM								1	.886**	.972**	-.151	.871**	.912**	.860**
W 60% RM									1	.908**	.062	.884**	.958**	.973**
Kg 60% RM										1	-.045	.916**	.924**	.874**
% RM-OP											1	.294	-.036	.034
Kg-OP												1	.863**	.839**
P_{max}													1	.976**
MPP														1

BP = Breast Pain; MPP = Mean Propulsive Power; A = Days with Breast Pain per month; *p<0.05; **p<0.01.

Table 11. *Correlations between performance variabless of Parallel Half Squat and questionnaire variables across the menstrual cycle.*

	Stress	Depression	Vigour	Fatigue	V_{max}	MPV	P_{max}	MPP	% RM-OP
Stress in MEN	1	**.651****	-.111	.148	**-.533***	**-.533***	-.429	-.415	.260
Depression in MEN		1	.260	**.615****	**-.611****	**-.509***	**-.475***	-.414	-.103
Vigour in FP			1	-.459	.134	.126	.429	**.488***	-.119
Fatigue in LP				1	-.105	.037	-.038	.095	**-.187***

MPV = Mean Propulsive Velocity; MPP = Mean Propulsive Power. The correlations are shown as the value obtained between the questionnaire variable in the indicated phase and the performance variable in the same phase. *p<0.05; **p<0.01.

Table 12. *Correlations between performance variables of CMJ and questionnaires variables in FP.*

	Vigour	Height	P_{max}	Take-off speed
Vigour	1	**.516***	**.487***	**.552***
Height		1	.916**	.708**
P_{max}			1	.760**
Take-off speed				1

*p<0.05; **p<0.01.

3.4. Discussion and Conclusion.

The main objective of this study was to investigate if the menstrual cycle phases could affect the performance of different mechanical power tests, and to be able to plan the loads of this type of training in the phase in which the best results were obtained. It was essential that the phases were well defined by hormonal values. Our values of progesterone and the detection of LH in urine confirming ovulation, corroborated that the measurements were correctly made in the proposed phases.

According to the action of estradiol, in moments prior to ovulation in which the first peak of this hormone is obtained (FP), better results could be obtained than in MEN, in which this hormone was low, or in LP when this hormone is high, but its effect may be diminished because the progesterone is also elevated (Carson & Manolagas, 2015; Gleeson & Shalet, 2005; Kraemer et al., 2012).

However, we found no differences when comparing the majority of the test results between the 3 phases. In the study 1 differences only were found in the 1-RM of the parallel half squat, but the sample was very small and no hormonal measurements were performed to corroborate the phases. According to the results of this study, and in line with our previous study, we verified that these tests can be performed at any menstrual cycle phase. Other studies support our results, in which no differences in the test used were found between the phases (Bushman et al., 2006; Ekenros et al., 2013; Giacomoni et al., 2000;

Lynch & Nimmo, 1998; Miskec et al., 1997; Sakamaki et al., 2012; Tsampoukos et al., 2010).

With respect to performance variables, when all the sample was analyzed as a single group, the MBI analysis only showed differences in MPV and V_{max} between the phases.

Maximal power output and maintenance of the optimal velocity test: The %RM in which the P_{max} was found was within the established ranges by the literature for each exercise (Castillo et al., 2012; Izquierdo et al., 2001; Izquierdo, Häkkinen, Gonzalez-Badillo, Ibáñez, & Gorostiaga, 2002).

However, in maintenance of the optimal velocity test, we found differences in the MPV in the parallel half-squat, obtaining its best result in FP. The MBI analysis showed that MPV was "possibly harmful" in MEN regarding FP, and "possibly beneficial" in FP in comparison with LP. FP showed a greater MPV of 15-16 hundredths with respect to MEN and LP. According to González-Badillo & Sánchez-Medina (2010), this could amount to an increase of 10% 1-RM in absolute values.

In the bench press throw, best results in the V_{max} also appear in FP. V_{max} was "likely harmful" in MEN with FP and in MEN in comparison with LP. In addition, FP seemed to be better than LP, being "possibly beneficial". To ensure that the difference in velocity between the phases was not due to a load change (%RM), a correlation between the Kg moved and the V_{max} was performed, without obtaining a significant correlation. In the maintenance of the optimal velocity test, it was kept in mind that the participants were able to mobilize the load until it decreased more than 10% of velocity. This criterion was maintained in all phases of the cycle, but we observed that this velocity was lower in MEN than in FP and that it is not due to the change in the load, so we could say that the hormonal change presented at that time may affect the movement´s velocity.

The power generated in the optimal velocity test did not vary during the phases. The power is the product of force (F) and velocity (V): if the force increases (displaced mass) and the velocity decreases, the power value obtained can be very similar. In this case, we can see that the lowest speed value (MEN) coincides with a small increase in %RM-OP in both parallel half-squat (MEN = 66.67 ± 5.23, FF = 65.92 ± 4.89, LP = 65.06 ± 5.44) and bench press throw (MEN = 58.50 ± 4.42; FP = 56.60 ± 6.22; LP = 55.12 ± 5.88), and therefore there was no change in the power output between phases. However, in our study the difference in %RM-OP between phases was not large enough to influence the number of repetitions obtained in the parallel half-squat (MEN = 8.0 ± 3.82, FP = 7.67 ± 3.09; LP = 8.17 ± 4.46) or in the bench press (MEN = 4.28 ± 1.71; FP = 4.06 ± 1.43; LP = 4.22 ± 1.35) within the optimal velocity range.

Jump and sprint variables: In line with other studies no differences were found in any of the jump or sprint variables (Fridén, Hirschberg, & Saartok, 2003; Giacomoni et al., 2000; Isacco et al., 2012; Lynch & Nimmo, 1998; Miskec et al., 1997; Tsampoukos et al., 2010).

However, when the group was divided according to the discrete variables of the questionnaires, the MBI analysis showed that in practically all variables, there was a better performance in those participants who did not show menstrual pain.

Parallel Half Squat, 20 m sprint and CMJ: Looking at the MBI analysis in these tests, some variables did not show a clear difference, since we only found that the result was "possibly beneficial" in the group that did not have pain. This meant that the trend of the data showed that this group could have better results, but we would need a larger sample to be able to corroborate it.

Bench Press Throw: The MBI results in the bench press throw were more solid, most of the variables were conclusive showing better results in the group that did not have breast pain, with a practical interpretation of "likely and very likely beneficial" in favor of the no pain group. There were no intra-group differences between the three phases, but there were inter-group differences in each phase, so we could say that each group kept its performance constant between the 3 phases.

In this line, different studies have highlighted the importance of the presence of discomfort associated with menstruation with a drop in performance, but none of these studies had performed tests in which the optimum velocity was maintained (Constantini et al., 2005; Fridén et al., 2003; Giacomoni et al., 2000; Möller-Nielsen & Hammar, 1989). Warren & Shangold (1997) showed that 45-80% of the female population suffered from dysmenorrhea. In our study, eight participants (44.44%) reported that their menstruation is usually painful, showing that of 12 menses a year, 7.25 ± 2.60 were painful, and they scored in

5.88 ± 1.95 the pain of their last menstruation (on a scale of 0-10), in which the data were collected.

With respect to questionnaire variables, when the sample was analyzed as a whole, MBI analysis only showed a difference between phases in RPE.

Reported perception of effort (RPE): The results of this questionnaire showed a lower value during FP, being “likely beneficial” in comparison with LP. Symptoms of dysmenorrhea are known as menstrual (as they appear in menstruation), and pre-menstrual (in LP) (Constantini et al., 2005; Giacomoni et al., 2000). Probably these symptoms caused an increase in the perception of effort in those moments, showing the lowest value in the moments prior to ovulation, when the symptoms decreased. In addition, when dividing the group according to the participants which showed a painful menstruation, we observed that RPE in MEN was much greater in the women with menstrual pain regarding those who did not suffer pain, that is, it was “likely beneficial” in the no pain group. We re-emphasized that at this stage the symptoms of dysmenorrhea are higher, which could explain the difference in the perception of effort between both groups. Other studies have found the same results (Gamberale, Strindberg, & Wahlberg, 1975; Higgs & Robertson, 1981; Pivarnik, Marichal, Spillman, & Morrow, 1992).

Profile of Mood States (POMS): There were no differences in the five dimensions between the phases. However, all dimensions of POMS showed correlations at some point of the menstrual cycle. In line with

Cockerill, Nevill, & Byrne, (1992), it was observed that the "negative" dimensions of POMS (stress, depression, fatigue and anger), had negative correlations with performance variables, while vigor showed a positive correlation. This supported the results of the study, since (besides the fact that the participants with pain obtained worse results) the presence -or not- of this pain could explain the worse results with other variables of the questionnaires. Therefore, participants with pain and those who scored high the negative dimensions, obtained worse performance test results.

Menstrual Pain Questionnaire: Days with breast-pain per month (one of the variables in this questionnaire) also showed negative correlations with the results of the bench press throw.

The days with breast pain can be considered a negative variable, as well as the dimensions of POMS mentioned above. This means that we have found worse results in the group with dysmenorrhea (Fridén et al., 2003). These results can be refuted through the correlations found between the negative variables of the questionnaires and the results of the tests (Cockerill et al., 1992). In addition, it could be said that the pain affected performance in a global way, and also that the discomfort in a particular area affected the exercises that will be performed with the musculature of this area, since the breast-pain showed worse results in bench press throw, and the low back-pain had a tendency to show worse results in the parallel half-squat, in the 20 m sprint and in the CMJ.

In conclusion, physically active young women seem to have a higher MPV in FP, that is, they were faster in both upper and lower body exercises, even though, the tests used to evaluate the power and velocity could be used at any time of the menstrual cycle, since there were no differences in the results of this test. We also found that participants with discomfort associated with menstruation obtained worse results, so their training sessions should be adjusted to the moments in which there was no menstrual or pre-menstrual pain, trying to increase performance.

As future lines of work, it would be necessary to check what happens if we train at different phases of the menstrual cycle, that is, the chronic adaptations of training at different menstrual cycle phases.

Chapter 4. Study 3

The use of Velocity-Based Resistance Training in elite rowers at different menstrual cycle phases affect performance improvements.

4.1. Introduction.

In the last decades there has been a growing interest in the study of women in sport due to their professionalization. The main problem of researchers is to try to understand the response to different types of training in relation to menstrual hormones and their fluctuation in the two largest phases of the menstrual cycle, the Follicular Phase (FP) and the Luteal phase (LP) (Constantini et al., 2005).

The two major hormones that vary along these phases are estradiol, which has been categorized as an anabolic hormone, and progesterone, which is considered catabolic (Ekenros et al., 2013; Sakamaki et al., 2012). The highest values of estradiol are found in the moments prior to ovulation, and in the middle of the LP, and progesterone is only high in the middle of the LP (Oosthuyse & Bosch, 2010). Variations in the levels of these hormones have reported changes in fluid retention, changes in body temperature and metabolism of the substrates, so they can influence performance since there is an affectation of numerous cardiovascular, respiratory, thermoregulatory and metabolic parameters (Constantini et al., 2005).

Other important hormones in training are testosterone (also considered anabolic) that reach their peak just before ovulation (Salonia et al., 2008), and cortisol (catabolic) that is higher in the middle of the LP (Genezzani et al., 1975). Estradiol has been shown to correlate with growth hormone (GH) values (Gleeson & Shalet, 2005), and together with the action of testosterone, it could be thought that there is a greater predisposition to obtain strength gains in the follicular phase.

Different studies have corroborated this hypothesis showing better strength gains during the first two weeks of the menstrual cycle. A recent study showed a greater maximum isometric force (F_{max}) and a higher increase in muscle diameter (Mdm) and in fiber diameter (Fdm) of type II fiber (Sung et al., 2014). An increase in squat jump (SJ) and counter-movement jump (CMJ), in peak torque values in hamstrings and in lean body mass of the legs have also been found (Wikström-Frisén et al., 2015). Reis et al. (1995) reported an increase in maximal strength and in ratio of maximal strength/muscle cross sectional area. Another recent study (Pallavi, Souza, & Shivaprakash, 2017) found a greater handgrip strength and lower fatigue rate percentage.

Although some of these studies have been based on new trends of training, none of them have used the method of velocity-based resistance training (VBRT). This method attempts to seek improvements in strength and power levels through the realization of a individualized number of repetitions until the velocity begins to descend, using the load at which the highest peak-power is generated (Pareja-Blanco et al., 2016).

The main objective of this study is to verify if the first two weeks of the menstrual cycle are more effective to perform this type of training in comparison to the last two weeks and to check if there are other factors associated with dysmenorrhea that may adversely affect the results of this type of training.

4.2. Methods.

4.2.1. Participants

Fourteen women, all physically active and elite rowers, took part in this study. All trained 7 days per week, with approximately two hours per training session. In general, each week was divided into two resistance training sessions, two water training sessions and three series training sessions on the row ergometer. Each session started with ten minutes or two kilometer warm-up in the row ergometer (except the water sessions where warm-up was done in the boat). The resistance and series sessions were aimed at the general physical preparation and its load depended on the moment of the season, and in the water sessions, the work was focused on the technique.

For the inclusion, they were required not to have any injury, not to suffer any hormonal irregularities, to have a regular menstrual cycle, to not smoke and to not have taken oral contraceptives (OCP) during the last six months. They were instructed to continue their usual diet and not to take caffeine on the day of the tests or on the day before. The descriptive data of the sample are shown in table 13.

Written informed consent was obtained from the participants before the research. The present study was approved by the institutional research ethics committee of the University, and conformed to the recommendations of the Declaration of Helsinki.

Table 13. *Participants descriptive data. Data are shown as means ± SD.*

n	Age (y)	Body mass (kg)	Height (m)	B.M.I.	Fat mass (%)	1-RM Bench Press	Menstrual cycle (days)
Total (n = 14)	19.71 ± 1.44	60.49 ± 6.13	1.63 ± 0.08	22.81 ± 1.91	16.6 ± 3.36	43.86 ± 7.92	28.04 ± 2.65

4.2.2. Procedures

Each participant performed six laboratory sessions. The first day included a general anamnesis, a questionnaire in which the participant had to answer about her menstrual history (menstrual pain questionnaire) and the familiarization session, performing all tests (the same tests that they would do during the intervention) in order to learn the protocol.

The second, third, fourth and fifth sessions correspond with Pre-test 1, Post-Test 1, Pre-test 2 and Post-Test 2 respectively, and between each pre- and post-test the participants performed 6 training sessions in their club, apart from their usual training. The first thing that was done in pre- and post-test sessions were two questionnaires: Karolinska Sleep Diary (KSD) and Profile of Mood States (POMS). After this, two performance tests (20 sec all-out in a row ergometer and bench press throw) were carried out. Thirty minutes after the end of the session, the participants answered a Rating of the Perceived Exertion (RPE), using the 0-10 Borg-scale (Borg, 1990). This can be seen in the annex 4. Before the tests, participants performed a standard warm-up (15 min including aerobic exercise in a row ergometer, general mobilization and ballistic exercises).

In these four sessions, the sample was counterbalanced into 2 groups. Pre-test 1 was carried out at different menstrual phase for each group: the group that performed training during the first two weeks of the menstrual cycle (gFP = 7) did the pre-test 1 at the beginning of bleeding, and the group that started to train during the last two weeks of the menstrual cycle (gLP, n = 7) did the pre-test 1 at the time of ovulation. The 6 training sessions began the day after the pre-test 1. Post-test 1 was performed one or two days after the last training session. Then both groups continued with their usual training for a month, and repeated the same protocol (Pre-test 2, the 6 training sessions and Post-Test 2) in the other phase of their menstrual cycle.

In order to control that the effects of their usual training did not interfere with our results, the study was performed at a time of the season in which they did not have to improve the maximum strength, and their strength training was limited at the specific and preventive strength. Counterbalance also blocked the training interference.

The sixth day included an anthropometry to characterize the sample. The experimental design is shown in figure 7.

Determination of the menstrual cycle.

Participants were monitored for three months before starting the first measurement to ensure they had a regular menstrual cycle. To confirm the phases, ovulation was detected using a luteinizing hormone (LH) KIT in urine. The reagent sensibility was 20 mIU/ml. When training was performed at FP, 3 days before ovulation was predicted (based on data collected during the 3 months prior to the start of the study), participants started using the LH reagent every day until the ovulation was detected to ensure that the last training session was still in FP and ovulation had not passed. When training was performed at LP, 3 days before the predicted ovulation, participants began to use the LH reagent every day until ovulation was detected, and the day after ovulation the first day of training began, and the last training session should have been performed before the next menstruation.

Only one participant was not able to perform the 6 training sessions, since the time from ovulation to the next menstruation was 10 days. This participant was in gLP when pre-test 1 was performed, that is, only 4 sessions could be completed in the luteal phase, but the results in the follicular phase were not compromised. When the measurements in this phase were repeated, four sessions were also made, so the volume of training was matched in both phases. The duration of FP was 14.64 ± 2.44 days, and the duration of LP was 13.93 ± 2.87 days.

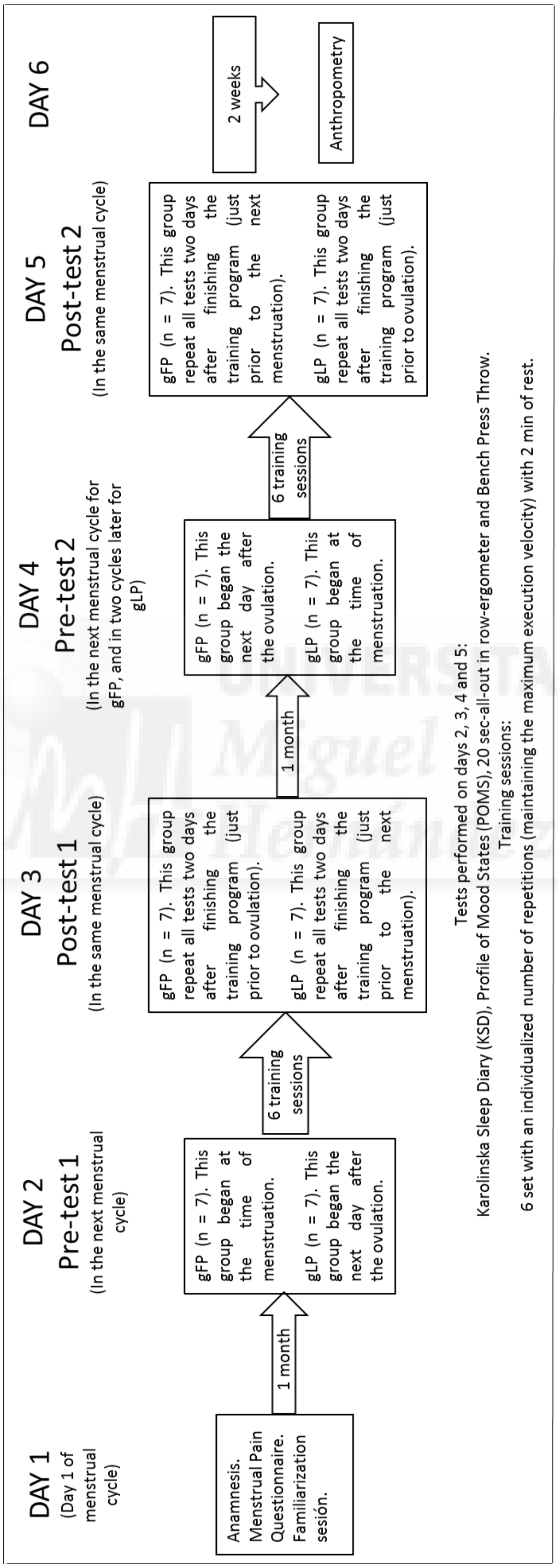

Figure 7. Experimental design for Study 3.

Menstrual pain questionnaire (Larroy et al., 2001).

This questionnaire provides information of different feelings of discomfort caused by menstruation (annex 1). It includes variables that were grouped in 6 dimensions: 1. factors that may influence menstrual pain (number of children, years since first menstruation); 2. characterization of menstrual pain (intensity and location of pain, number of painful menses, time of onset of pain); 3. request for professional help due to menstrual pain; 4. symptoms associated with menstrual pain; 5. strategies used to relieve pain (medication and rest); 6. other symptoms and disorders.

The questionnaire consists of 19 questions Nine were discrete variables with 2-6 options to choose from, depending on the question. Three of these questions are composed of several options (each option corresponds to one symptom), and the participant had to underline all of those symptoms that appeared. For its subsequent analysis, a 0 was used if the symptom was not present, and 1 if it was. In the remaining six questions, the participant had to choose a single possible option. Four of these questions had 2 options (yes or no); one had 4 options (which were transcribed to the database as 0, 1, 2 and 3); and the last one had six options (which were transcribed to the database as 0, 1, 2, 3, 4 and 5).

From the other 10 questions which were about continuous variables, the first three were age, number of pregnancies and number of children. Another of the ten questions was answered using a 0-10 scale, four using a 0-12 scale and the remaining 2 were answered in time (years) since this variable was presented. This questionnaire showed an α -Crombach of 0.99.

Karolinska Sleep Diary (KSD) (Torbjörn et al., 1994).

This questionnaire about the quality of sleep the previous night, consists of 7 questions (annex 2). Each option has 5 answers, and the final score was obtained by averaging the 7 questions. Cervelló et al, (2014) showed an α-Crombach that oscillated between 0.66-0.85.

Profile of Mood States (POMS) (Fuentes et al., 1995).

The reduced version of 29 items was used (annex 3). All items were grouped into five profiles (stress, depression, anger, vigour and fatigue). The score for each profile was obtained by the addition of the scores of each item that makes up each profile, and then a t-score was calculated using a conversion table. The abbreviated form of 29 items explains 92.9% of the total variance of the complete questionnaire (58 items), reducing the number of items by half, making it easier for the participants.

20 sec all-out row ergometer test.

The distance in meters (m) and the mean-power (P_{mean}) generated were recorded. The participants were instructed to row as fast and intensely as possible during 20 second in a row ergometer (Concept2, Model 2 PM5; Vermont, USA). This test is an adaptation of the 10 sec all-out test used by Redman & Weatherby (2004). In our study 20 seconds was used because it was the minimum time for which the row ergometer could program. A drag factor of 120 was placed on the ergometer.

1-RM for Bench Press.

The maximum dynamic force was measured using an indirect protocol to estimate 1-RM using an isoinertial dynamometer (T-Force Dynamic Measurement System; Ergotech; Murcia, Spain). The isoinertial dynamometer measures the velocity at which the barbell is being displaced, and with the barbell´s velocity, the 1-RM can be predicted (González-Badillo & Sánchez-Medina., 2010), and then the result was compared with the Brzycki formula (Brzycki, 1993).

The participants started the test with a warm-up series of twelve repetitions with 20% of their body weight. Then, three to four sets were carried out, increasing the weight mobilized in each series, until the participant could not perform more than four to six repetitions. A passive recovery of three to five minutes between sets was used.

The exercise was performed on a Smith machine (Technogym; Cesena FC, Italia). To standardize the movement, an anthropometric box (45x35x15cm) was placed in front of the bench, so the participant could support her feet and avoid hyperlordosis. In addition, an elastic band was placed under the bench, so the participant could touch it with her elbows in each repetition, ensuring a 90-degree of elbow flexion and shoulder abduction. The movement began with the participant holding the barbell with her elbows extended, and the barbell descended until the participant touched the elastic band with her elbows.

Maximal Power output test.

Four percentages of the 1-RM (30%, 40%, 50% and 60%) were measured in the concentric phase using an isoinertial dynamometer in a Smith Machine. This ballistic exercise was performed by throwing the bar to achieve the highest possible power and speed, that is, there was no stopping in the change from the concentric to the eccentric phase. We know that the ideal exercise to evaluate female rowers would have been an exercise involving the *latissimus dorsi*, but then it would not have been a ballistic exercise (since an oar or a pole can-not be thrown) and maximum power values could not be obtained.

To find the peak-power, one set of three repetitions was performed for each percentage (Baker et al., 2001a, 2001b). A two-minute passive recovery between sets was made. Instantaneous mechanical power output (P) was calculated as the product of vertical force and barbell velocity (P = F · V). Peak-power was taken as the maximum value of the power-time curve. González-Badillo & Sánchez-Medina, (2010) checked the validity and reliability of this system, showing ICC values ranging from 0.81 to 0.91 and a CV < 3.6%.

Maintenance of the optimal velocity test.

With the percentage in which a higher peak-power was found (%RM-OP), a single set was performed with this load (Kg-OP) to perform as many repetitions as possible (Repts-OP) until the velocity dropped by

10% during two consecutive repetitions. The participants had a visual feed-back system on the laptop screen for the power achieved in each repetition, provided by the isoinertial dynamometer software, in which the green colour meant a correct repetition and the red colour an incorrect repetition. The repetition in which there was a higher peak-power (P_{max}) and peak-velocity (V_{max}) was searched, and the average of the mean-power (MPP) and mean-velocity (MPV) of the propulsive phase (in those repetitions that were within the range of optimal speed) were calculated. Participants used this load and repetitions to train.

Training protocol.

The training sessions were performed before the participants' usual training. The six training sessions were performed on Monday, Wednesday and Friday for two consecutive weeks. If the beginning of bleeding for gFP (Day 1 cycle) or ovulation day for gLP (approximately day 15 of the cycle) corresponded to Monday or Tuesday, training began on Wednesday, if it was Wednesday or Thursday, the training started on Friday, and if it was Friday, Saturday or Sunday, training was started on Monday of the following week. Each training session consisted of 6 series of a bench press throw exercise, with a number of repetitions individualized for each participant, performed at maximum velocity, at the intensity (% RM) in which maximal power (P_{max}) was achieved, and with 2 minutes of recovery.

Table 14. *Volume and Intensity in each intervention phase. Data are shown as Mean ± SD.*

	FP	LP
%RM-OP	40.74 ± 6.70	37.88 ± 9.65
Kg-OP	18.00 ± 4.57	17.21 ± 5.63
Repts-OP	13.50 ± 6.76	14.36 ± 6.81

FP = Follicular Phase; LP = Luteal Phase; %RM-OP = %RM for optimal velocity; Kg-OP = Kg for optimal load; Repts-OP = Repetitions within optimal velocity.

Anthropometric test.

Body Max Index (BMI), % Fat Mass, weight and height were determined. Anthropometry was performed by an ISAK 2 technician, taking data of 4 diameters (humerus, wrist, femur and ankle), 12 perimeters (relaxed arm, contracted arm, forearm, wrist, neck, minimum abdominal, hip, 1cm-thigh, mid-thigh, calf, ankle and mesoesternal) and 10 skinfolds (triceps, subscapular, biceps, pectoral, axillary, supracrestal, supraspinal, abdominal, anterior thigh, mid-calf).

3.2.3. Statistical Analysis

Results were presented as mean ± standard deviation (SD). A paired T-test was performed to detect possible between-group differences both pre- and post-training intervention. In addition, data were analyzed to determine their practical significance using magnitude based inferences (MBI). This method is based on the use of confidence intervals to calculate the probability that a difference is significant. The threshold of inferences was set at 0.35, which according to Rhea (2004), was the value assigned for the analysis of strength data. Subsequently, the probability that any change in performance was greater / similar / lower between menstrual cycle phases, and between groups divided according to discrete variables of the questionnaires, was calculated with its 90% confidence limits (CL). The qualitative probability was assigned by the following quantitative chances: < 0.5%, most unlikely; 0.5% to 5%, very unlikely; 5% to 25%, unlikely; 25% to 75%, possibly; 75% to 95%, likely; 95% to 99.5%, very likely; and >99.5%, most likely. In addition, the clinical inference was represented as unclear, trivial, beneficial or harmful (Batterham & Hopkins, 2006). Depending of the direction (positive or negative) of the change, not related with really beneficial or harmful responses.

Relationships between the performance variables and variables of the questionnaires were calculated using a Pearson´s correlation coefficient (r). The strength of the correlation coefficient was determined on the basis of the classifications outlined by Cohen (1988) in which r = trivial (0.0), small (0.1), moderate (0.3), strong (0.5), very strong (0.7), nearly perfect (0.9), and perfect (1.0). Statistical signification was set at $p<0.05$.

4.3 Results.

Performance variables.

There were no differences between phases (between groups) in the pre-test. The pre- and post-test (within group) differences in each phase in the 1-RM test and in the Maximal Power Output test was shown in Table 15. Both groups obtained an improvement after training in 1-RM, and therefore in the relative loads (% 1-RM), and in the power generated in each one of those percentages. The differences between groups are shown in figure 8.

Training in FP produced improvements in the power values both in the Maintenance of the Optimal Velocity test and in the average power (P_{mean}) of the 20 sec-all out test. Regarding the Maintenance of Optimal Velocity Test, in FP the %RM-OP decreased and therefore there were improvements in the V_{max} and MPV. In LP, there was an increase of the %RM-OP decreasing the velocity values, an increase of the MPP, and there were no changes in any variable of the 20 sec-all-out (Table 16). The results between groups are shown in Figure 9.

Training at FP produced a higher gain of 1-RM. With low loads (30% RM), training at FP also produces greater improvements in velocity, with a consequent improvement in the power developed. The results of power in the rest of percentages of 1-RM are not clear. Improvements in the P_{max}, and in values of the 20 sec-all-out test also appear in training at FP in comparison with training at LP.

Table 15. *Changes in performance variables in 1-RM and Maximal Power Output test for FP and LP.*

Variable	FP (n = 14)					LP (n = 14)				
	Pre-test Mean ± SD	Post-test Mean ± SD	% difference (90% C.L.)	Chances	Clinical difference	Pre-test Mean ± SD	Post-test Mean ± SD	% difference (90% C.L.)	Chances	Clinical difference
1-RM	44.14 ± 8.10	47.18 ± 9.27	6.61 (4.07; 9.22)	100/0/0	Most Likely Harmful	45.21 ± 8.16	46.75 ± 8.53	3.35 (1.46; 5.27)	89/11/0	Likely Harmful
P 30% 1-RM	302.26 ± 62.21	342.48 ± 86.39	12.35 (6.80; 8.19)	100/0/0	Most Likely Harmful	304.04 ± 65.87	311.24 ± 75.72	1.30 (-6.90; 10.23)	44/30/25	Unclear
P 40% 1-RM	314.26 ± 68.17	330.29 ± 81.22	4.81 (0.41; 9.41)	86/13/1	Likely Harmful	304.48 ± 67.27	311.61 ± 69.31	2.27 (-0.28; 4.87)	57/42/1	Possibly Harmful
P 50% 1-RM	304.61 ± 65.51	318.07 ± 77.41	4.06 (-1.27; 9.67)	74/22/3	Possibly Harmful	294.35 ± 61.67	311.64 ± 78.14	4.96 (1.61; 8.43)	93/7/0	Likely Harmful
P 60% 1-RM	292.71 ± 72.05	313.71 ± 74.74	7.59 (2.44; 13.01)	96/4/0	Very Likely Harmful	283.47 ± 61.45	297.81 ± 81.33	3.77 (-2.37; 10.29)	69/25/6	Possibly Harmful
Kg 30% 1-RM	13.57 ± 2.62	14.21 ± 2.75	4.70 (1.67; 7.83)	93/7/0	Likely Harmful	13.36 ± 2.65	14.29 ± 2.37	7.47 (3.22; 11.90)	98/2/0	Very Likely Harmful
Kg 40% 1-RM	17.57 ± 3.25	18.93 ± 3.63	7.57 (4.58; 10.65)	100/0/0	Most Likely Harmful	18.21 ± 3.33	18.86 ± 3.42	3.56 (0.72; 6.49)	82/17/0	Likely Harmful
Kg 50% 1-RM	22.14 ± 4.33	23.93 ± 4.76	8.03 (5.61; 10.50)	100/0/0	Most Likely Harmful	22.64 ± 3.99	23.64 ± 4.50	4.14 (0.81; 7.57)	86/14/0	Likely Harmful
Kg 60%1-RM	26.57 ± 5.03	28.29 ± 5.81	6.14 (3.46; 8.89)	99/1/0	Very Likely Harmful	26.93 ± 5.24	27.93 ± 5.48	3.64 (0.65; 6.72)	82/17/0	Likely Harmful

FP = Follicular Phase; LP = Luteal Phase.

Table 16. *Changes in performance variables in Maintenance of the optimal velocity and 20 sec-all out test.*

	FP (n = 14)					LP (n = 14)				
Variable	Pre-test Mean ± SD	Post-test Mean ± SD	% difference (90% C.L.)	Chances	Clinical difference	Pre-test Mean ± SD	Post-test Mean ± SD	% difference (90% C.L.)	Chances	Clinical difference
% RM-OP	40.75 ± 6.70	37.51 ± 8.62	-8.93 (-18.79; 2.13)	5/9/86	Likely Beneficial	37.88 ± 9.65	39.84 ± 8.80	5.60 (-8.18; 21.44)	67/15/18	Possibly Harmful
Kg-OP	18.00 ± 4.57	17.71 ± 5.72	-2.90 (-13.55; 9.05)	23/21/56	Unclear	17.21 ± 5.63	18.93 ± 6.76	9.12 (-5.08; 25.45)	80/10/10	Likely Harmful
REP-OP	13.50 ± 6.76	10.93 ± 4.38	-18.24 (-33.71; 0.84)	4/3/93	Likely Beneficial	14.36 ± 6.81	14.86 ± 7.03	1.44 (-20.84; 29.99)	48/11/41	Unclear
V_{max}	1.45 ± 0.21	1.53 ± 0.28	5.02 (-5.01; 16.10)	69/18/12	Possibly Harmful	1.49 ± 0.27	1.42 ± 0.28	-4.83 (-14.62; 6.08)	14/18/68	Unclear
MPV	1.00 ± 0.15	1.04 ± 0.21	3.58 (-6.00; 14.15)	61/22/17	Possibly Harmful	1.02 ± 0.19	0.97 ± 0.20	-5.29 (-15.58; 6.25)	14/16/70	Unclear
P_{max}	315.99 ± 62.79	342.31 ± 78.16	7.80 (1.90; 14.05)	95/5/1	Likely Harmful	311.90 ± 61.46	318.79 ± 71.78	1.52 (-4.71; 8.15)	45/38/17	Possibly Harmful
MPP	208.47 ± 42.43	224.63 ± 51.78	7.24 (1.41; 13.40)	93/6/1	Likely Harmful	203.12 ± 42.58	213.20 ± 48.58	4.51 (-0.91; 10.23)	78/19/3	Likely Harmful
m 20 sec	97.63 ± 5.68	99.00 ± 6.28	1.38 (0.34; 2.43)	15/85/0	Likely Trivial	98.50 ± 6.32	98.25 ± 6.09	-0.24 (-1.32; 0.84)	0/99/1	Very Likely Trivial
P 20 sec	332.13 ± 55.88	346.13 ± 68.59	3.77 (0.09; 7.57)	80/19/1	Likely Harmful	341.63 ± 65.13	339.00 ± 60.21	-0.61 (-3.77; 2.65)	9/69/22	Possibly Trivial

FP = Follicular Phase: LP = Luteal Phase.

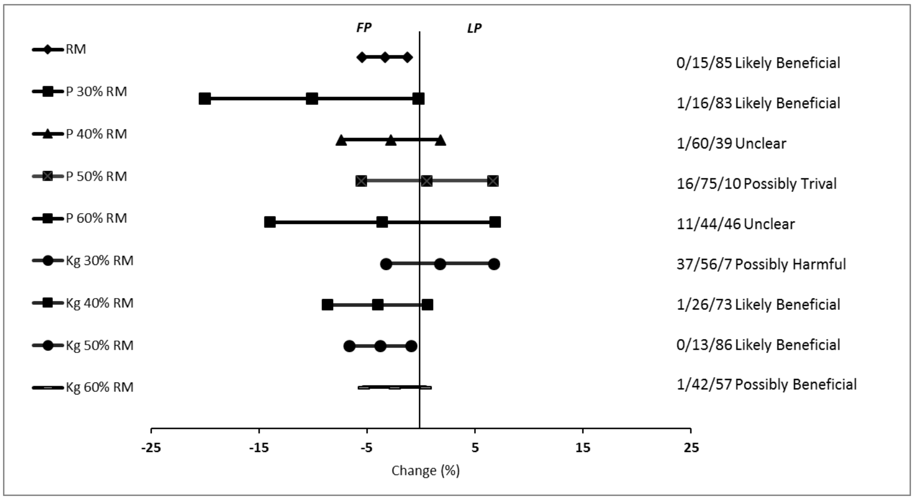

Figure 8. Inferences between FP and LP in 1-RM and Maximal Power Output Tests.

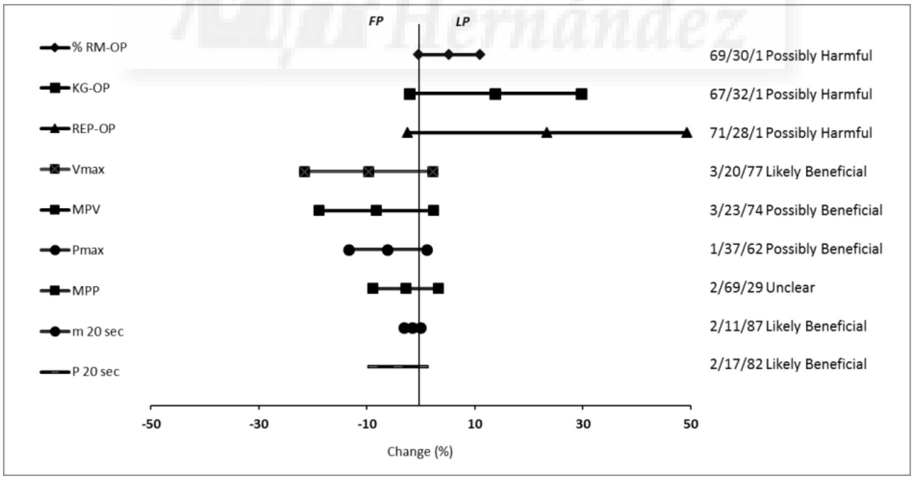

Figure 9. Inferences between FP and LP in Maintenance of the Optimal Velocity and 20 sec-all out Tests.

Questionnaires Variables.

There were no differences in pre- and post-test in any questionnaire in any phase. There were no differences between pre 1 and pre 2 either, nor between post 1 and post 2. The means of KSD were 3.23 ± 0.50, 3.49 ± 0.51, 3.38 ± 0.56 and 3.34 ± 0.71 (which are shown as pre- and post-test in FP, and pre- and post-test in LP respectively for all the questionnaires).

The means for POMS were: Stress 38.64 ± 6.61, 38.36 ± 6.74, 42.79 ± 11.27 and 37.29 ± 5.70; Depression 45.36 ± 6.03, 45.20 ± 4.30, 45.57 ± 4.54 and 45.57 ± 4.93; Anger 51.14 ± 11.03, 51.00 ± 11.60, 54.79 ± 10.91 and 52.70 ± 11.23; Vigour 43.14 ± 4.94, 43.64 ± 5.64, 43.00 ± 6.34 and 45.50 ± 6.90; Fatigue 48.57 ± 6.82, 48.56 ± 5.97, 49.57 ± 7.91 and 46.36 ± 8.2. Data for RPE were 4.96 ± 1.85, 4.14 ± 1.35, 4.57 ± 1.69 and 4.32 ± 1.42.

The group was divided into two groups, one with dysmenorrhea (pain group, n = 10), and one without pain (no pain group, n = 4). The group without menstrual pain presented better results in the pre-test of FP, showing values of likely, very likely and most likely beneficial (Figure 10a). In LP, the results were not conclusive, since values were possible beneficial, but the tendency was also to obtain better results in the no pain group (Figure 10b). In both FP and LP post-tests, we also found better results in the no pain group with likely, very likely and most likely beneficial values in almost all variables (Figure 11a and 11b). When the percentage change (% change) of both groups in each phase was compared, we can see that the no pain group obtained greater improvements in the FP (Figure 12a), while in LP both groups improved in the same way (Figure 12b).

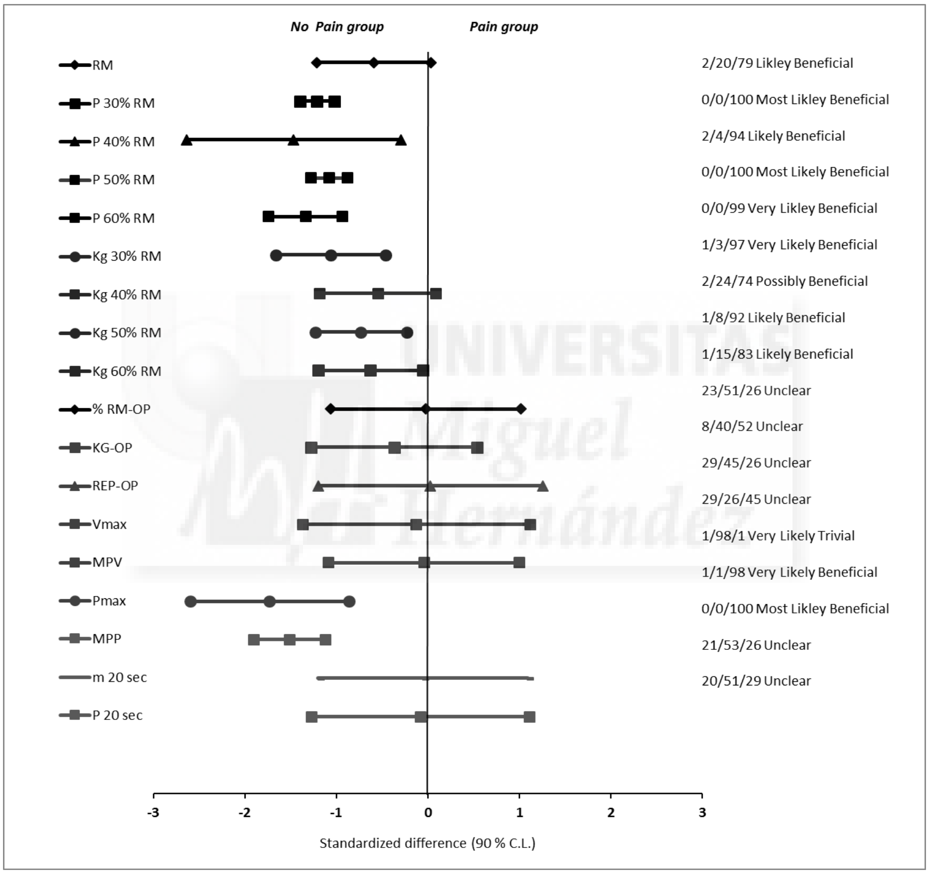

***Figure 10a*.** Inferences between Pain Group and No Pain Group in pre-test in FP.

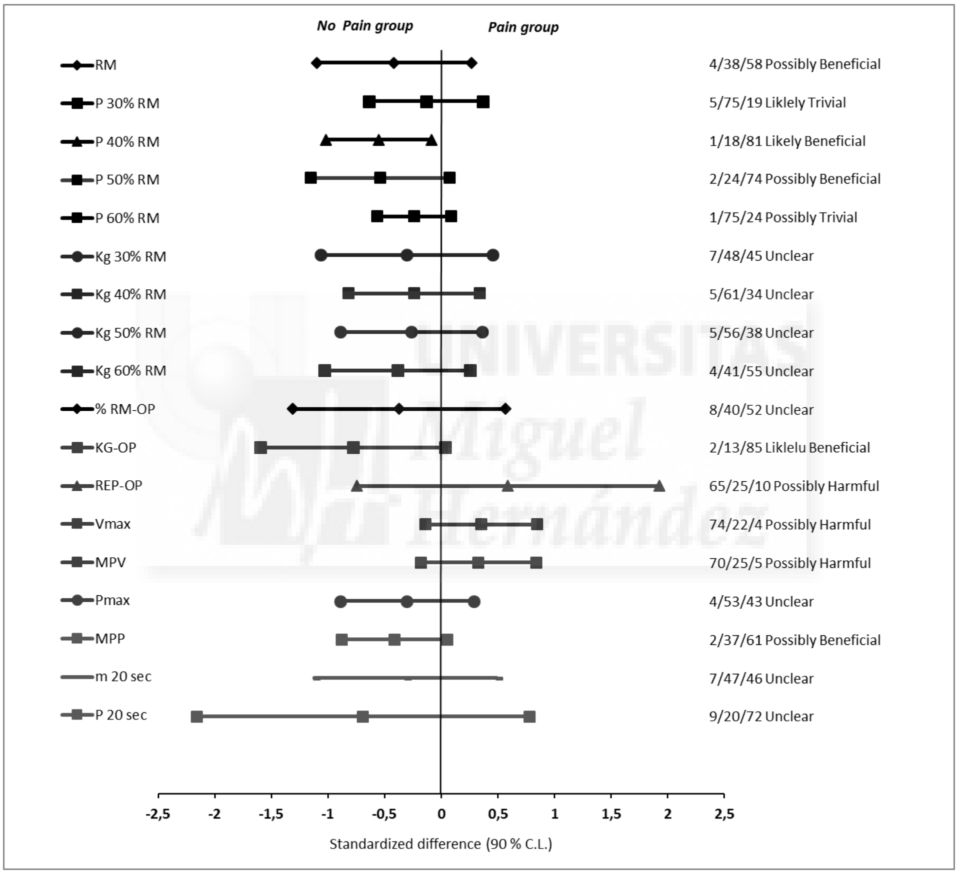

Figure 10b. Inferences between Pain Group and No Pain Group in pre-test in LP.

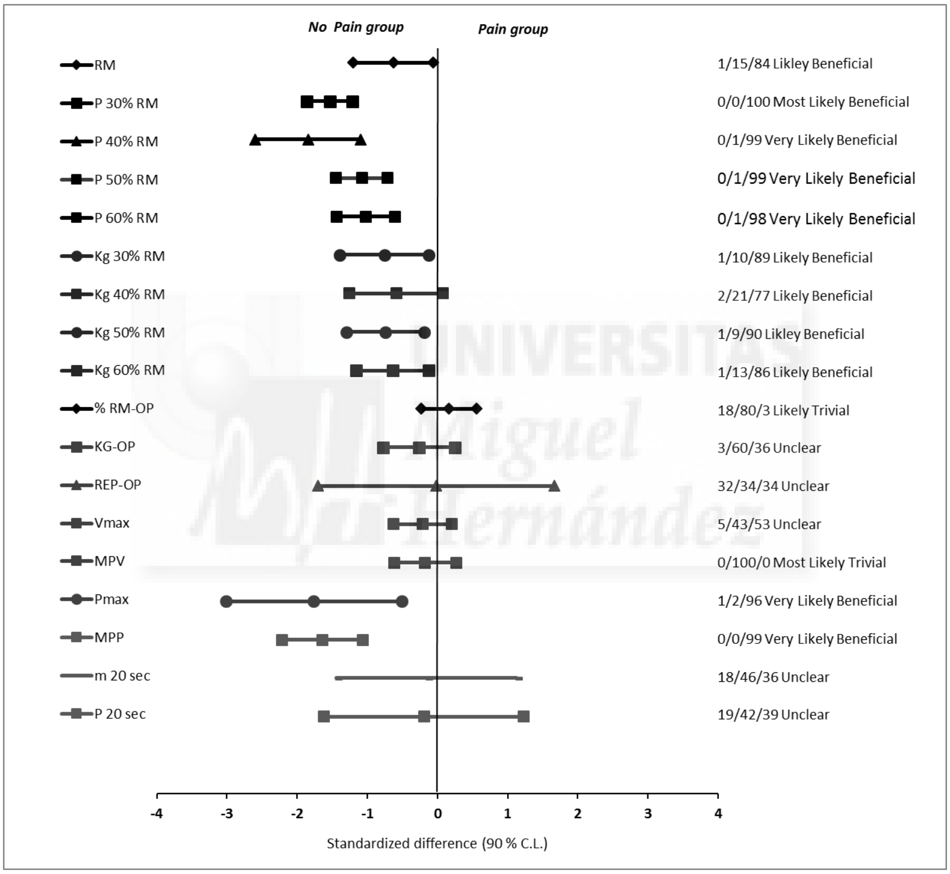

***Figure 11a*.** Inferences between Pain Group and No Pain Group in post-test in FP.

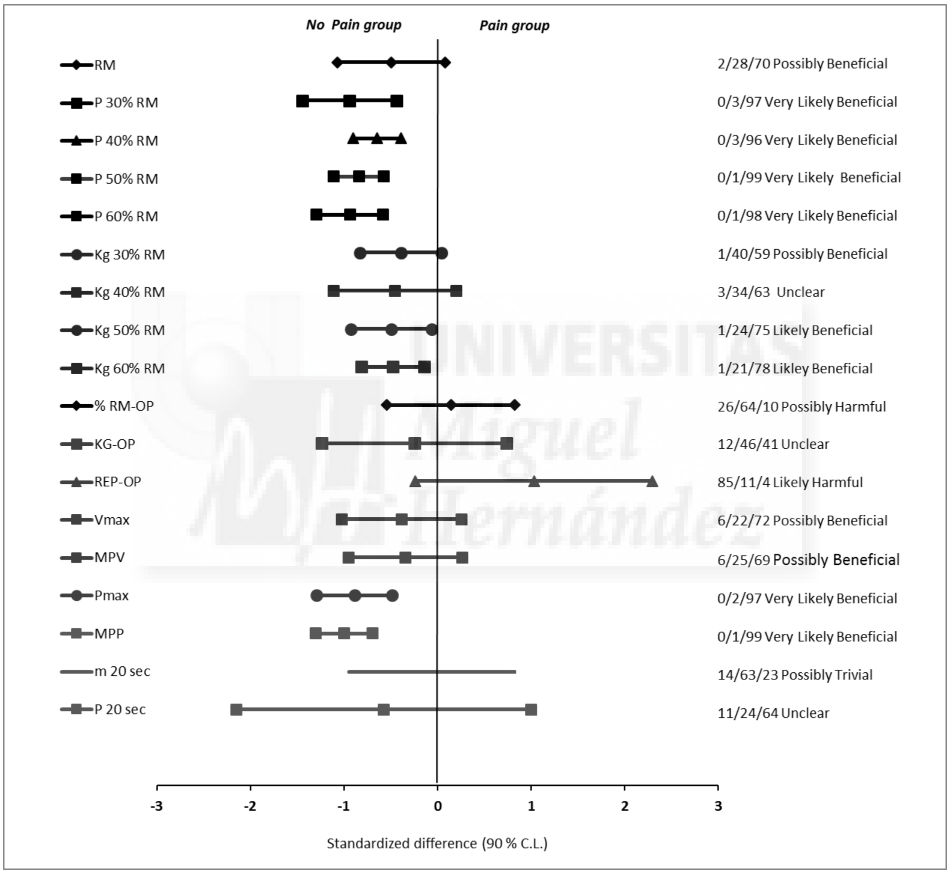

Figure 11b. Inferences between Pain Group and No Pain Group in post-test in LP.

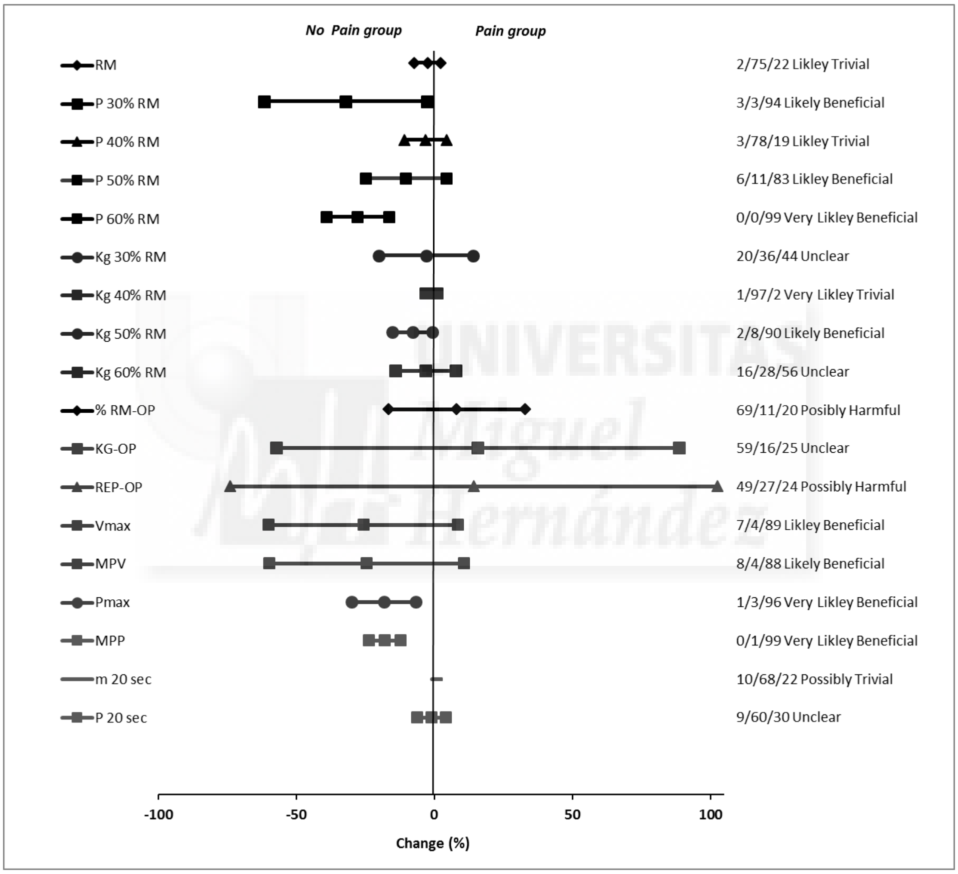

Figure 12a. Inferences between Pain Group and No Pain Group in % Change in FP.

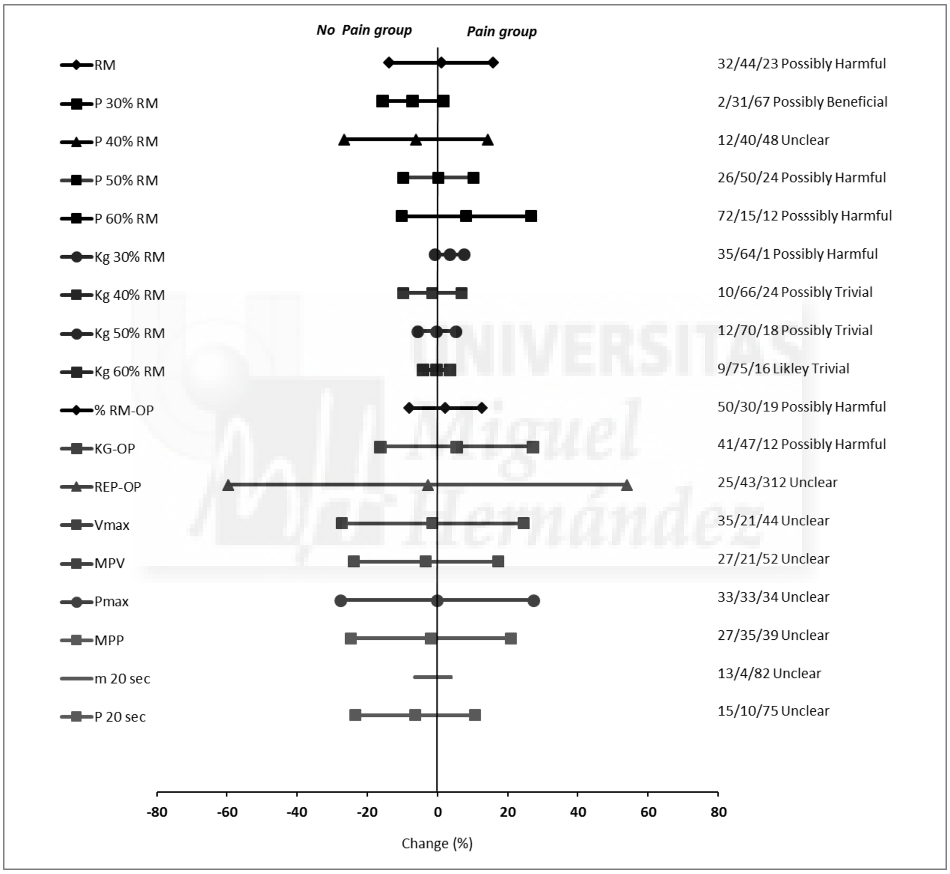

Figure 12b. Inferences between Pain Group and No Pain Group in % Change in LP.

Different correlations were found between performance and questionnaire variables. The results are shown in Table 17a, 17b, 17c and 17d.

Table 17a. *Correlations between Performance and Questionnaire Variables in pre-test in FP*.

	M	H	1-RM	Kg 30% 1-RM	P 40% 1-RM	Kg 40% 1-RM	P 50% 1-RM	KG 50% 1-RM	Kg 60% 1-RM
M	1	-.079	**-.589***	**-.582***	-.307	**-.607***	-.380	**-.659***	**-.640***
H		1	-.522	**-.543***	**-.522***	-486	**-.580***	-.459	-.473
1-RM			1	.982**	.906**	.988**	.911**	.989**	.991**
Kg 30% 1-RM				1	.887**	.967**	.888**	.988**	.966**
P 40% 1-RM					1	.877**	.963**	.873**	.880**
Kg 40% 1-RM						1	.885**	.983**	.983**
P 50% 1-RM							1	.871**	.892**
Kg 50% 1-RM								1	.984**
Kg 60% 1-RM									1

M = days with menstruation in the cycle; H = days with headache in the cycle; *p<0.05; **p<0.001.

Table 17b. *Correlations between Performance and Questionnaire Variables in post-test in FP.*

	Fatigue	1-RM	Kg 30% 1-RM	Kg 40% 1-RM	Kg 60% 1-RM	%RM-OP
Fatigue	1	**-.538***	**-.446***	**-.593***	**-.586***	**-.587***
1-RM		1	.986**	.992**	.985**	.824**
Kg 30% 1-RM			1	.976**	.985**	.861**
Kg 40% 1-RM				1	.964**	.805**
Kg 60% 1-RM					1	.856**
%RM-OP						1

*p<0.05; **p<0.001.

Table 17c. *Correlations between Performance and Questionnaire Variables in pre-test in LP.*

	H	Kg 30% 1-RM	P 30% 1-RM	Kg 40% 1-RM	P 40% 1-RM	Kg 50% 1-RM	P 50% 1-RM	P 60% 1-RM	Pmax	MPP
H	1	**-.589***	**-.618***	**-.553***	**-.645***	**-.540***	**-.594***	**-.640***	**-.700****	**-.625***
Kg 30% 1-RM		1	.896**	.951**	.857**	.954**	.846**	.854**	.886**	.889*
P 30% 1-RM			1	.877**	.931**	.926**	.954**	.926**	.972**	.946**
Kg 40% 1-RM				1	.868**	.966**	.852**	.866**	.855**	.871**
P 40% 1-RM					1	.860**	.937**	.938**	.952**	.943**
Kg 50% 1-RM						1	.910**	.903**	.892**	.859**
P 50% 1-RM							1	.978**	.934**	.880**
P 60% 1-RM								1	.918**	.886**
Pmax									1	.953**
MPP										1

H = days with headache in the cycle; *p<0.05; **p<0.001.

Table 17d. *Correlations between Performance and Questionnaire Variables in post-test in LP.*

	Fatigue	V_{max}	MPV
Fatigue	1	**-.746****	**-.738****
V_{max}		1	.955**
MPV			1

MPV = Mean Propulsive Velocity; *p<0.05; **p<0.001.

4.4 Discussion and Conclusion.

The main objective of this study was to analyze the differences after a period of velocity-based resistance training (VBRT) in the two great phases of the menstrual cycle. According to other studies, the action of estradiol, an anabolic hormone which increases during the follicular phase until reaching its peak before ovulation, suggests that there will be better results in this phase, since the progesterone (catabolic hormone) values are low and do not decrease the estradiol effect, as happens in the luteal phase (Reis et al., 1995; Sung et al., 2014). The results of our study corroborate this hypothesis.

In line with Pareja-Blanco et al. (2016), VBRT is an effective method of training, since improvements in the 1-RM in both phases, as well as in the peak-power values obtained in each % 1-RM have been reported, showing a practical significance of likely, very likely and most likely beneficial after training in both FP and LP. However, we can see that the response after training in each phase is different. In the FP, the participants were faster after training, since they obtained their peak-power in a smaller %RM-OP (likely beneficial), and also increased power at 30% RM, but they performed a smaller number of repetitions maintaining the optimal velocity (likely beneficial). However, after the intervention in LP there is an increase of %RM-OP (possibly harmful), but the number of repetitions remained constant. The fact that the %RM-OP varied through the phases, entailed a change in velocities. González-Badillo & Sánchez-Medina (2010) reported that each % 1-RM has a specific speed value associated to it. In our study, the% RM-OP decreased in the FF and we found better values of V_{max} and MPV after the intervention (possibly after training). In LP %RM-OP also increased, but we found worse values of V_{max} and MPV, although practical significance showed that it was unclear. However, the power values (P_{max} and MPP) improved in both phases (beneficial with training), independently of whether the %RM-OP increased or decreased. This means that in the FP participants were faster because they generated higher powers levels with greater velocities, and in the LP participants became stronger, since they generated their peak-power with higher loads.

Regarding the 20 sec-all-out test, the average power produced was likely beneficial after training, and although there was an improvement in the rowing meters, it seems to be trivial.

However, the major contributions of this study were that when comparing the change percentages between pre- and post-test in each phase, we can see that the results showed a greater improvement in FP in comparison with LP in elite rowers in 1-RM and their relative loads, in the velocity and power values analyzed during the test of maintenance of the optimal velocity and in the variables obtained from the 20 sec-all-out test. The power improvement at 30% RM is also interesting, which implies an important speed improvement with low loads in FP training. These results are in line with other studies (Markofski & Braun, 2014; Pallavi et al., 2017; Sarwar et al., 1996; Sung et al., 2014; Wikström-Frisén et al., 2015).

According to other studies, no differences were found between the phases in the POMS, KSD or RPE results (Julian, Hecksteden, Fullagar, & Meyer, 2017; Sakamaki-Sunaga, Min, Kamemoto, & Okamoto, 2015).

When the group was separated depending on dysmenorrhea, it can be observed that the no pain group obtained better values in pre- and post-test in FP in comparison with the pain group, showing a clinical difference of very likely and most likely beneficial. When comparing pre-test results between groups in LP, the results were not so clear, but the trends seemed to be show that the no pain group had better performance. In post-test of LP, better results were found in the no pain group. This means that both groups (pain and non-pain) are different at baseline, but when the percentage of change in each group was compared, we can see that the no pain group had a greater improvement in FP, and there were no differences between both groups in the LP. This can be explained by the fact that the pain group did not improve so much in the FP because it is the moment at which the menstrual syndrome is present. However, in LP, the discomfort associated with menstruation decreased, which possibly entailed that both groups improve equally (Constantini et al., 2005).

To support these results, negative correlations were found between different continuous variables of the questionnaires (such as headache, fatigue dimension of POMS or duration of menstruation) with performance variables such as 1-RM, Kg and peak-power in their relative loads, V_{max}, MPV, P_{max} and MPP. In line with other authors, different symptoms associated with menstrual pain can lead to poorer performance (Cockerill et al., 1992; Constantini et al., 2005; Fridén et al., 2003; Giacomoni et al., 2000; Möller-Nielsen & Hammar, 1989).

In conclusion, VBRT is a good method to improve the values of strength, power and velocity in elite rowers, but performing this type of training in the first two weeks of the menstrual cycle (FP) produces better results compared to training during the last two weeks (LP), so the distribution of training loads should be adjusted during these two weeks. In addition, the participants which reported menstrual pain obtained worse results, so the option of incorporating oral contraception (OCP) could be considered to alleviate the negative effects of dysmenorrhea. For future research, the effects of OCPs should be studied in this type of training.

Chapter 5. Epilogue

The three studies of this thesis are focused on researching what happens throughout the menstrual cycle when new tendencies of the strength training are applied. This design tries to look for greater complexity as the studies progresses, analyzing in an acute way - at first - the cycle divided in two phases, secondly in 3 phases, and thirdly intervening on the two great moments of the menstrual cycle (Figure 13).

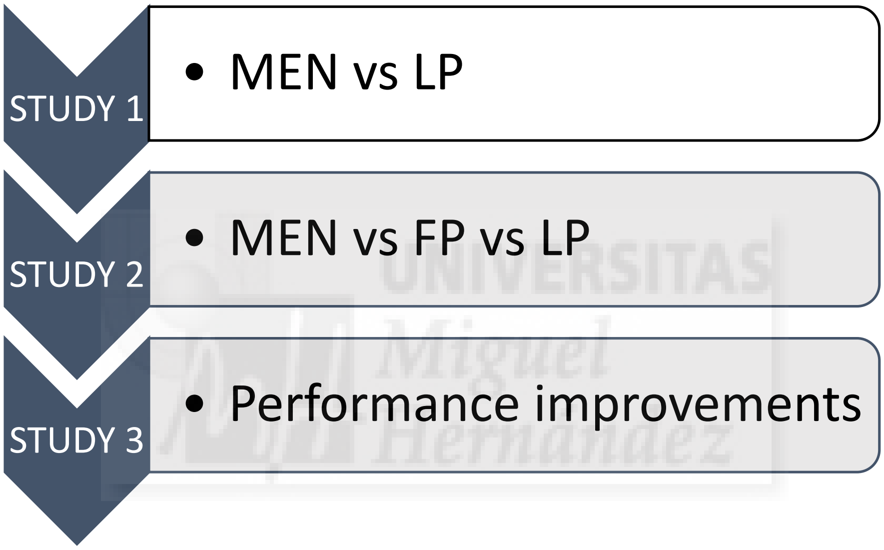

Figure 13. Graphical representation of the aims of investigation in each study of the thesis.

5.1. Major contributions.

The major contributions of this thesis are summarized in the following points:

- Different performance tests to evaluate the power output and executed at maximum velocity, as well as an indirect test to evaluate the 1-RM can be performed indistinctly at any phase of the menstrual cycle (Study 1 and 2).

- The maximal velocity (V_{max}) and the mean velocity during the propulsive phase (MPV) are higher in the follicular phase, just in moments prior to ovulation (Study 2).
- Discomfort associated with menstruation and premenstrual syndrome adversely affect the performance test results (Study 1 and 2).
- The reported perception of effort (RPE) by the participants is greater at the time of menstruation and prior to it (Study 2).
- After two-weeks of intervention in each phase of the menstrual cycle, better results were obtained in the follicular phase in all the applied tests (Study 3).
- The group reporting no discomfort associated with menstruation, obtained greater improvements in all tests in the follicular phase after two weeks of intervention, although it did not affect improvement in the luteal phase (Study 3).

5.2. Study limitations and future research.

During the development of this thesis we have encountered different limitations that can be used as a starting point for new research.

- **Check the menstrual cycle through hormonal values**. In our first study, the detection of the menstrual cycle was done through the technique of counting days, which can lead to measurement errors by not detecting the phase correctly.
- **Increase the sample**. In the first study (although it was a pilot study), the sample is very small. In the following studies,

although it has been possible to increase the number of participants, it may not be totally representative of this type of population.

- **Analyze in other sports**. The intervention of the last study was carried out with rowers, but we can-not state that these results are applicable to other sports.
- **Increase the number of consecutive menstrual cycles**. Performing the measurements in several consecutives cycles could help to know the variability of the participants and give greater consistency to the results.

Principales contribuciones

Las mayores aportaciones de esta tesis son resumidas en los siguientes puntos:

- Diferentes test de rendimiento para evaluar la potencia producida y ejecutados a máxima velocidad, así como un test indirecto para evaluar el 1-RM pueden ser realizados indistintamente en cualquier fase del ciclo menstrual (Estudio 1 y 2)
- La velocidad máxima (V_{max}) y la velocidad media durante la fase propulsiva (MPV) son mayores en la fase folicular, justo en los momentos previos a la ovulación (Estudio 2).
- Las molestias asociadas a la menstruación, y el síndrome pre-menstrual afectan negativamente a los resultados de los test de rendimiento cuando son aplicados en diferentes fases del ciclo menstrual (Estudio 1 y 2).

- La percepción de esfuerzo de los sujetos es mayor en los momentos de la menstruación y previos a ella (Estudio 2).
- Tras intervenir en cada una de las fases del ciclo menstrual, se obtuvieron mejores resultados en la fase folicular en todos los test aplicados (estudio 3)
- El grupo que indicó no tener molestias asociadas a la menstruación, obtuvo mayores mejoras en todos los test en la fase folicular tras dos semanas de intervención, mientras que ambos grupos mejoraron por igual en la fase lútea (Estudio 3)

Limitaciones de los estudios y futuras líneas de trabajo.

Durante el desarrollo de esta tesis nos hemos encontrado con diferentes limitaciones que pueden ser utilizadas como punto de partida para nuevas investigaciones:

- **Verificar el ciclo menstrual a través de valores hormonales**. En nuestro primer estudio, la detección del ciclo menstrual se hizo a través de la técnica de contar días, lo que puede conllevar a errores de medición por no detectar correctamente la fase.
- **Aumentar la muestra**. En el primer estudio (aunque era un estudio piloto), la muestra es muy pequeña. En los siguientes estudios, aunque se ha conseguido aumentar el número de sujetos, puede no ser totalmente representativo en este tipo de población.
- **Analizar en otro tipo de deportes**. La intervención del último estudio se llevó a cabo con remeras, pero no podemos afirmar que los resultados sean aplicables a otro tipo de deportes.

- **Aumentar el número de ciclos menstruales consecutivos**. Realizar las mediciones en varios ciclos seguidos puede servir para conocer la variabilidad de los sujetos y poder dar mayor consistencia a los resultados.

Chapter 6. Bibliography

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Chapter 7. Annexes.

ANNEX 1.

CUESTIONARIO DE DOLOR MENSTRUAL

Le agradecemos mucho que conteste a este cuestionario. La información que nos proporcione será tratada de modo absolutamente confidencial. Su colaboración será de gran utilidad para la realización de este estudio. Por favor, conteste a todas las preguntas de la manera más precisa posible. NO DUDE EN PREGUNTAR SI TIENE ALGUNA DUDA.

Edad: **Número de embarazos:** **Número de hijos:**

¿Cuántos años hace que tiene la menstruación (aprox)? [ ]

¿Su menstruación es dolorosa? (Rodee con un círculo) NO SI

Puntúe en la siguiente escala la intensidad del dolor en la última menstruación (rodee con un círculo).

0 1 2 3 4 5 6 7 8 9 10

Sin dolor Dolor muy intenso

Señale con una X en la línea siguiente cuál ha sido la intensidad del dolor de la última menstruación.

Sin dolor Dolor muy intenso

Si marcó que su menstruación sí es dolorosa, calcule cuántas son dolorosas en un año (rodee con un círculo el número).

0 1 2 3 4 5 6 7 8 9 10 11 12

En caso de que sus menstruaciones sean dolorosas, ¿cuánto tiempo hace que lo son (aprox)?

[ ]

¿Ha acudido a consulta ginecológica por el dolor menstrual? Rodee con un círculo NO SI

Durante la menstruación, el dolor se localiza en (subraye las alternativas correctas):

Parte baja de la espalda Cara interna de los muslos Vientre

Tensión en las mamas Otros lugares (especificar): [ ]

Antes o durante la menstruación, ¿se presenta alguno de estos síntomas? (subraye)

Mal humor Trastornos gástricos (e.g. diarrea, mareo, vómitos…)

Tristeza Vientre hinchado Pecho hincahdo, dolorido

Otros (especificar): [ ]

En caso de tener dolor, éste o las molestias menstruales suelen comenzar: (subraye)

Dos días antes de la menstruación

Un día antes de la menstruación

El mismo día de la menstruación

A veces el día de antes y a veces el mismo día.

¿Toma medicación para aliviar el dolor? Rodee con un círculo, y en caso de tomar medicación, indique cual.

NO SI ¿Cuál?

En caso de haber marcado sí en la pregunta anterior, **¿En cuántas menstruaciones en un año toma medicación? Rodee con un círculo. Si marcó que no, rodee el 0.**

0 1 2 3 4 5 6 7 8 9 10 11 12

En caso de tomar medicación ¿Ésta le alivia? (subraye la alternativa correspondiente).

Nada Un poco Bastante Mucho

En caso de tomar medicación, ¿En cuántas menstruaciones (al año) consigue aliviar el dolor? Rodee con un círculo. Si no toma medicación, rodee el 0.

0 1 2 3 4 5 6 7 8 9 10 11 12

¿Necesita dejar lo que está haciendo a causa del dolor? Rodee con un círculo.

NO SI

Si ha marcado que sí en la pregunta anterior, ¿en cuántas menstruaciones (al año) necesita dejar lo que está haciendo debido al dolor? Rodee con un círculo. Si ha marcado no en la pregunta anterior, rodee el 0.

0 1 2 3 4 5 6 7 8 9 10 11 12

En caso de abandonar sus tareas a causa del dolor, ¿por cuánto tiempo abandona lo que estaba haciendo? Subraye la correcta.

Menos de media hora	De media hora a una hora	De una a tres horas
De tres a seis horas	De seis horas a un día	Más de un día

En los periodos sin menstruación, ¿sufre Vd. alguno de estos síntomas? Subraye todos los que presente.

Alergia	Frío intenso en pies y manos	Alta tensión arterial
Dolor lumbar	Dolor de estómago o vientre	Dolor cervical
Dolor de cabeza	Alteración del ritmo cardíaco	

La siguiente tabla muestra los días de un mes. Por favor, señale con una M en la tabla que día comenzó su última menstruación. Si no lo recuerda exactamente, indique la fecha aproximada, y los días que duró. Señale también los síntomas que Vd. sufre, utilizando para cada síntoma el símbolo que se indica a continuación.

CAMBIOS DE HUMOR = H HINCHAZÓN EN EL VIENTRE = V
HINCHAZÓN EN EL PECHO = P IRRITABILIDAD (MAL HUMOR) = I
DEPRESIÓN = D DOLOR DE CABEZA = C
TRASTORNOS GÁSTRICOS = G

Así, si por ejemplo su menstruación comenzó el día 13, marcará con una x en la fila de la M en el cuadro que corresponde a ese día, y los siguientes (tanto como duró la menstruación); si sufrió hinchazón del pecho un día antes y el mismo día de la menstruación, marcará una señal en los cuadros correspondientes a los días 12 y 13, en las filas correspondientes al símbolo P; si además, desde dos días antes hasta dos días después del comienzo de la menstruación sufrió dolor de cabeza, pondrá una señal en los cuadros correspondientes a los días 11, 12, 13, 14 y15 en la fila correspondiente al símbolo C, y así con cualquier síntoma que se haya presentado.

Ahora, por favor, conteste en la tabla siguiente (marcando con una cruz) en qué días aparecieron la menstruación y los síntomas (si los sufrió), durante el último mes.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
M																															
H																															
V																															
P																															
I																															
D																															
C																															
G																															

ANNEX 2.

KAROLINSKA SLEEP DIARY.

Con este cuestionario pretendemos conocer la calidad del sueño y que con ello muestres como has dormido, por lo tanto, es necesario rellenar este cuestionario justo al despertar para que indiques de forma clara tus sensaciones. Lee con atención los enunciados y **marca con una cruz la casilla sombreada** que corresponda en función de las 5 opciones que ofrece el cuestionario, para cada una de las 7 preguntas.

		1	2	3	4	5
1	Calidad de sueño	Muy pobre	Bastante pobre	Ni bueno ni malo	Bastante bueno	Muy bueno
		1	2	3	4	5
2	Tranquilidad de sueño	Muy inquieto	Bastante inquieto	Ni inquieto ni tranquilo	Bastante tranquilo	Muy tranquilo
		1	2	3	4	5
3	Facilidad para dormirme	Muy difícil	Bastante difícil	Ni difícil ni fácil	Bastante fácil	Muy fácil
		1	3		5	
4	Despertar	Desperté demasiado temprano	Desperté un poco temprano		No desperté temprano	
		1	2	3	4	5
5	Facilidad para despertarme	Muy difícil	Bastante difícil	Ni difícil ni fácil	Bastante fácil	Muy fácil
		1	3		5	
6	Sensación de descanso	No descansé en absoluto	Algo descansado		Completamente descansado	
		1	2	3	4	5
7	¿Has dormido lo suficiente?	No, definitivamente muy poco	No, muy poco	No, muy poco, algo	Si, casi lo suficiente	Si, definitivamente lo suficiente

ANNEX 3.

POMS REDUCIDO 29 ITEMS.

Más abajo hay una lista de palabras que describen sensaciones que tiene la gente. Por favor, lee cada una cuidadosamente. Después rodea **con un círculo UNO de los números** que hay al lado, rodea el que mejor describa **COMO TE HAS SENTIDO DURANTE LA SEMANA PASADA INCLUYENDO EL DÍA DE HOY.**

0 = Nada	1 = Un poco	2 = Moderadamente	3 = Bastante	4 = Muchísimo

1.-	Intranquilo	0	1	2	3	4
2.-	Enérgico	0	1	2	3	4
3.-	Desamparado	0	1	2	3	4
4.-	furioso	0	1	2	3	4
5.-	Sin fuerzas	0	1	2	3	4
6.-	Deprimido	0	1	2	3	4
7.-	Lleno de Energía	0	1	2	3	4
8.-	Inquieto	0	1	2	3	4
9.-	Molesto	0	1	2	3	4
10.-	Agotado	0	1	2	3	4
11.-	Agitado	0	1	2	3	4
12.-	Luchador	0	1	2	3	4
13.-	Desdichado	0	1	2	3	4
14.-	Irritable	0	1	2	3	4
15.-	Cansado	0	1	2	3	4
16.-	Amargado	0	1	2	3	4
17.-	Animado	0	1	2	3	4
18.-	Nervioso	0	1	2	3	4
19.-	Enfadado	0	1	2	3	4
20.-	Exhausto	0	1	2	3	4
21.-	Tenso	0	1	2	3	4
22.-	Vigoroso	0	1	2	3	4
23.-	Triste	0	1	2	3	4
24.-	Enojado	0	1	2	3	4
25.-	Fatigado	0	1	2	3	4
26.-	Infeliz	0	1	2	3	4
27.-	Activo	0	1	2	3	4
28.-	Relajado	0	1	2	3	4
29.-	De mal genio	0	1	2	3	4

ANNEX 4.

ESCALA DE PERCEPCIÓN DEL ESFUERZO CR-10.

0	Nada
0,5	Muy, muy suave
1	Muy suave
2	Suave
3	Moderado
4	Algo duro
5	Duro
6	
7	Muy duro
8	
9	
10	Muy, muy duro