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EDUCAÇÃO FÍSICA / PHYSICAL EDUCATION

# Correlation between flexibility and muscular power in vertical jumps in women practitioners handball and weight lifters

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**ABSTRACT.** The present study has the objective to correlate the variables of flexibility and muscle power present in the vertical jumps, through tests done with female individuals, performing analyzes about two groups: Handball players (HG); weight lifters (WL). Initially, the protocol consisted on the performing of the flexibility test at Wells Bank. Subsequently, the jump test was performed, using the Counter movement jump (CMJ) and Squat jump (SJ). About the study groups, it can be observed that they have similar physical characteristics, but practice times (HG = 9.25 ± 3.28 versus WL = 1.85 ± 1.47 years) and weekly hours of activities (HG = 3.33 ± 1.23 versus WL = 5.29 ± 1.81 hours) were distinct. In the execution of SJ for HG, a high correlation was presented for all variables (Height 0.615; Power 0.718; Standard power 0.618). It also presented a high correlation in the non-normalized power (0.688) in CMJ. WL did not present a significant correlation for any of the variables. Based on the findings of the present study, jump test results have correlation with variables of flexibility, muscle power and handball players. However, there is no correlation for any variable for weight lifters.

**Keywords:** handball, weight lifters, muscle power, flexibility.

## Correlação entre flexibilidade e potência em saltos verticais de mulheres praticantes de handebol e musculação

**RESUMO.** O presente estudo tem o objetivo de correlacionar as variáveis de flexibilidade e potência presentes nos saltos verticais, através de testes feitos com indivíduos do sexo feminino, executando análises acerca de dois grupos: Praticantes de handebol (GH) e Praticantes de musculação (GM). Inicialmente, o protocolo consistiu na execução do teste de flexibilidade no banco de Wells. Posteriormente, foi realizado o teste de saltos, utilizando o *Counter movement jump* (CMJ) e *Squat jump* (SJ). Em relação aos grupos do estudo, pode-se constatar que possuem características físicas bastante semelhantes, porém os tempos de práticas (GH=9,25±3,28 versus GF=1,85±1,47 anos) e as horas semanais de atividades (GH=3,33±1,23 versus GF=5,29±1,81 horas) foram distintos. Na execução do SJ para o GH, foi apresentada alta correlação para todas as variáveis (Altura 0,615; Potência 0,718; Potência normalizada 0,618). Também, foi apresentada alta correlação na potência não normalizada (0,688) no CMJ. O GM não apresentou correlação significativa para nenhuma das variáveis. Com base nos achados do presente estudo, resultados de testes de saltos possuem correlações com variáveis de flexibilidade e potência em praticantes de handebol. No entanto, para praticantes de musculação, não existe correlação para nenhuma variável.

**Palavras-chave:** handebol, musculação, potência; flexibilidade.

## Introduction

Nowadays practicing physical activities is world-wide expanded among people (Tarp et al., 2016) and one of the activities most popular is Weight Lifting (Menegon et al., 2016). Weight lifters perform muscle group specific exercises (Carvalho et al., 2004; Cryino et al., 2004; Arazi, Pashazadeh, Rahmati, & Rezaei, 2015; Dias et al., 2005; Ueno et al., 2012). Another possibility to maintain an active lifestyle is to perform physical activities both alone in groups. Individual sports, like bodybuilding, can also include activities such as canoeing and swimming. Group sports, which are performed as a team include activities such as handball, soccer, or basketball.

Handball is a collective sport modality which is taught in schools through PE courses, or in clubs. Individuals of different ages (Eleno, Barela, & Kokubun, 2002), pass through several evolutionary processes, which consequently, succeed physiological adaptation and change the specific morphology of the athletes because of the so-called neuromuscular plasticity (Baroni et al., 2016).

The maximum performance in vertical jumps is indispensable to the success of athletes in many sport modalities (Gomes, Pereira, Freitas, & Barela, 2009). Handball is an example of a sport modality where the execution of this capacity can be the deciding factor in the outcome of a match.

Physical capacities, like flexibility and power, are studied in great frequencies through vertical jumps. Flexibility can be written by the amplitude in available movements or in an articulation of joint groups (Bertolla, Baroni, Junior, & Oltramari, 2007). Some exercises of flexibility can add greater elasticity to soft tissue and decrease the viscosity of muscle fiber (Coelho et al., 2014). The power rating can be characterized as the rate of work realization. This is shown as units of time, more specifically, the power produced by speech (Dal Pupo, Detanico, & Santos, 2012).

Performance in vertical jumps is considered one of the most efficient indicators of the level of muscle power, which is produced by the lower limbs muscles (Dal Pupo, Detanico, & Santos, 2012). An important variable that relates to power is the elastic energy stored in the elastic structures of the agonist muscles during the jumping impulse phase, which is based on the stretching-shortening cycle (CAE) (Komi, 2000). This allows for greater power when an eccentric muscular action is readily succeeded by a concentric muscular action (Coelho et al., 2011). In this way, the elastic energy stored in the musculotendinous assembly is used efficiently, and with minimal energy loss (Guglielmo, Greco, & Denadai, 2005).

Other than elastic energy, other mechanisms that occur with countermovement may be determinant for CMJ variables. According to Bobbert and Casius (2005), muscles stretch in the descending phase of an active jump, and the neural responses cause an increase in muscle stimulation in the ascending phase. In this way, the muscles can reach an active state of pre-contraction, reaching a high percentage of cross-bridge formation, which allows for a proper length-tension relation for impulse generation.

Another relevant mechanism to be considered is called neuromuscular plasticity. Neuromuscular plasticity occurs when joints that work in large amplitudes give muscles greater amounts of sarcomeres in sequence and, in turn, these muscle fibers which are composed of more sarcomeres increase their shortening speed (Jakobsen et al., 2012; Herzog, 2009). Besides that a quick transition between concentric-eccentric phases (Bobbert, Gerritsen, Litjens, & Van soest, 1996; Komi and Gollhofer, 1997) and tendon stiffness (Kubo et al., 2006) may contribute to velocity and to performance in CMJ.

More compliant tendons, however, should lessen the rapid transmission of tension to the bone, therefore impairing the development of potency (Wilson, Elliot, & Wood, 1992). However, flexibility results in a lower amount of alterations in tendon stiffness, and this physical capacity is altered mainly in the joint and articular capsule (47%) and in the musculature (41%) (Weineck, 2001). Therefore, with higher levels of flexibility, these structures provide the exercises with a greater range of motion, force, and power (Bertolla et al., 2007). In CMJ, the amplitude of the counter movement used is determinant for the efficiency of the CAE and, consequently, in its height (Ugrinowitsch, Tricoli, Rodacki, Batista, & Ricard., 2007). Cyrino et al. (2004) points out that adequate levels of muscle strength and flexibility are fundamental for good musculoskeletal functioning, and that the decline in flexibility levels will gradually hamper the performance of different daily tasks. They believe that loss of flexibility and strength are the main motor variables related to these limitations (Filho, 2006), denoting the possible relation between these capacities. Therefore, it is considered that the use of EAC (elastic energy) and the greater number of sarcomeres in series (which causes the muscle as a whole to shorten more rapidly), by individuals with greater flexibility should provide better performance in jumps, especially in the use of counter movement (eccentric / concentric transition). In this way, the hypothesis presents a correlation between the performances of these physical capacities. However, is there such a correlation in practitioners of different modalities?

Based on what was presented, the present study aims to correlate the flexibility and power variables present in the vertical jumps, through tests performed with female individuals, performing analyses of two groups: handball players (HG) and weight lifter (WL).

## Material and methods

### Ethical considerations

The informed consent form (TCLE) was signed by each participant. The project was approved by the Research Ethics Committee of the University Center Cenecista of Osório - UNICNEC by the protocol number 50191115.7.00005591.

### Sample and eligibility criteria

Based on the first table, the sample consisted of: not to have suffered osteomio articular lesion in the last six months, practiced the specific modality of each group for at least six months, and have signed the EHIC. As exclusion criteria, it was considered that participants could not present any type of vestibular disorder, visual impairment without correction, diabetes, musculoskeletal system injuries, or lower back pain.

### Data collection

The evaluations happened in the Exercise Physiology Laboratory of the University Center Cenecista of Osório - UNICNEC, Osório, Rio Grande do Sul State, Brazil. Initially, the participants completed an evaluation form containing sample demographic data including age, body mass, height, frequency of physical and sports activity, presence of injury, among others).

The evaluation procedure protocol consists of the ability to execute the Shapiro-Wilk test, also known as sit-and-reach test in order to demonstrate flexibility (Navega & Nogueira, 2011). The flexibility test was performed by having the subject sit on a mat, with the feet in full contact with the front of the mat and the lower limbs with knees extended and hips flexed. In the sequence the individuals were instructed to move the scale of the bench to the maximum that they could achieve, doing a hip flexion.

In a second moment was executed a test with the jump modalities such as Counter movement jump (CMJ) and Squat jump (SJ). The execution of the CMJ, was captured by placing a individual on a contact platform (CEFISE®), which was used to measure the power of each jump. This platform measured the power of each jump by calculating the force and speed. The participant was bare-foot and were asked to evenly distribute their weight on their lower limbs and place their hands on their waist. Once the participant was placed, he was asked to crouch down by flexing their knees at a 90-degree angle immediately before jumping vertically. He was instructed to keep their knees extended throughout the jump and come down on both feet evenly (Bosco, 1983).

When testing SJ, the technique and pattern of the test have basically the same executionof CMJ, however, the participant was asked to begin their movement from a crouched position with their knees flexed at approximately 90-degrees, they had to keep his torso upright and look forward. He must also keep their hands on their hips. The participant then performed a strong and rapid extension of the lower limbs without countermovement, while keeping their hands at his waist throughout the jump. The maximum performance was framed to align with the vertical jump as much as possible (Bosco, 1983).

In performing both tests, the jumps were invalidated when the following factors occurred:

- Knee flexion during the flight;
- Torso and/or head tilted at the front;
- Landing with the sole of the foot instead of touching the tip of the feet first;
- Arm movements
- The height of the jump is affected by the degree of knee flexion, so the jump was invalidated if the evaluated knee was not flexed by about 90 degrees, required in each execution.

In the CMJ test could have occurred frequent mistakes. For example, performing the countermovement below 90 degrees. While in the power squat jump test, lifting the heel in the static position and performing countermovement could nullify the attempt.

### Statistical analysis

The data was submitted to descriptive statistics. The normality in the distribution of the data through the Shapiro-Wilk test and homogeneity through the Levene test were evaluated. For comparisons among the distinct groups, the T-test for independent samples was used. Subsequently, the averages of the percentage of the variables correlated to the jumps with the data of flexibility were found to be related, through the Pearson test. The correlation strength among the variables was defined by the Malina criterion (Malina, 1996), being: weak for values lower than 0.3, moderate to values between 0.3 and 0.6, and strong to values greater than 0.6. The significance level for all tests was 5%.

## Results

**Table 1.** Characterization of the study sample. Averages and standard deviations of age and anthropometric data, besides the number of individuals in each group.

| | HG (n=16) | | WL (n=12) | | P-value |
|---|---|---|---|---|---|
| | Average | Standard deviation | Avarage | Standard deviation | |
| Age (years) | 21,13 | 3,59 | 19,50 | 3,34 | 0,234 |
| Structure (m) | 1,64 | 0,09 | 1,62 | 0,06 | 0,605 |
| Mass (kg) | 63,98 | 8,46 | 61,16 | 9,77 | 0,421 |
| IMC (kg $m^{-2}$) | 23,82 | 2,18 | 23,20 | 3,39 | 0,563 |
| PT (years) | 9,25 | 3,28 | 1,85 | 1,47 | <0,001* |
| WT (hours) | 3,33 | 1,23 | 5,29 | 1,81 | 0,003* |

HG = Handball Group; WL= Weight Lifter Group; WT= Weekly Training; PT = Practice Time.

**Table 2.** Averages and standard deviations of flexibility and lower limb power in the squat jump and countermovement jump tests for handball player and weight lifters.

| Variables | | HG | WL |
|---|---|---|---|
| | | Avarage ± Standard deviation | Avarage ± Standard deviation |
| Wells Bench (mm) | | 353,00 ± 53,28 | 341,00 ± 48,62 |
| Squat | A (cm) | 22,65 ± 4,23 | 22,93 ± 5,36 |
| | P (W) | 1317,77 ± 211,52 | 1273,26 ± 298,91 |
| | PN (W/$Kg^{-1}$) | 20,60 ± 1,93 | 20,67 ± 2,51 |
| CMJ | A (cm) | 24,77 ± 3,99 | 25,44 ± 5,91 |
| | P (W) | 1375,95 ± 181,71 | 1344,28 ± 330,01 |
| | PN (W $Kg^{-1}$) | 21,56 ± 1,74 | 21,78 ± 2,56 |

HH: heel height; P: Power: PN: Power normalized by body mass; HG: Handball Group; WL: Weight lifters Group; Squat: jump started from previous squat; CMJ: Jump using elastic energy.

**Table 3.** Correlation values and probability of significance between flexibility and muscular power for each of the groups (Handball and Weight lifters).

| Variables | | HG | | WL | |
|---|---|---|---|---|---|
| | | Correlation value | P-value | Correlation Value | P-value |
| Squat | A X Wells | 0,615 | 0,011* | 0,150 | 0,641 |
| | P X Wells | 0,718 | 0,002* | 0,279 | 0,379 |
| | PN X Wells | 0,618 | 0,011* | 0,136 | 0,674 |
| CMJ | A X Wells | 0,416 | 0,109 | 0,321 | 0,309 |
| | P X Wells | 0,688 | 0,003* | 0,349 | 0,267 |
| | PN X Wells | 0,412 | 0,112 | 0,301 | 0,341 |

Squat: jump started from previous squat; CMJ: Jump using elastic energy; A: heel height; P: Power: PN: Power normalized by body mass; X Wells: Relationship with test values in Shapiro-Wilk; HG: Handball Group; WL: Weight Lifter Group; P-value: probability of significance.

## Discussion

Several studies have been addressing the correlation between the variables of flexibility and power in jumps. One way to measure these variables is through a contact platform that measures the power in conjunction with the Wells bench test protocol, which leverages flexibility. Different vertical jumping modalities have been previously explored in different studies. These modalities evaluate the force parameters, which are indicators for lower limb power and have been related to performance in vertical jumps. This is especially noticeable in Countermovement Jump (CMJ) and in Squat Jump (SJ), which diverge in their accomplishments according to the protocols that are adopted (Dal Pupo et al., 2012).

In relation to the groups of the present study, it can be observed that both CMJs and SJs have very similar physical characteristics (age, mass, height and BMI). However, it is thought that, due to practice times and weekly hours of distinct activities, their muscles experience different functional and morphological changes (Table 1). This was seen in the execution of SJ for GH, which presented a high correlation between all of the variables (Tables 2 and 3). The specific type of practice could play a role in the outcome of our experiment, since vertical jumps are crucial to the execution of the modality. In addition, the time of practice could have caused a greater achievement of neural recruitment of the handball players (Table 1) (Dal Pupo et al., 2012; Moreira et al., 2008; Baroni et al., 2013, Jakobsen et al., 2012; Herzog, 2009).

The group of handball athletes presented a high correlation in the non-normalized power of CMJ. There is a propitious movement for the storage and use of elastic energy, which stores energy in the eccentric phase of movement through the aid of the body mass in conjunction with the elastic components of the lower limb muscles. This causes the performance of the jump to enjoy energy in the concentric phase. A justification for this outcome can be explained through the CAE. The CAE is extensively connected with the power and use of elastic energy by the musculature. Having muscles with a greater flexibility index (greater deformation), allows for a greater amount of elastic energy (LaRoche, Cremin, Greenleaf, & Croce, 2009). Due to the specificity of the task, athletes can perform better on length-tension and muscle strength curve. The muscle strength curve is a position in which actin and myosin filaments present a greater number of bonds during sliding. This generates an optimum position, which allows the individual to be able to produce greater force and power, in this case by squatting at an angle of around 90º (Dal Pupo et al., 2012, Jakobsen et al., 2012, Costa, Valim-Rogatto, & Rogatto, 2007).

The weight lifters did not present a correlation for any of the variables (Table 3). The specificity of the task may be one of the possible causes of WL not having obtained correlation, especially not obtaining an optimal position for a high percentage of cross-bridged links. In weight lifting, vertical jumping is not common in training routines, lower limb work is done by localized exercises, usually with load, and without the use of jumps (Duarte, Alca, Gesser, Krebs, & Rempel, 2009), making it a serie of movements with little familiarity for the said group or little functionality of these exercises (Ueno et al., 2012).

Thus, the voltage plateau of the length-tension curve of the WL, should be shifted to smaller lengths, due to the lower values of flexibility observed in this work and in other recent studies (Moreira et al., 2008; Jakobsen et al., 2012; Herzog, 2009). The power normalized by the body mass, for the HG in the CMJ, did not verify a correlation with flexibility, which is different from non-standard data. This demonstrates that the ability to store energy in the elastic components of handball players is dependent on their body masses. So, while performing a CMJ, the handball players put their bodies into motion, which transfers their potential energy to kinetic energy. This energy is stored elastically in series and parallel elastic components, and is returned to kinetic energy during the rise of the jump (Hall, 2016; Coutinho, Barroso, Tricolli, & Batista, 2003).

## Conclusion

It is possible to conclude, based on the findings of the present study, that the results of the jumping tests have shown correlation between variables of flexibility and power in handball athletes. On the other hand, for weight lifters there is no correlation between these variables.

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